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Full Length Research Paper

Combining ability for maize grain yield and other agronomic characters in a typical southern guinea savanna ecology of Nigeria

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Field experiments were conducted at the University of Ilorin Teaching and Research Farm in 2005 and 2006 cropping seasons with the objective to evaluate the combining ability for maize grain yield and other agronomic characters in 10 open pollinated maize varieties, which have been selected for high yield and stress tolerance. General combining ability (gca) and year (y) effects were significant for all the parameters except plant height, while specific combining ability (sca) and gca x year effects were significant only for grain yield. However, Tze Comp4 Dmr Srbc2, Tze Comp4 C2 and Acr 94 Tze Comp5 which are good general combiners for maize grain yield, also showed positive significant gca x year effects for flowering traits. Significant sca x year interaction effects were recorded for maize grain yield and days to flowering, with Hei 97 Tze Comp3 C4 combining very well with 3 parents (Acr 90 Pool 16-Dt, Tze Comp4-Dmr Srbc2 and Tze Comp4 C2). These parents and their hybrids probably have genes that can be introgressed into other promising lines in developing early maturing and high yielding varieties for cultivation in the Nigeria savannas.

Key words: *Zea mays* L., general combining ability, specific combining ability, grain yield, Nigeria savannas.

INTRODUCTION

Maize production in the southern guinea savanna (SGS) of Nigeria is constrained by several factors including drought, low soil nutrient status and susceptibility to pests and diseases as well as poor adaptation to the agro-ecologies (Olaoye et al., 2004). Maize breeders have therefore devoted effort to developing superior genotypes for grain yield and adaptation to the different stress factors (Olaoye et al., 2005). To establish a sound basis for any breeding programme, aimed at achieving higher yield, breeders must have information on the nature of combining ability of parents, their behaviour and performance in hybrid combination (Chawla and Gupta, 1984). Such knowledge of combining ability is essential for selection of suitable parents for hybridization and identification of promising hybrids for the development of improved varieties for a diverse agro-ecology such as the SGS of Nigeria (Alabi et al., 1987). Combining ability of an inbred rests on its ability to produce superior hybrids in combination with other inbreds. General combining ability (gca) as defined by Sprague and Tatum (1942) is the average performance of a genotype in hybrid combination while specific combining ability (sca) as those cases in which certain combinations perform relatively better or worse than would be expected on the basis of the average performance. Falconer (1989) observed that gca is directly related to the breeding value of the parent and is associated with additive genetic effects, while sca is associated with non-additive such as dominance, epistatic and genotype x environment interaction effects (Rojas and Sprague, 1952).

Estimate of combining ability using diallel-mating design has been widely used to provide information on the performance of parental populations and their heterotic pattern in crosses, identify heterotic groups and predict performance of new populations (composites) derived from such crosses (Miranda Filho, 1985). This approach has been used in identifying suitable maize genotypes for improvement of grain yield and other agronomic traits (Castilo-Gozalez and Goodman, 1989; Iken and Olakojo, 2002), adaptation to tropical environ-

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Table 1. Combined analyses of variance across years for maize agronomic characters at Ilorin (Nigeria).

Source of variation	Df	Maize establishment count	Days to 50% tasselling	Days to 50% silking	Anthesis-silking interval (days)	Plant height (cm)	Grain yield t/ha $^{-1}$
Year	1	0.72*	1.44*	1.38*	0.57*	0.15	0.75*
GCA	9	0.75*	1.23*	0.97*	1.02*	0.28	0.68*
SCA	45	0.03	0.56	0.65	0.48	0.32	0.72*
GCA x Year	9	0.14	0.70	0.58	0.39	0.25	0.96*
SCA x Year	45	0.82*	2.10*	1.21*	1.36*	0.32	0.65*
Pooled error	108	0.06	0.01	0.07	0.03	0.03	0.05
$\sigma^2 s / \sigma^2 g$		0.011	0.023	0.015	0.045	0.032	0.038

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

ment (Vasal et al., 1992), good ear placement and uniformity in flowering (Martinez et al., 1993), as well as selecting for high heterosis and adaptation to diverse agro-ecologies (Peresvelasques et al., 1995). Thus, a diallel cross of ten open pollinated maize varieties (OPVs) was used to estimate gca and sca effects for grain yield potential in a typical SGS ecology of Nigeria with the view to identifying promising candidates either for cultivation as varietal hybrids or for extraction of inbred lines for hybrid development.

