International Scholars Journals

African Journal of Plant Breeding ISSN: 2375-074X Vol. 12 (1), pp. 001-008, January, 2025. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Evaluating the Combining Ability for Maize Yield in Striga-Prone and Non-Striga Regions of the Southern Guinea Savanna, Nigeria

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Accepted 3 October, 2024

Combining ability studies for maize grain yield and other agronomic characters were carried out using ten open-pollinated maize varieties and their 45 F_1 hybrids in a *Striga hermonthica* (Del.) Benth endemic zone (Shonga) and non-endemic zone (Ilorin) in Kwara State, Nigeria, during the 2005 cropping season. Both general combining ability (GCA) and specific combining ability (SCA) effects for *Striga* related characters such as *Striga* shoot counts, syndrome ratings, flowering *Striga* shoots and barren maize plants were generally low, suggesting the role of additive and dominant gene action in tolerance to *S. hermonthica* (Del.) Benth. Parents Acr 94 Tze Comp5 and Tze Comp3 C2 had significant ($p < 0.05$) positive GCA effects for grain yield and other agronomic characters in both *Striga* endemic and non-endemic environments respectively. Crosses Tze Comp3 C2 x Hei 97 Tze Comp3 C4, Tze Comp3 C2 x Acr 94 Tze Comp5 and Ak 95 Dmr - Esrw x Acr 94 Tze Comp5 had significant ($p < 0.05$) positive SCA effects for grain yield only in *Striga* endemic environment. These parents and hybrids appeared to have gene pools for *S. hermonthica* tolerance that can be manipulated and used to develop promising hybrids for early maturity and high grain yield across the Southern Guinea Savanna ecology.

Key words: *Striga hermonthica*, tolerance, combining ability, grain yield, Nigeria.

INTRODUCTION

Striga infestation is one of the most serious constraints to cereals production by smallholder farmers in sub-Saha-ran Africa. Infestation usually results in substantial yield losses, averaging more than 70% of *Striga* free environ-ment (Kim, 1991). Much of the damage occurs before *Striga* emerges from the ground and the degree of damage depends on susceptibility of the cultivar, *Striga* species, level of infestation, and any additional stress in the host's environment (Shinde and Kulkarni, 1982; Vasudeva Rao et al., 1982; Basinki, 1995). Of the five *Striga* species, *S. hermonthica* (Del.) Benth and *S. asia-tica* (L.) Kuntze are the most noxious weeds threatening 44 million hectares of agricultural land in Africa (Sauer-born, 1991). *S. hermonthica* (Del.) Benth infestation in particular constitutes a serious threat to maize production in the savanna ecologies of Nigeria. Breeding for tole-rance/resistance to *S. hermonthica* (Del.).

Benth offers a viable option for the management of this weed and is economically compatible with the low-cost input requirement of the subsistence farmers in controll-ing *Striga* (Ramaiah, 1986; Kim et al., 2002). Available data suggests that *Striga* resistance is controlled by a relatively few genes with additive effects (Shinde and Kul-kani, 1982; Vasudeva Rao et al., 1982). Kim (1994b) observed a considerable variability in the resistance of maize varieties to *S. hermonthica.* Findings from two independent studies, (Mumera and Below, 1996; Gurney et al., 2002) revealed that identification of *Striga* resis-tance maize genotypes should focus on the ability of ear sink to successfully compete with *Striga* for assimilates. However, maize breeding programmes designed for the development of commercial maize hybrids and improved maize genotype tolerant to *Striga* parasites usually requi-res a good knowledge of combining ability of the genetic materials to be used. Kim (1994a) used combining ability approach to study the genetics to maize tolerance of *S. hermonthica* in 10 inbred parents under *S. hermonthica* infestation in Mokwa, Nigeria. The results showed that such study was highly suitable for the development of *Striga* tolerant maize genotypes. Mumera and Below

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(1996) reported that counts of *Striga* emerged plants differed by more than three folds between the most and least susceptible genotypes with early maturing types generally being the most resistant. Kim et al. (2002) reported that tolerant open pollinated varieties (OPVs) produced 2.0 - 2.5 times the yield of susceptible varieties, especially under high *Striga* infestation. Also, Kim and Adetimirin (1997) studied responses of tolerant and susceptible maize varieties to timing and rate of nitrogen fertilizer under *S. hermonthica* infestation in southern guinea savanna ecology of Nigeria. Their results revealed that among all the tolerance factors studied, the most important component for *Striga* management was genetic tolerance. Hence, development of *S. hermonthica* tolerant genotypes appears feasible and promising in these agro-ecological zones.

