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Combining ability and heterosis for phenologic and agronomic traits in maize (*Zea mays* L.) under drought conditions in the Northern Guinea Savanna of Borno State, Nigeria

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Five International Institute of Tropical Agriculture (IITA) drought tolerant and open pollinated varieties (OPVs) (lines) and four local varieties with various level of susceptibility to drought (testers) were used. These maize varieties were crossed using a line x tester mating design during the 2007 cropping season to determine the general combining ability (GCA) and specific combining ability (SCA); also the level of heterosis was investigated. Parental lines and hybrids were evaluated in Biu in 2008 and 2009 cropping seasons. Results from the analysis of variance and combining ability shows that there was high and significant level (P< 0.05) of genetic variability among the parental lines used and their hybrids in days to tasseling, days to silking, anthesis silking interval (ASI), plant height, ear height, weight of cobs, dehusked cobs and grain yield, thus suggesting the possibility for genetic improvement. The study established that, there were significant (P<0.05) differences of GCA effects of parents and that of SCA effects of hybrids. Estimates of GCA were consistently lower than SCA effects in almost all the traits evaluated. This suggests that high performing hybrids such as EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE, EVDT-99WSTRC0 x EX-DAMBOA YELLOW andTZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE may be used to develop potential varieties. The parents: EVDT-99WSTRC0, EVDT-99WSTRQPMC0, TZE-COMP$_3$DTC$_1$ and EX-BIU WHITE were identified as the best general combiners in terms of GCA for days to tasseling, days to silking, ASI, plant height, ear height, dehusked cobs and grain yield.

Key words: Maize, combining ability, additive, non-additive genetic effects, drought tolerance.

INTRODUCTION

Maize (*Zea mays* L.) is a tropical cereal and belongs to the plant family Gramineae (Poaceae). Globally, maize is ranked the third most important cereal crop, after wheat and rice (Jaliya et al., 2011). It is one of the most widely

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cultivated cereal crops due to it adaptation to a wide range of environments. It is also a major staple food crop in Nigeria and in many developing countries receiving much attention in industrial development

World maize production was estimated to be 950 million tonnes, for the 2012/2013 season, an increase of 9% from 2011/2012 (Brandt 2013). However, according to International Institute of Tropical Agriculture (IITA, 2011); worldwide maize production is 785 million tonnes with the largest producer, the United States, producing 42%. Africa imports 28% of the required maize from countries outside the continent.

As a result of continuous shortage and unpredictability of rains in the drier areas of the world, possibly due to the effect of climate changes (Sodangi et al., 2011), research attention is being directed toward producing maize hybrids that can withstand moisture stressed ecologies. Drought is one of the most important environmental stresses affecting agricultural productivity worldwide and can result in a considerable yield loss (Ludlow and Muchow, 1990). It is a major abiotic constraint to maize production which is mostly rain fed in Africa. A lack of adequate rainfall can lead to decrease in yield and trigger food shortages. The effect of drought on maize production and food supplies are most severe in the dry savanna zone of West Africa (Fajemisin et al., 1985). This is because rainfall in this region is very unpredictable in terms of timing (may start early or very late in the season), quantity (some times less than 600 mm/annum) and distribution (could be poorly distributed) (Izge and Dugje, 2011).

Combining ability and heterosis concepts have been successfully studied in this work for the production of drought tolerant hybrids. The need for breeding maize crop tolerant to drought conditions is pertinent. The choice for selection and breeding procedure to be used for genetic improvement of crop plants therefore will largely depend on the magnitude of genetic variability and the nature of gene action governing the inheritance of desirable traits. It is eminent for plant breeders to be familiar with the potentials of local materials before embarking on population improvement (Aminu and Izge, 2013). It is also important to 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 (Alabi et al., 1987). As such, drought tolerance breeding has been used as a tool for identifying traits that are most vital in selection in order to improve crop yield and other yield attributes (Hallauer and Miranda, 1988). Therefore, this study was performed to estimate the general combining ability effect of parents, specific combining effect of hybrids and to determine the high parent heterosis existing among the traits.

MATERIALS AND METHODS

Nursery experiments were conducted at the Faculty of Agriculture, Teaching and Research Farm, University of Maiduguri (latitudes 11° 14'N and longitude 13° 04'E on an altitude of 354 m above sea level) for the initial breeding population (F_1 hybrids). Five drought tolerant and open pollinated varieties (OPVs) were used as parental lines: EVDT-99WSTRC0, TZE-WDTSTRQPMC0, EVDT-99WSTRQPMC0, TZECOMP$_3$DTC$_1$ and BG9TZECOMP$_{3x4}$. These lines were developed at IITA, in Ibadan, Nigeria, from diverse sources of germplasm through evaluation and selection at multiple locations. In addition, four local cultivars susceptible to drought were used as testers: EX-BIU WHITE, EX-BIU YELLOW, EX-DAMBOA WHITE and EX-DAMBOA YELLOW. These local cultivars are those predominantly growing by the farmers in the study areas. The materials were crossed in line by tester mating design during the dry season of 2007 under manual irrigation to generate twenty F_1 hybrids.

