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Full-Length Research Paper

Genetic Analysis among Elite Nigerian Open-Pollinated Varieties and Inbred Lines of Maize (*Zea mays L.*) for Grain Yield and other Yield Components

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ABSTRACT: The purpose of this study was to determine the combining ability of open-pollinated maize varieties for grain yield using nine (four males and five females) parents. In the 2018 dry season, a nursery trial for the formation of an initial F1 breeding population using a line tester mating design was carried out at Lushi Irrigation Station in Bauchi. The nine parents and their resultant 20 F_1 were evaluated in a Randomized Complete Block Design (RCBD) with three replications at Bauchi and Jos during the 2019 cropping season. Significant differences were found among the genotypes studied. The combining ability analysis revealed significant differences in all traits except number of kernels per row and days to tasseling; days to silking and number of kernels per row. The findings also revealed that both additive and non-additive gene action in maize were important in controlling grain yield and other agronomic traits. For most traits, the parents TZEEI-112, TZEEI-29, TZEI-68, SAMMAZ-15, SAMMAZ-33, SAMMAZ-45, and SAMMAZ-51 have been identified as good general combiners. SAMMAZ-33 TZEI-65, SAMMAZ-15 TZEEI-112, SAMMAZ-33 TZEEI-112, and SAMMAZ-51 TZEEI-112 have also been identified as good specific combiners for kernel yield. For all traits except 300 kernel weight, number of ears per plant, and number of rows/ear, the ratio of GCA variance to SCA variance was less than one, indicating a preponderance of non-additive gene action.

Keywords: lines, testers, additive, non-additive, gene action

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INTRODUCTION

Maize (*Zea mays* L.) is a significant cereal crop due to its high yield, ease of processing, ease of digestion, and lower cost than other cereals (Jaliya *et al*., 2008). It has a wide range of applications, including animal feed in the livestock industry, export purposes, human food, and industrial products. Between 90 and 95 percent of maize is grown for grain, with the remaining 5 to 10% grown for silage (Jaliya *et al*., 2008). It can be used as a major research plant in a variety of academic disciplines, including genetics, physiology, soil fertility, and biochemistry. Maize contains 80% carbohydrate, 10% protein, 3.5% fiber, and 6.5% mineral iron and vitamin B, according to IITA (2001). In Africa, maize is grown primarily for carbohydrate and provides staple food for more than 300 million people (Banziger and Diallo, 2001). It provides 15 % of the total caloric intake in West and Central Africa (Badu-Aparaku *et al.,* 2011). In 2017, Africa produced approximately 75 million tons of maize, accounting for 7.5 percent of global maize production (FAO, 2017). Maize accounts for approximately 24 percent of farmland in Africa, with an average yield of around 2 tons per hectare per year. Nigeria is the largest African producer, with over 33 million tons produced, and followed by South Africa, Egypt, and Ethiopia. Because most maize production in Africa is done under rain-fed conditions, Africa imports 28% of its required maize grain from countries outside the continent. During droughts, irregular rainfall can lead to food shortages and famines

(FAOSTAT, 2018). As a result, there is an urgent need to increase maize crop productivity through breeding in order to stabilize grain yield and meet Nigeria's increasing demand for food and feed. Increasing maize production can be accomplished through the use of improved agronomic techniques, as well as the development and adoption of superior yielding varieties. The maize breeding program places a strong emphasis on the development of improved varieties with superior qualitative and quantitative traits, as well as resistance to biotic and abiotic stresses, for commercial use to meet the growing demand for human food and animal feed. The information about the genetic structure and combining ability of the parents is one of the most important criteria for identifying high yielding hybrids (Ceyhan, 2003). However, to breed high yielding varieties, breeders often face difficulties in selecting parents and crosses. In this context, the line × tester analysis method introduced by Kempthorne (1957) was used to obtain information on the nature of combining abilities of genotypes and their behavior and performance in a hybrid combination. Such knowledge of combining ability is essential for selection of suitable parents for hybridization and identification of promising hybrid for development of improved varieties for a diverse agro-ecology such as Nigeria (Alabi *et al*. 1987). This study was informed because of the need to determine the combining ability of inbred lines and hybrids for yield and yield determining traits so as to ascertain their possible value in current and future maize improvement programmes. It was also to determine the combining ability variances and estimate the general combining ability effects of parents and specific combining ability effects of crosses for grain yield and other yield traits and also to compare yield performance of top crosses with their parental open-pollinated varieties for grain yield and its related traits.

MATERIALS AND METHODS

The formation of initial breeding population through a line × tester mating design was conducted in 2018 dry season at Lushi Irrigation Station, Bauchi, Nigeria. Lushi is located on latitude 10^{o} 17′ N; 9^{o} 49′ E at an altitude of 690.2 m above sea level. In 2019 raining season, the 20 F_1 and the nine parents were evaluated in two locations viz: Bauchi and Jos. The experiments were conducted at Bauchi State College of Agriculture Research Farm in Bauchi, Bauchi State, Nigeria and in Jos, Plateau State, Nigeria. A total of five maize open pollinated varieties (OPVs) and four inbred lines were used for the study. The OPVs and inbred lines were obtained from the Institute for Agricultural Research, Ahmadu Bello University Zaria. The OPVs, SAMMAZ-15 and SAMMAZ-26 are of good grain quality, while SAMMAZ-48 and SAMMAZ-51 are drought tolerant and high yielding varieties respectively. On the other hand, TZEEI-29 and TZEEI-112 are extra-early inbred lines, while TZEI-65 and SAMMAZ-33 are early maturing maize varieties. The inbred lines were used as males, hereafter referred to as testers and the OPVs designated as lines were used as females. The inbred lines and OPVs were planted on a 2 × 3 m, 6 rows plot on spacing of 50 cm × 75 cm (0.50 m × 0.75 m) between and within rows respectively at Lushi in January of 2019. Before planting, land preparation was done by ploughing, then harrowing to produce soil with fine tilt. At planting, three seeds were sown per hole and thinned to two after establishment, two weeks after planting. Compound fertilizer NPK 15:15:15 was applied at 400 kg/ha at 10 days after planting and later top dressed with 90:60:60 Urea. Weeding was done manually as required. Three percent of Carbofuran was applied into the whorls of the plants at the rate of 2kg/ha at 6 weeks after planting to prevent stem borer's attack. The crosses or hybrids were obtained through line × tester mating design as described by Singh and Chaudhary, (1985) where each male in a group of four was mated to five set of females to arrive at 20 hybrids.