Striga infestation has reached an endemic status not only in the northern guinea savanna, but also in the Southern Guinea Savanna (SGS) of Nigeria. It constitutes a serious threat to maize production and farmers are being compelled to abandon their farmlands to *Striga,* or change to production of less susceptible crop. The objectives of this study therefore were (1) to assess both general and specific combining abilities of ten open pollinated maize varieties for maize grain yield and other agronomic characters in *Striga* endemic and *Striga* free environments and, (2) to identify open pollinated varieties and hybrids that combined tolerance to *S. hermonthica* with grain yield and suitable agronomic traits for use in commercial hybrid maize production in *Striga* endemic zones of the Southern Guinea Savanna of Nigeria.

MATERIALS AND METHODS

The genetic materials used for this study comprised of 10 open pollinated maize varieties, which have been developed for yield and adaptation to biotic and abiotic stress factors. They are also early to medium maturing white cultivars with maturity period of 90 to 100 days. The varieties were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Partial diallel crosses were made between the 10 open pollinated maize varieties during 2004 cropping season at the Teaching and Research farm, University of Ilorin, Nigeria. The resultant 45 F_1 hybrids were harvested, processed and stored in the cold room prior to field evaluation. The field study was carried out in *Striga* endemic (Shonga) and *Striga* free (Ilorin) environments both in the Southern Guinea Savannah (SGS) of Kwara State of Nigeria during the raining season of 2005. The trial was laid out in a Randomized Complete Block Design with four replicates. Entries which included the hybrids and parents were made in two- row plots of 5 x 1.5 m each and planted at inter-row spacing of 75 cm and within row spacing of 50 cm to enhance a plant population of about 53,555 stands per hectare. Three seeds were planted on a hill but were later thinned to two at three weeks after planting (WAP). NPK 20-10-10 fertilizer was applied at the rate of 80 kgNha^{-1} in split doses immediately after thinning and at 6 WAP. In the *Striga* endemic zone, *Striga* related parameters such as *Striga* shoot counts at 10 WAP and *Striga* syndrome ratings using a Scale 1 - 9 as described by Kim (1994a) were collected. Others included: number of flowering *Striga* plants as well as barren maize plants. At *Striga* endemic and non-endemic fields, agronomic parameters such as maize establishment plant count, days to anthesis and silking and plant height were also measured. Plant height was measured from soil level to the base of the tassel. Days to 50% silking (number of days from planting to when 50% of the population have silked) as well as days to 50% pollen shed (number of days from planting till the time 50% have shed pollen) were recorded. Anthesis-silking interval was estimated as the difference between days to pollen shed and silking. Maize grain yield (t/ha) was also measured after adjusting for moisture at harvest. Data collected were subjected to separate diallel analyses using Griffing (1956) Method II (parents and crosses together), Model I (fixed effects). General and specific combining abilities (GCA and SCA) were computed using SAS (1999) for the 10 parents open pollinated varieties (OPVs) and their 45 F_1 hybrids with respect to *Striga* related and maize agronomic characters.