MATERIALS AND METHODS

The parent materials used in this study comprised of 10 open pollinated varieties (OPVs) of maize, developed for grain yield and adaptation to abiotic (drought) and biotic (Stalk rot, Striga and Downy mildew) stress factors. They are early to medium maturing white cultivars with maturity period of 90 to 100 days. The cultivars were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan. The 10 varieties were crossed in a partial diallel to generate 45 F_1 hybrids during 2004 and 2005 cropping seasons at the teaching and research (T and R) farm of university of Ilorin (Latitude 8^0 29'N, Longitude 4^0 35'E and annual rainfall of 945 mm). The resultant hybrids were harvested, processed and stored in the cold room prior to field evaluation. The genetic materials were evaluated using a randomized complete block design (RCBD) with 4 replicates in 2005 and 2006 respectively. Entries were made in 2-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 53,333 stands per hectare. 3 seeds were initially planted on a hill but were later thinned to 2 at 3 weeks after planting (WAP). NPK 20-10-10 fertilizer was applied at the rate of 80 kg N ha^{-1} in 2 equal doses immediately after thinning and at 6 WAP respectively. Data collected each year included maize establishment plant count (EPC); plant height (cm) (PHT) measured from the soil level to the flag leaf. Days to 50% pollen shed (PS) and silking (SK) were taken as number of days from planting to the time 50% of the plant have shed pollen and had silk extrusion. Maize grain yield (GY) (t/ha^{-1}) was also measured after adjusting to 12% moisture content.

Data collected were subjected to diallel analyses using Griffing (1956) Method II (parents and crosses together), Model I (fixed effects), first on individual year basis, before a combined analyses across the 2 years. Both general and specific combining abilities (gca and sca) were computed using SAS PROC. (1999) for the parent OPVs and hybrids with respect to maize grain yield and other agronomic characters respectively.

RESULTS AND DISCUSSION

Combined ANOVA for maize grain yield and agronomic traits across the two years (2005 and 2006) are presented in Table 1. Almost all the characters showed significant differences between years except plant height. This suggests differential response of OPVs to factors of environment (climatic) in the 2 years. gca effects were significant also for all the parameters except plant height, while sca effect was significant for grain yield only. Year x gca effect was significant only for grain yield, but sca x year effects were significant for almost all the characters except plant height. This indicates high variability among the parents and crosses in their responses to different climatic changes in both years. This underscores earlier view of Kang (1988) who noted that environment played prominent role in phenotypic expression of agronomic characters. The author suggested that ignoring environmental component in the fields would likely reduce progress and advances in selection. The corollary is that climatic (rainfall, sunshine, relative humidity etc.) variation could be an important factor in breeding for desirable characters including grain yield in the SGS of Nigeria. The ratio of estimated sca to gca effects indicated a preponderance of gca component in the expression of all the traits. The results therefore suggest that additive type of gene action is primarily involved in determining grain yield and other agronomic parameters.

General combining ability x year effects for grain yield and agronomic traits

Estimates of general combining ability x year interaction effects in the parents for grain yield and agronomic traits are presented in Table 2. Significant gca x year interacttive effects were recorded for maize establishment count, which is an indication of how broad the genetic base of the maize OPVs used are with respect to this trait. Parents Acr 90 Pool 16-Dt, Tze Comp4 C2 and Tze Comp4 Dmr Srbc2 exhibited significant gca x year effects for establishment count and could be ideal general com-

Table 2. Estimates of general combining ability (gca) x year interactive effects for maize yield and agronomic traits in 2005 and 2006 (Ilorin, Nigeria).