Each set of crosses were grown on a plot of 6 m^2 in ratio of two males: two females occupying 4 rows per plot with the males on two side rows and the female in center rows. Both the male and female inflorescence were covered with parchment paper bags (10 × 30 cm in size) and clipped at the base. However, during bagging date were indicated on the bag in order to assist in assessing viability of pollen. Best time for bagging was morning for maximum pollen viability. Bags were checked every day for ready pollen. Bags with ready pollen were held tightly above the point of pollen accumulation and the clip removed to release accumulated pollen on the females and clipped. Once crossing was completed the bags were marked (×) plot or entry number of pollen parent and this completed the crossing. The combinations provided 29 genotypes consisting of 20 hybrids, 4 inbreds and 5 OPVs. Ears were harvested, dried and shelled manually and kept in controlled environment for evaluation in the following cropping season.

Land preparation for the evaluation in 2019 cropping season began with application of roundup (Glyphosate) herbicide at rate of 4.0 l/ha. Ploughing and harrowing of field was done manually to provide fine tilt for seedling growth and establishment. Field was laid out in a Randomized Complete Block Design with three replications. The experimental area was 25 m × 39 m (975 m^2). The whole area was divided into three blocks containing twenty-nine treatments. All F_1 hybrids along with parental lines were planted manually under rain-fed conditions on 28th of June, 2019 and 16th of July in Jos and Bauchi respectively and later thinned to two plants per stand at two weeks after planting. Stand that did not have plants were gap-filled during first weeding. The plot consisted of 2 m × 3 m with an inter row spacing of 0.50 m and intra row spacing of 0.75 m respectively. Compound fertilizer of NPK 15:15:15 was applied at 400 kg/ha rate at 14 days after planting and later top dressed with urea (46:0:0) at 35 days after planting.

During the trial plants were kept weed free using a mixture of Atrazine and Gramozone applied at rate of 4.5 and 1.0 L/ha respectively supplemented with hoe weeding. The prevalence of stem borer attack on maize necessitated the use of 'pawa' insecticide (Lambda cyaholathrin) at two weeks after planting and four weeks after planting at the rate of 2.0 L/ha. In addition, Carbofuran was applied at the rate of 2 kg/ha at 6 weeks after planting into whorls of each plant. Losses from rodent's attack (ground squirrel) were minimized using numerous control measures through trap setting and baiting.

Harvesting of ears was done at physiological maturity. Ten plants were harvested per plot. Harvested ears were bagged in labeled large brown envelopes and used for data collection on yield and yield traits. Samples were dried to 15 % moisture content for yield assessment. Ten plants were randomly tagged for recording observations of each entry for all quantitative traits except days to 50 % tasseling and silking. Mean of ten plants for each entry in each replication was worked out for statistical analysis. Data were collected on all required parameters. Data obtained were subjected to analysis of variance as described by Obi (2002). Fisher's least significant difference ($F_{.\ LSD}$) was used to detect significant differences for mean separation among treatments. Combining ability variance and effects were determined and computed according to line × tester method according to Singh and Chaudhary, (1985).

The variance for general and specific combining abilities were tested against their respective error variances derived from analysis of variance of different traits. Additive and dominance genetic variance (σ^2A and σ^2D) were calculated by taking inbreeding coefficient (F) equal to one. Significant test for general combining ability and specific combining ability effects were performed using t-test. Estimation of proportional contributions of lines, testers and their interactions to total variance was also computed.

RESULTS AND DISCUSSION

Analysis of variance for combining ability, estimates of genetic variance and proportional contribution to total variance are presented in (**Table** 1). The treatment variance estimates for all traits were greater than environmental variance. The environmental variance is low and in some cases negligible. The result indicated highly significant difference in plant height (0.06**), ear height (0.04**), cob weight (0.01**), rows/ear (4137.12**), kernels/row (1048.01**), 300 kernel weight (132.04**) and kernel yield/plant (43.95**). Other traits did not show any significant difference. The result also shows highly significant or significant difference in days to silking (3.90**), plant height (0.10**), ear height (0.06**), cob weight (0.38*), ears/plant (0.03**) and rows/ear (0.69**) for line × tester across. On the other hand, the result shows that there was highly significant difference among location × treatment in plant height (0.10**), ear height (0.08**), cob width (0.01**), rows/ear (0.45**), 300 kernel weight (0.14**) and kernel yield/plant (1.55**). All other traits did not show significant difference in location × treatment. However, the mean square of location × line indicated that there was highly significant or significant difference in ear height (0.10**), cob length (0.12**), cob width (0.02**), cob weight (0.50**), rows/ear (3.75**), kernels/row (10.74*), 300 kernel weight (0.53*) and kernel yield/plant (1.28**). Location × tester shows highly significant or significant difference in days to tasseling (1.77**), days to silking (16.62**), ear height (0.05**), rows/ear (1.44**), kernels/row (12.83**), 300 kernel weight (2.13*) and kernel yield/plant (2.20**). There was highly significant difference in days to silking (4.16**), plant height (0.13**), ear height (0.08**), cob width (0.01**), rows/ear (0.70**), 300 kernel weight (0.47**) and kernel yield/plant (1.47**) under location × tester interaction. All other traits did not differ significantly among location and between line × tester interactions. The result for genetic components of variance shows that variance of GCA was consistently higher than other components for days to tasseling (0.03), days to silking (0.04), cob length (0.002), cob weight (0.003), ears/plant (0.78), rows/ear (0.41), 300 kernel weight (0.05) and kernel yield/plant (0.04). The result for the variance of SCA indicates high component for plant height only. The results for σ2GCA/ σ2SCA ratio for all traits were less than unity except for ears/plant (9.75) and rows/ear (7.5). Result for proportional contribution of lines to total variance was higher than that of line × tester in number of ear/plant (97), rows/ear (68.4), kernels/row (54.7) and 300 kernel weight (38.4). The result for line × tester contribution to total variance on the other hand was higher than of lines in days to tasseling, days to silking, plant height, ear height, cob length), cob width, cob weight and kernel yield/plant.