RESULTS

General and specific combining ability effects for *Striga* parameters

ANOVA for GCA effects of parents for *Striga* related traits in the *Striga* endemic environment are presented in Table 1. GCA effect for *Striga* shoot count was very low probably due to high tolerance of the parents to *S. hermonthica* emergence. The highest GCA effect for this trait was 95.50 from Ak 95 Dmr-Esrw as against the least value of 0.22 in parent Tze Comp4-Dmr Srbc2. GCA effect was also low among the parents for number of flowering shoots at 12 weeks after maize was planted, with Hei 97 Tze Comp3 C4 and Acr 97 Tze Comp3 C4 having the least effects. However, Ak 95 Dmr-Esrw was significant for this trait. GCA effect for number of barren maize plants was very low in most of the parents with parents Tze Comp3 C2 and Hei 97 Tze Comp3 C4 having the least GCA effects, while Acr 90 Pool 16-Dt had significant GCA effect for this character. GCA effect for *Striga* syndrome rating was also generally low with parents Tze Comp3 C2 and Acr 97 Tze Comp3 C4 recording the least effects. However, significant GCA effect was observed for *Striga* syndrome rating in Acr 90 Pool 16-Dt.

Specific combining ability (SCA) effects for *Striga* related parameters are presented in Table 2. SCA effects for both *Striga* shoot count (that is, emergence and infestation) and number of flowering *Striga* plants were generally low. However, highly significant SCA effect was observed in crosses Tze Comp4 C2 x Tze Comp3 C2, Acr 97 Tze Comp3 C4 x Tze Comp3 C2, Hei 97 Tze Comp3 C4 x Acr 94 Tze Comp5, Acr 94 Tze Comp5 x Ak 95 Dmr-Esrw and Tze Comp3 C2 x Ak 95 Dmr-Esrw for *Striga* shoot count at 8 WAP. Similarly, SCA effect for number of flowering *Striga* plants at 12 weeks after Maize was planted was significant for hybrids Acr 90 Pool 16-Dt x Acr 94 Tze Comp5, Acr 90 Pool 16-Dt x Tze Comp3 C2, Tze Comp4 C2 x Tze Comp3 C2, Acr 97 Tze Comp3 C4 x Tze Comp3 C2, Hei 97 Tze Comp3 C4 x Ak 95 Dmr-Esrw and Acr 94 Tze Comp 5 x Ak 95 Dmr-Esrw. Values recorded in respect of the remaining crosses were very low and non-significant.

Non-significant SCA effects were observed in the hybrids for number of barren maize plants (Table 3).

Table 1. Estimate of GCA effects for *Striga* related parameters in *Striga* endemic environment (Shonga) of southern guinea savanna of Nigeria.

Parents	*Striga* shoot count	Number of flowering *Striga*	Number of barren maize plants	*Striga* syndrome rating
Acr 90 Pool 16-Dt	35.36	13.94	137.48*	1120.08**
Tze Comp 4-Dmr Srbc2	0.22	1.50	40.71	6.51
Tze Comp4 C2	15.95	10.69	13.97	141.37
Acr 97 Tze Comp3 C4	11.27	0.01	122.89	1.44
Hei 97 Tze Comp3 C4	0.23	1.05	0.81	7.45
Acr 94 Tze Comp5	35.27	14.13	39.98	49.65
Tze Comp3 Dt	11.07	7.56	277.18	76.31
Tze Comp3 C2	34.78	13.87	0.06	0.35
Ak 95 Dmr-Esrw	95.50	70.04**	17.96	11.22
Tze Msr-W	1.02	2.05	1.13	8.21

*, ** Significant at < 0.05 and < 0.01 levels of probability respectively.

However, SCA effects were significant for *Striga* syndrome ratings in crosses Tze Comp4- Dmr Srbc2 x Acr 97 Tze Comp3 C4, Tze Comp4-Dmr Srbc2 x Tze Comp3 Dt, Tze Comp4-Dmr Srbc2 x Tze Comp3 C2, Tze Comp4 C2 x Acr 97 Tze Comp3 C4, Hei 97 Tze Comp3 C4 x Tze Comp4 C2 and Tze Comp3 Dt x Ak 95 Dmr-Esrw.