The hybrids produced and their parents were evaluated in Biu location in 2008 and 2009 rainy seasons. Biu is located in Northern Guinea Savanna and is characterized by a rainy season period of 130 - 160 days per year, with average annual rainfall ranging between 900 - 1400 mm. Biu geographic locations is latitude 11° 2'N and longitude 13° 2'E on an altitude of 687 m above sea level. The soil type is clay or black cotton vertisols (FAO/UNESCO, 1998). The treatments were laid out in a randomized complete block design (RCBD), with three replications. Each plot size was 5 x 2.75 m (13.75 m^2), with four rows spaced at 0.75 x 0.40 m intra-row spacing. The planting was done in August ending (30th August) to subject the genotype to moisture stress.

Every plot was fertilized twice: 10 days after and four weeks after planting, applying 333.33 kg/ha of NPK (15:15:15) fertilizer and 110 kg/ha of urea, respectively. All fertilizers were dibbled by side placement during the application according to Kamara et al. (2004). On every plot, number of plants/plot, days to 50% tasseling, days to 50% silking, ASI, plant height (cm) and ear height (cm) were recorded. The parameters number of cobs per plant, number of cobs harvested per plot, 100 seed weight (g) and grain yield (kg/ha) were also recorded.

The combining ability analysis and the GCA and SCA effects estimation were carried out based on the procedures described by Kempthorne (1957) and Singh and Chaundhary (1985), using SPAR 2.0 Statistical Package for Agricultural Research. The significant differences ($P < 0.05$) among GCA effects and SCA effects were tested using the formula of Cox and Frey (1984). High parent heterosis was estimated according to Liang et al. (1972).

RESULTS AND DICUSSION

Analysis of combining ability

The analysis of variance for combining ability and variance in a line x tester for twelve agronomic traits in maize combined across years are presented in Table 1. The results indicate that mean squares due to lines were significant for days to 50% tasseling, days to 50% silking, ear height, weight of cobs and 100 seed weight. The results also reveal that the mean squares were significant in testers for days to 50% tasseling, days to 50% silking, plant height, weight of cobs, dehusked cobs and grain yield. However, the analysis of variance for combining ability showed that the mean squares due to line x tester interaction were significant ($p < 0.05$) for ASI, plant

Table 1. Analysis of combining ability variance and variance for twelve agronomic traits combined across years.

Source of variation	DF	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
Line	4	24.02	42.97*	51.58*	0.25	510.77	853.91*	0.36	47.62	627345.31*	3929744.58	19.65*	1317984.41
Tester	3	8.88	138.22**	56.10*	0.56	38399.73**	505.97	0.97	17.82	7206633.30*	119713532.22**	4.92	50280622.81**
Line x tester	12	42.94	10.91	18.06	1.54*	967.02*	1557.75**	0.67	80.45	4275712.82	2194899.58	10.46*	948263.50
Error	56	37.21	20.415	20.25	0.32	423.28	371.13	0.52	48.84	2781073.04	3864283.23	7.42	1368782.44
Variance component estimates													
Line		-0.79	1.34	1.40	-0.06	-10.68	13.71	-0.008	-0.88	31036.25	72285.21	0.19	15405.04
Tester		-1.14	4.24	1.27	-0.09	1254.43	931.94	0.078	41.79	4833748.36	3917287.76	1.65	1644411.98
δ^2gca		-0.14	0.39	0.19	0.03	85.92	65.43	0.005	2.82	336418.46	276110.05	0.13	114804.89
δ^2sca		-1.85	6.27	3.42	0.43	2047.84	1444.69	0.091	66.42	7450987.76	6070852.55	2.05	2576335.30
δ^2gca/sca		0.07	0.06	0.06	0.07	0.04	0.05	0.055	0.04	0.05	0.05	0.06	0.05
Proportional contribution to total variation													
Line		15.06	23.96	34.90	24.44	1.62	3.36	2.17	2.32	2.59	3.93	13.37	3.15
Tester		4.17	18.25	28.46	26.60	7.28	5.86	16.61	12.48	5.91	6.57	16.51	6.79
Line x tester		80.77	57.80	36.64	48.96	91.11	90.78	71.22	85.21	91.51	89.52	70.12	90.06
GCA (line + tester)		19.23	52.21	63.36	51.04	8.90	9.22	28.78	14.80	8.50	10.50	29.88	9.94
GCA/SCA		0.24	0.90	1.73	1.04	0.10	0.10	0.404	0.17	0.09	0.12	0.43	0.11