Maize is a fundamental economic food crop in Africa, Asia and Latin America and in some parts of the world (Aminu *et al.,* 2007). It plays significant role in human and animal nourishment in a number of countries worldwide (Prassana *et al.,* 2001; Hussain *et al*., 2006). To breed high yielding varieties breeders, face problem of selecting parents for hybridization and identification of promising

Table 1: Analysis for combining ability, estimates of genetic variance and proportional contribution to total variance among traits of maize

Source of Variation	DF	DFT	DFS	PHT	EHT	CBL	CWT	CWG	NEP	NRE	NKR	300KW	KYP
Location	1	0.03	1.20	0.06**	0.04**	0.007	0.01**	0.13	0.01	4137.12**	19482.01**	132.04**	43.98**
Replicate	4	1.43	0.69	0.01	0.02	0.08*	0.02**	0.31*	0.02**	0.23	8.74	0.74**	0.12**
Treatment	19	2.96**	4.28**	0.09**	0.04	0.08	0.01*	0.41**	0.80*	2.14	7.45	0.80**	1.12
Lines (GCA)	4	3.95**	7.47**	0.13**	0.03	0.04	0.01**	0.16	3.68**	6.95**	19.36**	1.46**	2.04*
Testers (GCA)	3	2.93**	1.54	0.02	0.01	0.21**	0.02**	0.84**	0.03**	1.52**	7.76	1.81**	1.30**
Line × tester (SCA)	12	2.63	3.90**	0.10**	0.06**	0.06	0.01	0.38*	0.03**	0.69**	3.40	0.33	0.77
Location × Treatment	19	2.86	5.55	0.10**	0.08**	0.06	0.01**	0.30	0.01	0.45**	8.29	0.74**	1.55**
Location × Line	4	1.51	1.43	0.05	0.10**	0.12**	0.02**	0.50**	0.01	3.75**	10.74*	0.53*	1.28**
Location × Testers	3	7.77**	16.62**	0.03	0.05**	0.002	0.004	0.18	0.01	1.44**	12.83**	2.13*	2.20**
Location × Line × tester	12	2.08	4.16**	s0.13**	0.08**	0.05	0.01**	0.26	0.01	0.70**	6.34	0.47*	1.47**
Error	76	3.89	5.120	0.08	0.06	0.11	0.01	0.40	0.03	0.60	14.03	0.56	1.20
Genetic Components of Variance													
σ^2Treatment		9.37	13.35	0.29	0.13	0.25	0.03	1.30	2.53	6.78	23.58	2.53	3.55
σ^2Line		0.05	0.15	0.001	0.0	0.0	0.0001	0.0	0.15	0.26	0.67	0.05	0.05
σ^2Tester		0.10	0.0	0.0	0.0	0.005	0.0004	0.02	1.39	0.03	0.15	0.05	0.02
σ^2GCA		0.03	0.04	0.0	0.0	0.002	0.0003	0.003	0.78	0.15	0.41	0.05	0.04
σ^2SCA		0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.0008	0.02	0.0	0.0	0.0
GCA:SCA		0.03	0.04	0.0	0.0	0.002	0.0	0.003	9.75	7.5	0.41	0.05	0.04
σ^2 A		0.13	0.16	0.0	0.0	0.008	0.001	0.01	0.31	0.59	1.66	0.19	0.14
σ^2 D		0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.003	0.06	0.0	0.0	0.0
σ^2 E		0.65	1.07	0.02	0.02	0.02	0.003	0.07	0.004	0.53	2.34	0.19	0.38
Proportional contribution to total variance													
Line		28.0	36.8	30.2	12.2	9.3	21.1	21.1	97	68.4	54.7	38.4	38.3
Tester		15.7	5.7	2.6	4.1	46.2	33.6	33.6	0.6	11.2	16.5	35.8	18.4
Line × Tester		56.3	57.5	67.2	83.7	44.5	45.3	45.3	2.4	20.4	28.8	25.8	43.3