General and specific combining ability effects for maize grain yield and related traits

Estimates of GCA effects for grain yield and agronomic traits in *Striga* endemic and *Striga* free environments are presented in Table 4. GCA effects for maize agronomic characters in *Striga* endemic and *Striga* free environments differed significantly in the parents. Parent Acr 90 Pool 16-Dt recorded significant GCA effects only for maize establishment count and maize grain yield in both *Striga* endemic and *Striga* free environments. Parent Acr 94 Tze Comp5 exhibited significant GCA effects for days to pollen shed and grain yield in *Striga* free environment, and also had significant GCA effects for both days to silking and grain yield in *Striga* endemic environment. Tze Comp3 C2 only showed positive and significantly high GCA effects for both anthesis-silking interval and grain yield in both *Striga* endemic and *Striga* free environments. Acr 94 Tze Comp5 only had significant GCA effect for plant height also showed significant effect for grain yield in *Striga* endemic environment.

GCA effects for maize grain yield in *Striga* endemic environment were generally low in many of the parents. However, Acr 94 Tze Comp5 and Tze Comp3 C2 exhibited high GCA effects for maize grain yield and some of the agronomic characters in both *Striga* endemic and *Striga* free environments. Acr 90 Pool 16-Dt and Tze Comp4 Dmrsrbc2 recorded high GCA effects for grain yield in *Striga* free environment.

SCA effects for maize establishment count (Table 5) in *Striga* endemic and non-endemic environments were highly significant in hybrid Tze Comp4 C2 x Acr 97 Tze Comp3 C4. Acr 90 Pool 16-Dt x Hei 97 Tze Comp3 C4 had significant SCA effects for days to 50% pollen shed and grain yield in *Striga* free environment, while SCA effects for days to 50% silking in *Striga* endemic and non-endemic environments were highly significant in cross Acr 90 Pool 16-Dt x Hei 97 Tze Comp3 C4. Conversely, non-significant SCA effects were recorded for anthesis-silking interval and plant height. Yield assessment in *Striga* endemic environment showed significant effects in crosses Tze Comp3 C2 x Hei 97 Tze Comp3 C4,Tze Comp3 C2 x Acr 94 Tze Comp5 and Ak 95 Dmr-Esrw x Acr 94 Tze Comp5. Hybrids Tze Comp4 C2 x Acr 97 Tze Comp3 C4, Acr 90 Pool 16-Dt x Hei 97 Tze Comp3 C4 had significant SCA effects for maize grain yield and also for maize establishment count and flowering traits respectively in *Striga* free environment.

Table 2. Estimates of SCA effects for *Striga* shoot count (upper diagonal) and number of flowering *Striga* (lower diagonal) in F_1 hybrids 8 WAP in *Striga* endemic environment (Shonga, Nigeria).

Parent	Acr 90 Pool 16-Dt	Tze Comp4-Dmr Srbc2	Tze Comp4 C2	Acr 97 Tze Comp3 C4	Hei 97 Tze Comp3 C4	Acr 94 Tze Comp5	Tze Comp3 Dt	Tze Comp3 C2	Ak 95 Dmr-Esrw	Tze Msr-W
Acr 90 Pool 16-Dt		0.20	0.01	5.33	24.12	11.47	9.39	60.00	12.87	2.67
Tze Comp4-Dmr Srbc2	1.89	_	6.94	4.10	4.71	36.28	0.23	0.52	28.90	4.67
Tze Comp4 C2	0.28	2.58	_	1.94	1.18	41.84	9.30	110.12**	21.42	3.78
Acr 97 Tze Comp3 C4	1.05	3.64	0.25	_	2.14	54.71	32.47	105.57**	7.72	8.34
Hei 97 Tze Comp3 C4	8.60	0.01	3.99	0.01	_	105.15**	9.34	18.09	36.96	5.76
Acr 94 Tze Comp5	48.23*	29.27	23.58	34.00	64.39	_	1.30	56.89	77.67*	2.45
Tze Comp3 Dt	3.20	4.55	1.92	8.34	0.89	4.16	_	3.62	106.38**	6.46
Tze Comp3 C2	43.03*	0.31	62.90*	64.27**	7.11	3.28	1.31	_	3.63	11.62
Ak 95 Dmr-Esrw	10.04	20.84	15.01	5.32	39.72*	73.39**	30.56	32.31	_	7.53
Tze Msr-W	1.78	3.41	5.87	3.45	4.86	7.32	8.56	2.93	4.34	_

*, ** Significant at < 0.05 and 0.01 levels of probability respectively.