Parent	Maize establishment count		Days to 50% pollen shed		Days to 50% silking		Anthesis-silking interval		Plant height (cm)		Grain yield (t/ha)	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Acr 90 Pool 16-Dt	**246.32***	**381.74***	**0.29**	**19.86**	**0.01**	**0.60**	**7.07**	**0.64**	**306.35**	**390.72**	**2.45***	**0.79**
Tze Comp 4-Dmr Srbc2	352.01*	485.6**	6.03	16.06	16.94	24.50*	0.45	0.04	74.71	361.26	0.08	2.74*
Tze Comp4 C2	494.93**	16.92	9.44	36.87	3.80	0.15	36.98*	31.22*	12.00	14.89	0.45	2.45*
Acr 97 Tze Comp 3 C4	4.68	37.36	0.02	4.65	8.68	47.34	5.07	9.47	85.36	34.44	0.04	0.43
Hei 97 Tze Comp 3 C4	455.2**	835.9**	2.38	1.73	24.96*	0.24	0.75	13.23	933.43*	92.65	0.01	0.43
Acr 94 Tze Comp5	92.32	102.97	2.85	7.12	5.43	2.39	4.38	1.63	67.59	167.33	0.01	1.32*
Tze Comp3 Dt	402.2**	106.22	0.19	0.35	0.04	2.96	7.20	5.43	55.23	45.00	0.13	0.07
Tze Comp3 C2	12.36	29.72	8.31	1.09	0.01	0.23	3.11	0.08	161.66	278.90	0.49	1.71*
Ak 95 Dmr-Esrw	95.84	218.86	8.00	3.82	0.44	0.06	5.05	2.75	120.96	25.85	0.01	0.14
Tze Msr-W	0.01	78.00	11.45	17.09	0.22	0.03	0.23	0.32	0.23	0.78	0.02	0.03

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

biners for this character as they also showed significant effect for grain yield. This indicated that some populations presented superior behaviour in their crosses when compared with others included in the diallel. Tze Comp4 Dmr Srbc2, Tze Comp4 C2 and Acr 94 Tze Comp5 which are good combiners for maize grain yield, also showed significant gca x year effects for flowering traits. These parents probably have genes that can be introgressed into other promising lines for early maturity and high grain yield. This report agrees with that of Paul and Debenth (1999) who noted significant gca effects for days to anthesis. The authors further stressed that additive gene action played a major role in the inheritance of days to maturity in the test genotypes. Similarly, El-Hosary et al. (1994) reported significant gca x year effect for all the flowering traits in the 2 years of their study.

Anthesis-silking interval is a trait used mostly in screening genotypes for tolerance to stresses. It is a measure of nicking (synchronization) of pollen shed with silking. Parent Tze Comp4 C2 only showed positive significant gca x year effects for both anthesis-silking interval and grain yield. This OPV could be regarded as the most desirable parent for this trait. This report is in line with earlier independent studies by Shanghai et al. (1983) and Paul and Debenth (1999) who independently reported that gca effects were significant for anthesis-silking interval and that additive gene action played a major role in the inheritance of the character. Significant gca x year interaction effects for maize grain yield recorded for Acr 90 Pool 16 Dt, Tze Comp4 Dmr Srbc2 and Tze Comp3 C2, Acr 94 Tze Comp5 and Tze Comp3 C2 suggests that they could be good general combiners for high grain yield. Therefore these hybrids probably have potential as parents of hybrid varieties, as well as for inclusion in breeding programmes, since they may contribute superior alleles in new populations for high grain yield.

Specific combining ability x year effects of selected hybrids for grain yield and agronomic traits

The estimates of SCA effects of top ranking 16 crosses are presented in Table 3. Significant sca x year interaction effects, which reflect individual cross differences in the 2 years were observed for maize grain yield and other agronomic traits. Sca x year interactive effects for both maize establishment count and grain yield were significant in the hybrids with Tze Comp3 Dt combining very well with Acr 90 Pool 16-Dt, Acr 94 Tze Comp5 and Tze Comp3 C2. Hybrids Tze Comp4 C2 x Tze Comp4-Dmr Srbc2 and Tze Comp3 C2 x Ak 95 Dmr-Esrw also recorded significant sca x year interaction effects for establishment count and grain yield. This suggests that these hybrids

Table 3. Specific combining ability (sca) x year interactive effects of selected crosses for maize grain yield and agronomic characters in 2005 and 2006 (Ilorin, Nigeria).