Key:
DFT= Days to 50 % tasseling
PHT = Plant height
CBL = Cob length
CWG = Cob weight
NRE = No. of rows/kernel
300KW = 300 kernel weight
DFS = Days to 50 % silking
EHT = Ear height
CWT = Cob width
NEP = No. of ears/plant
NKR = No. of kernels/row
KYP = Kernel yield/plot

hybrids for development of improved varieties for diverse agro-ecology such as Nigeria (Alabi *et al.,* 1987). Knowledge about germplasm diversity and relationship among diverse germplasm is useful for plant breeders because it enables them to select suitable parents for crossing (Dwivedi *et al.,* 2001). Significant differences were observed among the genotypes and their hybrids for different agronomic traits, implying that both the parents and the hybrid derived from them would most likely respond to selection. The significant difference among the genotypes for most of the traits indicates the presence of significant variations among genotypes, which is the backbone for any crop improvement programs. The observed significance in the hybrid is as a result of the gene actions which are important in control of the traits observed. Falconer (1981) pointed out that the amount of improvement that can be achieved by selection among a number of crosses is dependent on the amount of variation between the crosses and the intensity of selection, since selection is ultimately applied to the crosses. The significant differences observed in days to tasseling, days to silking, plant height, cob width, cob weight, ears/plant and kernel weight could also be due to varietal difference. Shahrokhi and Khorsani (2013) also observed significant variations amongst maize genotypes for plant height, ear height, grains/cob and grain yield. Ahmed (2013) also observed significant variation amongst maize genotypes for days to tasseling, days to silking, plant height, ear height, cob length, 100 grain weight and grain yield. Similar result was reported by Venugopal *et al.* (2002) and Joshi *et al.,* (2002). The relative importance of GCA to SCA variance was judged from the ratio of the GCA to SCA variances which help to indicate the preponderance of either additive or non-addictive gene action. The σ^2GCA/σ^2SCA ratio was less than unity for almost all the traits. This implies that the inheritance of these traits was due mainly to non-additive gene action. This result contradicts findings of (Sanghi *et al.,* 1983; Paul and Debanth, 1999) for grain yield and Fan *et al*., (2008) and Mosa *et al*., (2010) for rows/ear. The implication of the preponderance of non-additive gene in the expression of the traits studied is that identifying good parents would be difficult for these traits. Instead, specific crosses should be looked out for. The results obtained from this study indicated that the male parents contributed more variation in number of ears/plant and number of kernels/plant and therefore means that the male parents brought more variation to the studied traits.

Mean performance of parental lines, testers and their hybrids across locations

The mean performance in traits of lines, testers and their hybrids are presented in (**Table** 2). The results indicated that significant differences were found in all traits among lines, testers and hybrids except for ear height. The result shows that SAMMAZ-45, SAMMAZ-51 and SAMMAZ-33 had the highest number of days to tasseling among lines, while TZEEI-112 had highest days to tasseling among testers. The hybrids SAMMAZ-26 × TZI-86 and SAMMAZ-51 × TZI-86 on the other hand had the highest days to tasseling (54). These values did not differ significantly among themselves, but significantly higher and different to other values. The result further indicated that SAMMAZ-26, SAMMAZ-45 and SAMMAZ-23 had highest days to silking (59) among lines while, TZEEI-112 had highest days to silking (61) among testers. Hybrids having highest days to silking were SAMMAZ-15 × TZEI-65, SAMMAZ-26 × TZEEI-29, SAMMAZ-28 × TZI-86, SAMMAZ-51 × TZI-86 and SAMMAZ-51 × TZEEI-112 each having 60 days. SAMMAZ-15 and SAMMAZ-26 were the tallest plants with 1672.2 cm and 167.7 cm respectively. Tallest plant among testers was TZEEI-112 with 171.2cm. The result shows that tallest hybrid was SAMMAZ-15 × TZEEI-29 with 171.5 cm. Lines and testers with tallest ear height were SAMMAZ-15 and SAMMAZ-51 with values of 51 cm and 51.2 cm respectively. The result also indicated that cob length was significantly different among parents and hybrids. SAMMAZ-33 had the lengthiest cob (16) among lines while, TZEEI-112 had the lengthiest among testers. Hybrid with lengthiest cob was SAMMAZ-26 × TZEI-65. Among lines, SAMMAZ-51 was the heaviest in terms of weight (183 g) while TZEEI-112 was the heaviest among testers with 183.5 g. The hybrid that was heaviest in terms of weight was SAMMAZ-51 × TZEI-65 with 181.8 g. The result for number of ears/plant indicated that only SAMMAZ-33 produced two ears per plant. Hybrids SAMMAZ-45 × TZEI-65 and SAMMAZ-33 × TZEEI-112 also produced two ears per plant. The parent that produced two ears (SAMMAZ-33) was among hybrids that produced two ears. SAMMAZ-33 had the highest number of rows per ear among parents with 16 rows. SAMMAZ-26 × TZEEI-29 and SAMMAZ-45 × TZEI-65 had highest number of rows among hybrids. On the other hand, SAMMAZ-51 had the highest number of kernels/row (41) among parents, while SAMMAZ-51 × TZI-86 had the highest number of kernels/row among hybrids with 42 rows. TZI-86 was the heaviest among the parents in terms of 300 kernels weight with 80.7 g followed by SAMMAZ-33, while SAMMAZ-15 × TZEEI-29 was the heaviest in terms of 300 kernel weight among hybrids followed by SAMMAZ-15 × TZI-86. The result further indicated that SAMMAZ-51 and TZEEI-112 were the best yielders among parents with 0.8t/ha while SAMMAZ-33 × TZEI-65 was the best yielder in terms of kernel yield/plant with 0.9t/ha. The mean performance of the hybrids AMMAZ-33 × TZEI-65, SAMMAZ-15 ×

Table 2: Mean performance of maize parental lines and their hybrids for twenty-nine traits at Bauchi and Jos combined, 2019 cropping season.