Table 3. Estimates of SCA effects for number of barren plants (upper diagonal) and *Striga* syndrome rating (lower diagonal) in F_1 hybrids 12 WAP in *Striga* endemic environment (Shonga, Nigeria).

Parent	Acr 90 Pool 16-Dt	Tze Comp4-Dmr Srbc2	Tze Comp4 C2	Acr 97 Tze Comp3 C4	Hei 97 Tze Comp3 C4	Acr 94 Tze Comp5	Tze Comp3 Dt	Tze Comp3 C2	Ak 95 Dmr-Esrw	Tze Msr-W
Acr 90 Pool 16-Dt	-	25.94	46.71	139.02	118.74	8.94	37.59	39.24	23.48	0.41
Tze Comp4-Dmr Srbc2	6.75	-	120.14	228.14	2.15	5.54	145.67	124.74	94.49	0.21
Tze Comp4 C2	101.23	48.43	-	323.35	177.16	1.24	4.46	2.51	316.07	0.42
Acr 97 Tze Comp3 C4	49.91	251.5*	268.57*	-	17.96	31.56	161.84	4.28	15.77	0.23
Hei 97 Tze Comp3 C4	3.27	37.51	251.11*	12.39	-	265.2	10.43	15.83	12.32	0.31
Acr 94 Tze Comp5	0.37	24.48	19.67	18.69	195.77	-	108.09	26.65	138.49	0.32
Tze Comp3 Dt	111.07	389.5*	157.31	99.72	6.32	5.53	-	0.82	393.32	0.17
Tze Comp3 C2	141.71	254.9*	12.31	21.67	3.26	21.07	11.51	-	290.64	0.43
Ak 95 Dmr-Esrw	171.09	7.59	6.39	2.26	23.45	62.07	397.5*	164.51	-	0.02
Tze Msr-W	7.59	8.58	4.52	32.58	25.84	21.23	3.45	251.00	2.02	-

*, ** Significant at < 0.05 and 0.01 levels of probability respectively.

Table 4. Estimate of GCA effects for maize grain yield and agronomic traits under *Striga* endemic (Shonga) and non-endemic environments (Ilorin) of southern guinea savanna of Nigeria.

	Maize establishment plant count		**Days to 50% pollen shed**		**Days to 50% silking**		**Anthesis-silking interval**		**Plant height**		**Grain yield**	
Parent	***Striga* endemic**	***Striga* free**	***Striga* endemic**	***Striga* free**	***Striga* endemic**	***Striga* free**	***Striga* endemic**	***Striga* free**	***Striga* endemic**	***Striga* free**	***Striga* endemic**	***Striga* free**
Acr 90 Pool 16-Dt	711.02*	384.05*	0.01	9.10	9.10	0.60	0.01	0.67	9.10	390.72	0.20	1.04*
Tze Comp 4-Dmr Srbc2	28.80	485.53*	16.16	88.41	88.41	24.50*	0.72	0.04	88.41	361.25	1.98	1.02*
Tze Comp4 C2	54.32	16.93	2.80	9.96	9.96	0.02	1.87	11.54	9.96	14.89	1.86	0.73
Acr 97 Tze Comp3 C4	16.08	37.36	0.55	153.56*	153.22*	47.03*	0.03	9.47	153.82*	34.44	5.75	0.53
Hei 97 Tze Comp3 C4	146.77	835.45*	0.49	0.95	0.95	0.24	0.06	13.04*	0.95	92.65	0.25	0.36
Acr 94 Tze Comp5	173.07	102.97	0.24	163.11*	163.43*	2.39	0.70	1.63	163.35*	167.33	66.11*	1.45*
Tze Comp3 Dt	327.83*	106.22	1.20	118.32*	118.31*	2.96	4.99	5.43	118.45*	45.00	4.04	0.06
Tze Comp3 C2	37.16	29.72	3.31	55.23	55.23	0.23	12.13*	20.08*	55.23	287.90	55.14*	1.07*
Ak 95 Dmr-Esrw	119.43	218.34*	0.14	9.29	9.29	0.06	1.83	0.05	9.29	25.85	7.88	0.19
Tze Msr-W	4.67	3.67	7.89	4.57	4.57	11.14	0.61	7.80	4.57	452.54	0.41	0.07

*, ** Significant at < 0.05 and < 0.01 levels of probability respectively.