Hybrid	Maize establishment count		Days to 50% tasselling		Days to 50% silking		Anthesis-silking interval (days)		Plant height (cm)		Grain yield (t/ha)	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Acr 90 Pool 16-Dt x Hei 97 Tze Comp3 C4	82.94	57.26	39.08*	16.73*	27.05*	43.57*	0.76	7.12	8.10	18.08	0.03	1.41*
Acr 90 Pool 16-Dt x Tze Comp3 Dt	86.64	210.45*	3.09	1.36	0.01	0.02	2.18	0.23	148.86	13.37	2.35*	3.14*
Acr 90 Pool 16-Dt x Ak 95 Dmr-Esrw	0.15	2.85	7.44*	5.53	9.94*	4.47	0.27	0.01	11.16	265.02	1.87*	2.15*
Tze Comp4-Dmr Srbc2 x Tze Comp4 C2	84.79	687.07*	9.71*	4.06	0.04	2.22	11.44*	9.70	2.65	172.92	0.22	2.58*
Tze Comp4-Dmr Srbc2 x Hei 97 Tze Comp3 C4	2.82	61.46	25.05*	6.90	20.81*	24.38*	0.11	6.52	232.53	40.74	0.05	1.12*
Tze Comp4 C2 x Acr 97 Tze Comp3 C4	42.24	334.45*	1.42	7.39	2.09	3.60	0.05	2.00	263.99	177.64	1.17*	0.35
Tze Comp4 C2 x Hei 97 Tze Comp3 C4	4.15	199.07	10.94*	1.75	4.82	16.77*	1.62	1.69	163.05	2.48	1.19*	0.02
Tze Comp4 C2 x Tze Comp3 C2	39.33	0.28	8.25	0.69	1.18	0.01	13.24*	0.27	206.13	21.79	0.03	2.13*
Acr 97 Tze Comp3 C4 x Hei 97 Tze Comp3 C4	58.90	97.02	3.02	10.24*	0.50	5.16	1.26	1.56	6.67	244.64	1.15*	1.39*
Hei 97 Tze Comp3 C4 x Acr 94 Tze Comp5	4.30	48.58	0.14	1.11	2.88	0.13	0.33	2.65	440.80	63.04	1.72*	0.07
Hei 97 Tze Comp3 C4 x Tze Comp3 Dt	0.36	3.54	2.97	12.79*	0.03	5.42	2.39	3.00	4.75	2.25	2.31*	2.50*
Acr 94 Tze Comp5 x Tze Comp3 Dt	316.63*	69.09	35.56*	9.82	0.01	10.49	1.35	0.35	213.24	293.52	0.59	1.51*
Acr 94 Tze Comp5 x Tze Comp3 C2	2.12	0.10	21.15*	3.91	5.75	11.60	3.73	22.64*	143.65	25.95	0.71	6.79*
Acr 94 Tze Comp5 x Ak 95 Dmr-Esrw	1.34	0.23	1.88	0.07	0.36	0.12	3.70	0.15	1.54	0.21	0.46	1.42*
Tze Comp3 Dt x Tze Comp3 C2	55.05	415.76*	0.43	0.60	0.01	0.24	0.26	1.13	51.66	12.68	0.69	1.78*
Tze Comp3 C2 x Ak 95 Dmr-Esrw	97.48	349.23*	0.04	1.48	0.96	3.67	1.07	0.24	66.24	08.54	0.33	1.12*

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

are better specific combiners for maize establishment count and high yielding and they could form an initial gene pool for good germination and seed viability for enhanced high stand count. Significant sca x year inter-action effects for days to 50% tasselling was recorded in the crosses with Hei 97 Tze Comp3 C4 combining very well with 5 parents (Acr 90 Pool 16-Dt, Tze Comp4-Dmr Srbc2, Tze Comp4 C2, Tze Comp3 Dt and Acr 97 Tze Comp3 C4). Similarly, sca x year interaction effects were significant among the hybrids for days to silking, with Hei 97 Tze Comp3 C4 combining very well with 3 parents (Acr 90 Pool 16-Dt, Tze Comp4-Dmr Srbc2 and Tze Comp4 C2). It is noteworthy that Hei 97 Tze Comp3 C4 appeared to have genes that can be introgressed to exploit heterosis for earliness and high grain yield. These results are in line with earlier inde-pendent studies of Kumar et al. (1998), Joshi et al. (1998) and Perez-Velasquez et al. (1996) who reported that maize grain yield and flowering traits were under the control of non-additive (sca effect) type of gene action.

Significant sca x year interaction effects for anthesis-silking interval and grain yield were recorded in the crosses with Tze Comp4 C2 which combined very well with Tze Comp4-Dmr Srbc2 and Tze Comp3 C2. On the other hand, non-significant sca x year effect was recorded for plant height. This indicated uniformity in plant height among the hybrids in the different years of evaluation. Therefore , the parents and hybrids which featured prominently with respect to better general and specific combining abilities for maize grain yield and other agronomic traits, could form an initial gene pool for further breeding programme in developing high yielding varieties for cultivation in the Nigerian savannas.

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