Parents	DFT	DFS	PHT	EHT	CBL	CWT	CWGT	NEP	NRE	NKR	300KW	KYP
Lines												
SAMMAZ-15	52.2	57.8	167.2	51	14*	14	165.7	1.0	12.7	37	69.3	0.7
SAMMAZ-26	52.2	58.5	167.5	49	15*	14	171.3	1.0	12.7	39.3	73.3	0.6
SAMMAZ-45	52.8	58.8	166	48.2	12.7*	13.8	157.8	1.0	12.8	35*	60.5	0.7
SAMMAZ-51	52.5	58.2	163	51.2	17.3*	14.7	183*	1.0	12.8	40.5*	64.3	0.8
SAMMAZ-33	53	59.2	166	50	15.8*	14.2	169	2.0*	15.8*	37.3	76.5	0.7
Mean	52.5	58.5	165.9	49.9	19.0	14.1	170.2	1.2	13.3	38.1	68.3	88.8
CV (%)	3.66	4.97	5.63	7.27	13.7	6.9	9.2	0.0	8.4	10	23.4	27.5
Testers												
TZEEI-29	51.7	58.2	168.7	40.2	14.8	14.2	164.2	1.0	12.5	39.2	76.3	0.7
TZEI-65	53.3	59.3	164.2	48.3	13.5	14.2	157.8	1.0	13.3	39	69.3*	0.7
TZI-86	53	60.2	170.2	49.8	14.2	14.2	157.8	1.0	12.7	34.7	80.7	0.6
TZEEI-112	54.7	60.8	171.2	49	16	13.5	183.5*	1.2	12.8	37.8	53.2*	0.8
Mean	53.2	59.6	168.7	48.1	14.6	14	165.9	1.0	12.8	37.7	71.1	87.3
CV (%)	4.2	3.7	3.9	7.50	14.7	6.5	7.0	19.6	10.9	9.8	18.4	24.3
Hybrids												
SAMMAZ-15 × TZEEI-29	51.8*	58	171.5*	50.2	14.7	13.8	158.9*	1.0*	12*	36.5	75*	0.6*
SAMMAZ-15 × TZEI-65	52.2	60	164	49.7	15.7	14.2	174.7*	1.0*	12.5*	39.5	69.3	0.7
SAMMAZ-15 × TZI-86	51.3	58	164.2	47.8	13.7	13.7	156	1.0*	12.3*	36.2	77.8	0.6
SAMMAZ-15 × TZEEI-112	52.2	57.5	166.7	49.3	15.2	13.7	167.7	1.0*	12.5*	37.5	67.2	0.7
SAMMAZ-26 × TZEEI-29	53	59.7	159.7	50.3	15	13.7	169.5	1.8	15*	41.2	73.7	0.7
SAMMAZ-26 × TZEI-65	52.5	58*	162.8	48.5	17.2	14.2	180.8	1.0	12.2*	38.8	74.5	0.6
SAMMAZ-26 × TZI-86	54.3	59.5	158.8	51.3	14.2	13.5	160.7	1.0	12.3*	38.8	75.2	0.7
SAMMAZ-26 × TZEEI-112	53	59.5	165	51.8	15.2	13.8	174.7	1.0	12.2*	40	55.3	0.8
SAMMAZ-45 × TZEEI-29	51.7	57.8	166	49.7	16	13.8	177	1.0	13.7*	39.8	69.5	0.7
SAMMAZ-45 × TZEI-65	52.7	58.3	167.3	48.8	16	14.2	177.3	2.0	15*	40.3	75.5	0.6
SAMMAZ-45 × TZI-86	51.8	57.7	165.7	50.5	16	14.5	168.2	1.0	12.2*	40.3	71.5	0.6
SAMMAZ-45 × TZEEI-112	53.2	59.2	165.2	50	15.5	13.8	175	1.0	12.5	37.7	73.8	0.7
SAMMAZ-51 × TZEEI-29	52.7	59	160.8	48.3	15.3	14.3	171.8	1.0	13.2	39.7	70.2	0.7
SAMMAZ-51 × TZEI-65	52.7	59	165.8	49.5	16.5	14	181.8	1.0	12.7	40.7	72	0.7
SAMMAZ-51 × TZI-86	53.5	59.7	168.7	51	15.8	14	171.2	1.0	14.2	41.7	74.2	0.7
SAMMAZ-51 × TZEEI-112	53.2	60	164.8	48.2	13.8	14.7	162	1.0	14.3	36.5	68.8	0.8
SAMMAZ-33 × TZEEI-29	52.5	58.5	163.3	49.3	14.5	14.3	172	1.0	14.3	39.8	68.8	0.6
SAMMAZ-33 × TZEI-65	53.3	59.2	161.7*	51.5	14.8	14	171.8	1.0	13.3	38.2	56.8	0.9
SAMMAZ-33 × TZI-86	52.7	58	168*	48.2	14.2	14.3	162.5	1.0	13.5	36.8	58*	0.8
SAMMAZ-33 × TZEEI-112	52.7*	59.8	168*	50.5	15.3	13.8*	170.2*	2.0	14.6*	41.2	69*	0.7*
Mean	52.6	58.8	164.9	49.7	15.3	14	170.5	1.2	13.2	39.1	69.8	87.1
CV (%)	3.7	3.8	4.5	6.9	17.3	6.1	9.7	13.6	8.7	12.3	22.5	24.5

Key: DFT= Days to 50 % tasseling, DFS = Days to 50 % silking, PHT = Plant height, EHT = Ear height, CBL = Cob length**,** CWT = Cob width**,** CWG = Cob weight**,** NEP = No. of ears/plant
NRE= No. of rows/kernel**,** NKR = No. of kernels/row, 300KW = 300 kernel weight, KYP = Kernel yield/plot.