DISCUSSION

General and specific combining ability effects for *Striga* parameters

In breeding for *Striga* tolerance, the lower the value obtained for *Striga* related parameters, the better the genotypes with respect to these traits. Significant GCA and SCA effects recorded in *Striga* endemic environment for *Striga* related parameters such as *Striga* shoot count, *Striga* syndrome ratings, flowering *Striga* shoots and barren maize plants, suggest differential reaction of the genotypes to *Striga* infestation. These results showed that both additive and non-additive gene effects played major roles in the inheritance of tolerance to the parasite both in the OPVs and hybrids respectively. Low GCA effects recorded for *Striga* shoot count and number of flowering *Striga* plants in the parents is also indicative of high tolerance to *S. hermonthica* emergence and survival, consequently, a reduction in the rate of *Striga* seed multiplication in the soil. The low GCA effects for *Striga* syndrome rating and number of barren maize plants similarly suggest their tolerance to *S. hermonthica* infestation. Parents Tze Comp4 Dmr Srbc2 and Tze Msr-W with very high GCA effects for *Striga* shoot count could be regarded as susceptible while Tze Msr-W and Acr 97 Tze Comp3 C4 with low GCA effects have good tolerance to *S. hermonthica*. Kim (1994a) had earlier reported low GCA effects for *S. hermonthica* emergence and host-plant response for most tolerant maize inbreds and high GCA effects for the susceptible. In the present study, additive gene action played a greater role in inheritance of tolerance to *S. hermonthica* (Del.).

Benth as previously observed by Adetimirin et al. (2001). Generally, the result obtained from our study showed that some parents were tolerant to *S. hermonthica*, but level of tolerance varied probably due to differences in genetic background among the parental populations used. These results also support the findings of Ransom et al. (1990) who observed that maize genotypes differed significantly in their tolerance to *Striga asiatica* infestation. This would suggest that a significant portion of *Striga* tolerance is derived from gene complexes (Kim et al., 1998), which may be best exploited in hybrid combinations where disrupttion through segregation would be minimized.

Significant SCA effects recorded for *Striga* related characters indicated differential response of the crosses to these *Striga* parameters. In other words, non-additive gene action played significant role in the inheritance of *Striga* tolerance in most of the crosses. The most resistant crosses are those involving Acr 94 Tze Comp5 and Tze Comp3 C2 which are both resistant *Striga*. In the earlier study, Kim (1991) reported that the highest level of tolerance to *S. hermonthica* was obtained from crosses involving two resistant parents while most of the susceptible hybrids were from crosses involving of susceptible x susceptible parents as

Table 5. Estimate of SCA effects of selected crosses for maize grain yield and agronomic traits in *Striga* endemic (Shonga) and non-endemic (Ilorin) environments of the southern guinea savanna of Nigeria.