TZEEI-112, SAMMAZ-33 × TZEEI-112 and SAMMAZ-45 × TZEEI-112 recorded greater or equal values when compared to the best parent SAMMAZ-45 and TZEEI-112 for kernel weight. This shows that genes controlling kernel yield in the parents contributed positively in the crosses. It also showed that the parents were different in their genetic background and combined well to produce promising crosses. Similar yield increases of variety cross up to 56 % heterosis have also been reported by Ogunbodede *et al.,* (2000). For such level of heterosis, it was recommended that the parents of such crosses be maintained and used as single cross hybrid for high kernel yield. The potential for early maturing exist in the parental lines and their hybrids in TZEEI-29 and SAMMAZ-33 × TZEEI-29 for days to tasseling. This hybrid could be subjected to further selection to obtain very early and extra early maturing varieties because early maturing varieties are essential for successful production in areas where rainfall regime is short and unpredictable in order to escape short duration drought. The results revealed that the best performing genotype in terms of plant height compared to the best parents SAMMAZ-15 and SAMMAZ-26 was SAMMAZ-15 × TZEEI-29, which showed that the genes controlling plant height in the plants have contributed significantly in the crosses. Similar results were reported by Ahmed (2013). The results also identified SAMMAZ-26 × TZEI-65 with shorter plant height compared to the shortest parent TZEI-65. The mean performance of hybrids for kernels/row was higher than of the parents. This signifies the positive contribution of gene controlling number of kernels/row from parents to progenies and the crosses can be considered as good candidates in future breeding. The mean performance result showed that SAMMAZ-51 is the best genotype across locations for kernel weight. SAMMAZ-26 × TZEEI-29, SAMMAZ-26 × TZEI-65 and SAMMAZ-33 × TZEI-65 were the best genotypes across locations for ear height. This observation supports the earlier report on maize by Ahmed (2013).

Estimates of general combining ability effects

Estimates of GCA effects of lines and testers are presented in (**Table** 3). Results shows that SAMMAZ-15 had significant positive GCA effects for plant height, ear height, cob length, cob width, cob weight and kernel yield/plant. SAMMAZ-26 and SAMMAZ-51 had highly significant positive GCA effects for plant height, ear height, cob length, cob width and cob weight, while SAMMAZ-33 recorded highly significant or significant positive GCA effects for plant height, ear height, cob length, cob width, cob weight and kernel weight. Result indicated that, TZEEI-29 recorded highly significant or significant positive GCA effects for days to silking, plant height, ear height, cob length, cob width, ears/plant, rows/ear and kernel yield/plant. TZEI-65 had significant positive GCA effect for plant height, ear height, cob length, cob width, cob weight, rows/ear, kernels/row, 300 kernel weight and kernel yield/plant. TZI-86 had significant positive GCA effects for days to tasseling, days to silking, plant height, ear height, cob length, cob width, cob weight, ears/plant, rows/ear, 300 kernel weight and kernel yield/plant. On the other hand, TZEEI-112 had highly significant or significant positive GCA effects in days to tasseling, plant height, ear height, cob length, cob width, cob weight, ears/plant and rows/ear. Combining ability is the ability of parents to transmit desirable performance to its progeny. It is the capacity of parents to produce superior progeny or otherwise when crossed with another parents (Izge *et al.,* 2007). Combining ability analysis helps in evaluation of inbred in terms of their genetic value and selection of suitable parents for hybridization (Alabi *et al.,* 1987). The GCA effects revealed that TZEEI-29 and TZI-86 were best general combiners among males for grain yield. Inbred lines identified for good general combining ability could be utilized in maize grain improvement programs for traits of interest as these lines have high potential to transfer desirable traits to their progenies as reported by Ahmed (2003) and Shenawy *et al.,* (2009). TZEEI-29 is a good general combiner for number of ears, while TZI-86 is a good general combiner for ear height, rows/ear and 300 kernel weight. The results are in general agreement with that of Bello and Olaoye (2009). For plant height and cob weight, TZEEI-112 was found to be a good general combiner, while TZEI-65 and TZI-86 were poor general combiners in same traits. This indicates that TZEEI-29 has a tendency to increase plant height whereas TZEI-65 and TZI-86 has a tendency to reduce plant height in the hybrid progenies. This result is in conformity with the findings of Habtamu (2010). SAMMAZ-33 is a good combiner for ear height and cob width. SAMMAZ-45 is also a good general combiner for cob length, cob width and cob weight.

Estimates of specific combining ability effects

The results of specific combining ability effects are presented in (Table 4). Eighteen hybrids had highly significant or significant positive SCA effects for plant height, ear height, cob length, cob weight, ears/plant, rows/ear and 300 kernel weights. The grain yields of SAMMAZ-15 × TZEEI-29, SAMMAZ-15 × TZEI-65, SAMMAZ-15 × TZI-86, SAMMAZ-26 × TZEEI-29, SAMMAZ-26 × TZEI-65, SAMMAZ-51 × TZEEI-29 and SAMMAZ-51 × TZI-86 had highly significant or significant positive SCA effects for kernel yield/plant. The exploitation of heterosis through useful cross combination

Table 3: Estimates of GCA effects of parents in Bauchi and Jos combined, 2019 cropping season.

Parents	DFT	DFS	PHT	EHT	CBL	CWT	CWG	NEP	NRE	NKR	300KW	KYP
Lines												
SAMMAZ-15	0.45	0.47	0.49**	0.38**	0.66**	0.12**	0.22**	0.64	0.52	0.24	0.42	7.5*
SAMMAZ-26	0.25	0.40	0.28**	0.42**	0.35**	0.70**	0.63**	0.64	0.68	0.62	0.41	9.6
SAMMAZ-45	0.28	0.26	0.37**	0.24**	0.48**	0.70**	0.40**	0.64	0.86	0.89	0.40	9.4
SAMMAZ-51	0.42	0.33	0.54**	0.34**	0.32**	0.51**	0.41**	0.12	0.12	0.19	0.21	8.2
SAMMAZ-33	0.45	0.47	0.49**	0.38*	0.66**	0.12**	0.22**	0.64	0.57	0.61	0.63*	18.2
Error	0.36	0.50	0.07	0.08	0.04	0.02	0.07	0.35	0.48	0.80	0.22	0.26
Testers												
TZEEI-29	0.18	0.42*	0.63**	0.33**	0.52**	0.30**	0.30*	0.78**	0.60**	0.28	0.37	7.1*
TZEI-65	0.28	0.26	0.37**	0.24**	0.48**	0.70**	0.40**	0.64	0.95**	0.96*	0.95**	5.3**
TZI-86	0.66*	0.70**	0.55**	0.58**	0.37**	0.55**	0.46**	0.23**	0.40*	0.23	0.66**	6.5*
TZEEI-112	0.66*	0.24	0.64*	0.45**	0.30**	0.30**	0.54**	0.43**	0.95**	0.28	0.32	7.1
Error	0.27	0.20	0.02	0.02	0.07	0.02	0.15	0.03	0.20	0.44	0.21	0.18

Key:
DFT= Days to 50 % tasseling
DFS = Days to 50 % silking
PHT = Plant height
EHT = Ear height
CBL = Cob length
CWT = Cob width
CWG = Cob weight
NEP = No. of ears/plant
NRE = No. of rows/kernel
NKR = No. of kernels/row
300KW = 300 kernel weight
KYP = Kernel yield/plot

is determined by specific combining ability. Fellahi *et al.* (2013) reported that, even though SCA effects do not contribute tangibly in the improvement of self-pollinated crops (except in situations where exploitation of heterosis is feasible). Best hybrids are expected to generate transgressive segregants which could be selected as potential homozygous lines. SAMMAZ-15 × TZI-86, SAMMAZ-33 × TZI-86 and SAMMAZ-45 × TZEI-65 were good specific combiners in grain yield. This result is in agreement with the work of Igbal *et al.,* (2007) who reported significant and highly significant level of SCA effects in most of the crosses they studied and especially for grain yield in maize. SAMMAZ-45 × TZEI-65 are good specific combiners in plant height. Estimates of SCA effects in ear height were significant in almost all the crosses. SAMMAZ-15 × TZEI-65, SAMMAZ-15 × TZI-86, SAMMAZ-26 × TZEEI-29, SAMMAZ-26 × TZEEI-112, SAMMAZ-26 × TZEEI-112 and SAMMAZ-45 × TZEI-65 were best specific combiners as they show the tendency to increase ear height. SAMMAZ-15 × TZEI-65 and SAMMAZ-45 × TZI-86 and SAMMAZ-45 × TZEEI-112 were good specific combiners for 300 kernel weights. SAMMAZ-15 × TZEEI-29, SAMMAZ-33 × TZEEI-29 and SAMMAZ-45 × TZEEI-29 showed

Table 4**:** Estimates of SCA effects in all the traits in a line × tester in Bauchi and Jos combined in 2019 cropping season.

Hybrids	**DFT**	**DFS**	**PHT**	**EHT**	**CBL**	**CWT**	**CWG**	**NEP**	**NRE**	**NKR**	**300KW**	**KYP**
SAMMAZ-15 × TZEEI-29	0.95	0.71	0.06	0.30**	0.55**	0.24**	0.57**	0.88**	0.72*	0.29	0.46*	3.4*
SAMMAZ-15 × TZEI-65	0.95	0.71	0.33**	0.30**	0.06	0.98**	0.10	0.65**	0.01	0.41	0.18	7.2
SAMMAZ-15 × TZI-86	0.22	0.19	0.74**	0.36**	0.94**	0.67**	0.63**	0.45**	0.57*	0.51	0.97**	4.5**
SAMMAZ-15 × TZEEI-112	0.18	0.04	0.53**	0.36**	0.12	0.44**	0.54*	0.65**	0.02	0.38	0.52*	5.9*
SAMMAZ-26 × TZEEI-29	0.76	0.12	0.71**	0.88**	0.07	0.04*	0.12	0.88**	0.67*	0.21	0.84**	4.5
SAMMAZ-26 × TZEI-65	0.05	0.53	0.19*	0.38**	0.03	0.10*	0.03	0.65**	0.50	0.81	0.57**	3.9**
SAMMAZ-26 × TZI-86	0.86	0.74	0.42**	0.83**	0.89**	0.25**	0.95**	0.45**	0.59*	0.58	0.65**	4.6*
SAMMAZ-26 × TZEEI-112	0.15	0.09	0.90**	0.61**	0.66**	0.36**	0.50*	0.65**	0.56*	0.34	0.74**	20.0
SAMMAZ-45 × TZEEI-29	0.13	0.25	0.70**	0.10	0.22*	0.71**	0.14	0.88**	0.91**	0.35	0.22	13.0
SAMMAZ-45 × TZEI-65	0.67	0.22	0.25*	0.13	0.72**	0.97**	0.73**	0.65**	0.79**	0.41	0.55**	100
SAMMAZ-45 × TZI-86	0.92	1.00	0.35**	0.12	0.82**	0.22**	0.99**	0.45**	0.68**	0.51	0.09	6.4*
SAMMAZ-45 × TZEEI-112	0.23	0.96	0.55**	0.09	0.27**	0.41**	0.25	0.65**	0.79**	0.27	0.28	11.1
SAMMAZ-51 × TZEEI-29	0.37	0.52	0.92**	0.63**	0.83**	0.73**	0.96**	0.88**	0.50	0.02	0.34	7.7
SAMMAZ-51 × TZEI-65	0.18	0.92	0.93**	0.84**	0.99**	0.96**	0.91**	0.65**	0.15	0.09	0.80**	5.4*
SAMMAZ-51 × TZI-86	0.48	0.19	0.67**	0.85**	0.47**	0.71**	0.23	0.45**	0.71*	0.84	0.18	8.6
SAMMAZ-51 × TZEEI-112	0.80	0.56	0.67**	0.43**	0.34**	0.44**	0.18	0.65**	0.67*	0.41	0.04	5.9*
SAMMAZ-33 × TZEEI-29	0.33	0.45	0.01	0.70**	0.82**	0.86**	0.64**	0.55**	0.63*	0.33	0.21	9.7
SAMMAZ-33 × TZEI-65	0.34	0.17	0.30**	0.12	0.87**	0.88**	0.86**	0.08	0.46	0.74	0.93**	14.0
SAMMAZ-33 × TZI-86	0.43	0.74	0.38**	0.49**	0.66**	0.89**	0.43*	0.004	0.94**	0.58	0.92**	9.8
SAMMAZ-33 × TZEEI-112	0.41	0.78	0.51**	0.62**	0.41**	0.14**	0.88**	0.08	0.25	0.92	0.20	7.1
Error	0.51	0.62	0.10	0.08	0.08	0.03	0.20	0.06	0.26	0.58	0.18	0.28