	Maize establishment plant count		Days to 50% pollen shed		Days to 50% silking		Anthesis-silking interval		Plant height		Grain yield	
Hybrid	***Striga* endemic**	***Striga* free**	***Striga* endemic**	***Striga* free**	***Striga* endemic**	***Striga* free**	***Striga* endemic**	***Striga* free**	***Striga* endemic**	***Striga* free**	***Striga* endemic**	***Striga* free**
Acr 90 Pool 16-Dt x Hei 97 Tze Comp3 C4	3.00	82.94	5.14	9..25*	17.69*	27.05*	0.17	0.76	24.98	8.10	1.07	2.03*
Acr 90 Pool 16-Dt x Tze Comp3 Dt	3.53	86.64	0.14	0.47	0.01	0.01	2.28	2.18	45.68	148.86	0.76	2.35*
Acr 90 Pool 16-Dt x Ak 95 Dmr-Esrw	1.40	0.15	1.05	1.98	5.83	9.94	2.05	0.27	2.45	11.16	0.49	1.87*
Tze Comp4 C2 x Acr 97 Tze Comp3 C4	234.44*	240.61*	0.30	0.24	0.41	2.09	3.48	0.05	152.99	263.99	0.36	1.07*
Tze Comp4 C2 x Hei 97 Tze Comp3 C4	60.84	58.90	0.27	0.96	0.06	4.82	2.67	1.62	47.37	163.05	0.14	1.19*
Acr 97 Tze Comp3 C4 x Hei 97 Tze Comp3 C4	37.25	43.90	0.44	0.01	0.24	0.50	8.18*	1.26	8.87	257.51	0.29	1.15*
Hei 97 Tze Comp3 C4 x Acr 94 Tze Comp5	62.56	4.30	0.02	2.06	1.07	2.88	0.01	1.27	24.00	329.55	0.09	1.72*
Hei 97 Tze Comp3 C4 x Tze Comp3 Dt	5.00	0.36	0.23	3.52	0.45	0.03	5.57	8.75	38.55	11.14	0.86	2.31*
Tze Comp3 C2 x Hei 97 Tze Comp3 C4	5.76	183.50	0.41	0.46	0.63	0.06	1.17	2.47	82.26	28.17	1.83*	0.01
Tze Comp3 C2 x Acr 94 Tze Comp5	8.70	2.12	4.14	5.33	0.36	5.75	7.90	3.37	42.23	143.65	3.67*	0.71
Ak 95 Dmr-Esrw x Acr 94 Tze Comp5	0.66	1.34	0.04	3.22	2.11	0.36	0.02	3.70	70.90	1.54	1.60*	0.46

*, ** Significant at < 0.05 and < 0.01 levels of probability respectively.

as observed with Tze Comp3 Dt in this study. The result suggests that genes for tolerance may be recessive since *S. hermonthica* tolerance appears more common in tolerance x tolerance crosses compared with tolerance x susceptible crosses.

General and specific combining ability effects for maize grain yield and agronomic traits

There were differential responses among the parent OPVs for maize agronomic characters in both *S. hermonthica* endemic and non-endemic environments. Low GCA effects recorded for maize grain yield in *Striga* endemic environment in many of the parents indicate poor general combination in terms of grain yield under heavy *Striga* infestation and lack of heterotic response for grain yield in many of the parents used. However, two parents (Tze Comp3 C2 and Acr 94 Tze Comp5-W), which exhibited high GCA effects for maize grain yield, will be suitable as parents for yield improvement in *Striga* endemic environ-ment. Badu-Apraku and Lum (2007) reported that varieties differed significantly in grain yield under both S*triga* endemic and S*triga* free conditions. The authors also identified Acr 94 Tze Comp 5-W as the most promising genotypes in terms of grain yield, reduced *Striga* damage and low *Striga* emer- gence. In an earlier study conducted in Abuja and Mokwa (Nigeria), Menkir et al. (2001); Badu-Apraku et al. (2008) independently reported low grain yield for most of parents used in the present study under *Striga* infestation. Both studies also identified OPVs Acr 94 Tze Comp5 and Tze Comp3 C2 as being superior for grain yield under *Striga* infestation which further confirmed their suitability as cultivar *per se* in *S. hermonthica* endemic environment as well as sources of genes for *S. hermonthica* tolerance and higher maize grain yield across the SGS ecology. Therefore, apart from their suitability as cultivar in *S. hermonthica* endemic environment, these two parents could be hybridized with other proven cultivars to increase grain yield in *Striga* endemic environment of Nigeria savannas.

The significant GCA effects for maize establishment count exhibited by many of the parents indicated that the present gene pools can be manipulated for better germination and survival especially since the environment is also drought-prone. Highly significant GCA effects recorded among some parents for flowering traits (days to 50% tasselling and silking) indicated late maturity of the parents, while those with low effects indicate earliness in maturity. The significant GCA effect recorded for Tze Comp3 C2 in both environments for anthesis-silking interval shows differential response of the parent to differences in environmental factors and also could be crossed with other promising genotypes to generate populations with early maturity and high yielding. Shanghi et al. (1983); Revilla et al. (1999) in independent studies also reported the importance of GCA effects for days to tasselling, silking and maturity in open pollinated varieties of maize.

Plant height is also an important trait to be considered in maize breeding especially since maize plant with high plant height could lodge easily. Significant GCA effects for plant height in parents Acr 94 Tze Comp5, Acr 97 Tze Comp3 C4 and Tze Comp3 Dt under *Striga* infestation, showed variability in plant height among these genotypes. Thus, Acr 94 Tze Comp5 and Tze Comp3 C2 which combined high maize grain yield with reduced *Striga* damage, plant height and anthesis- silking interval could be ideal cultivar *per se* or utilized in hybrid combinations for further testing in *Striga* endemic area to ascertain consistency in performance.

SCA effects for maize grain yield and other related characters in *Striga* endemic environment were generally low in many of the hybrids indicating poor specific combination for these traits under severe *Striga* infestation. However, crosses Tze Comp3 C2 x Hei 97 Tze Comp3 C4, Tze Comp3 C2 x Acr 94 Tze Comp5 and Ak 95 Dmr-Esrw x Acr 94 Tze Comp5 with significant SCA effects for maize grain yield, appeared to be ideal specific combiners for grain yield in *Striga* endemic environment. This suggests that non-additive gene effects played a major role in the expression of grain yield among crosses under *Striga hermonthica* infestation which is also similar to earlier report (Olakojo and Olaoye, 2005) of importance of non-additive gene action in the inheritance of tolerance to *S. lutea* infestation in the southwestern ecology of Nigeria. Therefore, these three hybrids could be utilized as sources of inbred line extraction for the development of high yielding varieties for cultivation in *Striga* endemic ecology of the Nigeria Guinea Savanna. Hybrid, Tze Comp4 C2 x Acr 97 Tze Comp3 C4 with significant SCA effects for maize grain yield and maize establishment count, could be crossed with other promising genotypes to generate populations with better germination, survival and high grain yield in the drought-prone ecology of the SGS. Acr 90 Pool 16-Dt x Hei 97 Tze Comp3 C4 on the other hand could be ideal for early season cultivation in the SGS, having exhibited significant SCA effects for earliness and maize grain yield.

The parents used in this study as well as the crosses generated exhibited different levels of significant GCA and SCA effects for *Striga* tolerant traits, maize agronomic traits and grain yield in *S. hermonthica* endemic and non-endemic environments. Several studies (Kim, 1994ab; Berner et al., 1995; Abreu, 1997; Akanvou et al., 1997; Lane et al., 1997) have also shown that both additive and non- additive gene effects are important in the inheritance of different *Striga* parameters and grain yield. However, the results from present study which corroborates earlier findings of Kim (1994a); Berner et al., (1995); Akanvou et al., (1997) which were conducted in West and Central Africa on the relative importance of GCA to SCA effects for the different *Striga* parameters, differed from those of Lane et al. (1997). For example, reports of earlier authors noted that GCA effects played important role in the inheritance of plant host damage while SCA effect was more important for *S. hermonthica* emergence. Lane et al. (1997) in their own study reported that both additive and non -additive gene effects played equal and important roles in the inheritance of *Striga* parameters. In other words, relative importance of GCA and SCA effects for *Striga* parameters may vary depending on population sampled or environment where the study was conducted.

Menkir et al. (2001) suggested the establishment of parallel breeding programme targeted for yield improvement in *Striga* endemic and *Striga* free environment. Therefore OPV parents Acr 94 Tze Comp5 and Tze Comp3 C2, besides being ideal as cultivar *per se*, represent new sources of *Striga* tolerance genes for future breeding of high yielding *Striga* tolerant maize varieties for *S. hermonthica* endemic ecologies of Nigeria's savannas. Acr 94 Tze Comp5 and three other parents which exhibited high GCA effect for grain yield in *Striga* free environment could form a parallel gene pool for development of future varieties for high grain yield and general adaptation to the Nigeria savannas.

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