Key:
DFT= Days to 50 % tasseling
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NRE = No. of rows/kernel
NKR = No. of kernels/row
300KW = 300 kernel weight
KYP = Kernel yield/plot

significant positive SCA effect for ear/plant. The result is in conformity with the findings of Shashidhara (2008). The superior crosses were from different parental combinations, where both parents are with high GCA effects (high × high, high × low and low × high). The cross combinations showing high SCA effects arising from parents with high and low GCA values for any traits indicates that there is influence of non-additive genes on their expression. Parents of these crosses can be used for bi-parental mating or reciprocal recurrent selection for developing superior varieties with high yield. Crosses with high SCA effects having both parents with good GCA effects could be exploited by pedigree method of breeding to get transgressive segregants.

Conclusion

The research was conducted to study the general and specific combining ability effect and genetic component analysis in nine maize genotypes and their crosses. This was to establish vital genetic information for identifying promising parents and F_1 hybrids with good breeding values of important agronomic traits for developing high yielding maize varieties. Line × tester mating design was used to cross four males with five females. Twenty-nine crosses were evaluated in two locations and replicated three times each in a randomized complete block design. The analysis of variance found the existence of significant difference among parents and hybrids for most traits revealing the presence of genetic variability among these genotypes which could be exploited to enhance selection for further population improvement in maize. The study found the importance of both gene actions in the control of maize traits. In this study however, ratio of GCA variance to SCA variance (σ^2SCA/ σ^2GCA) for days to tasseling, days to silking, plant height, ear height, cob length, cob width, kernels/row and kernel yield/plant was less than unity, suggesting the preponderance of non-additive genes in the control of most traits in maize. Such type of gene action clearly indicates that selection of superior plants, in terms of these traits should be postponed to later generation, where the traits can be improved by making selection among the recombinants within the segregating populations. On the other hand, number of ears/plant, rows/ear, 300 kernels weight and kernel yield/plant respectively had more than unity σ^2GCA/σ^2SCA ratio, indicating that additive gene action played a major role than non-additive gene action in governing the inheritance of the mentioned traits. This means that the traits can easily be transmitted, indicating the utilization of selection in the improvement of such traits. Among the parental lines, TZEEI-112 and SAMMAZ-45 were identified as the best in terms of kernel yield/plant. TZEEI-29, TZEI-86, SAMMAZ-15, SAMMAZ-26, SAMMAZ-33 and SAMMAZ-51 have been identified as good general combiners for most of the traits. The parents having good GCA for several agronomic traits could be exploited to develop broad based composite populations with improved agronomic traits. SAMMAZ-33 × TZEI-65, SAMMAZ-15 × TZEEI-12, SAMMAZ-33 × TZEEI-112 and SAMMAZ-51 × TZEEI-112 was also identified as good specific combiners for kernel yield across locations. Based on the findings of this study, the following recommendations can be put forward:

TZEEI-29, TZI-86, SAMMAZ-15, SAMMAZ-26 and SAMMAZ-33 are good general combiners for most traits. Therefore, they can be deployed in breeding programmes targeted at improving certain traits of interest. SAMMAZ-33 × TZEI-65, SAMMAZ-15 × TZEEI-112, SAMMAZ-33 × TZEEI-112 and SAMMAZ-51 × TZEEI-112 are good specific combiners for kernel and therefore can be used in hybrid development breeding programme. SAMMAZ-33 × TZEI-65, SAMMAZ-15 × TZEEI-112, SAMMAZ-33 × TZEEI-112 and SAMMAZ-51 × TZEEI-112 was identified as high yielding hybrids across locations and can be fully utilized by farmers for cultivation. The genotype SAMMAZ-26 showed outstanding trait for earliness, it was not only the earliest but nearly all the hybrid involving it were earlier than the mid-parents. This shows that SAMMAZ-26 will contribute in any breeding effort to develop extra early maturing maize variety.

Disclosure of conflict of interest

None

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