NSP, Number of stands per plot; ASI, anthesis silking interval; NCPL, number of cobs per plant; DC, dehusked cobs; DTT, days to 50% tasseling; PHT, plant height; NCPT, number of cobs per plot; HSW, 100 seed weight; DTS, days to 50% silking; EHT, ear height; WC, weight of cobs; GRY, grain yield; *Significant; **Highly significant (P< 0.05).

height, ear height and 100 seed weight. Therefore, the result shows that both additive and non-additive gene actions were important and responsible for the genetic expression. These results are in agreement with those of Joshi et al. (2002), Asif et al. (2007), Premlatha and Kalamani (2010) and Aminu and Izge (2013). The fact that both additive and non-additive gene actions were important in genetic control of most traits studies means that there is the existence of tremendous amount of variability in the genetic materials evaluated, confirming the results of Izge et al. (2007) and Bello and Olaoye (2009).

The estimates of variance components indicated that the ratio of GCA to SCA variance shows the importance and the predominance of non-additive genetic effects because the SCA variance was higher than the GCA and most of the ratios were less than unity. However, the results were in agreements with that of Sharma et al. (2004) who found the preponderance of additive genetic effects in the control of traits in maize. The proportional contribution of lines to total variation is lower than the testers for seed weight.

General combining ability effects of parents

The estimate of general combining ability of effects of lines and testers in maize combined across years are presented in Table 2. Line EVDT-99WSTRCO expressed positive significant GCA effects for almost all the traits except for number of cobs per plant. Therefore, the result indicated it is the highest general combiner. Similarly, TZE-COMP$_3$DTC$_1$ exhibited positive GCA effects for anthesis silking interval, number of cobs per plant, number of cobs per plot, weight of cobs, dehusked cobs and grain yield. However, it expressed negative significant GCA effects for plant height and ear height. Parents with high negative GCA effects for days to tasseling, days to silking, plant height and ear height are desirable under drought and windy environment as these parents could escape drought and lodging in stormy areas. Similar results were reported by Izge et al. (2007) and Aminu and Izge

Table 2. Estimate of general combining ability effect for male and female parents for 12 agronomic traits in maize combined across years.

Entry	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
Male entries												
EVDT-99WSTRC0	12.20**	7.17**	4.92*	2.47*	60.00*	58.16**	0.86	12.35**	4588.68**	4159.68**	12.13*	2656.20**
TZE-WDTSTRQPMC0	12.62**	3.75*	2.33	-1.72*	83.50*	62.14**	-0.63	-14.48**	-4730.57**	-4270.40**	23.54*	-2795.10
EVDT-99WSTRQPMC0	-10.80**	-3.08	-2.83	-1.05*	-13.42	-7.85	-1.34	0.85	268.68	328.02	-1.88*	241.05
TZE-COMP$_3$DTC$_1$	0.72	-1.75	-4.75*	5.95**	-77.46*	-43.96*	2.95*	12.77**	4622.85**	3971.35**	0.75	2526.50**
BG 97 TZECOMP$_{3\ x4}$	-13.30**	-6.08*	0.33	-0.72	-52.61	-68.47**	-1.84	-11.48**	-4749.65**	-4188.65**	-3.53*	-2628.65**
SE (±)	2.03	1.51	1.50	0.18	6.86	7.97	0.53	2.33	555.89	655.26	0.91	389.98
Female entries												
EX-DAMBOA WHITE	0.48	1.77	1.57	3.35**	11.84	-5.94	3.89**	2.50	856.62	743.95	3.50*	585.95
EX-DAMBOA YELLOW	-4.89*	1.50	1.57	-1.18*	14.89*	24.58*	-1.16	-6.03*	-529.98	1389.35**	-1.40	-383.20
EX-BIU WHITE	-3.58*	-3.10*	-3.23*	1.98	-19.87*	-13.86*	-1.32	4.83*	1568.02**	-529.98	-0.87	783.59*
EX-BIU YELLOW	-1.78	-0.17	0.10	-1.18*	-10.46	-4.88	-1.41	-1.30	-1843.32**	-103.22*	-1.23	-986.35*
SE (±)	1.6600	1.3000	1.3000	0.1600	5.9400	6.9000	0.4600	2.0100	481.4100	567.4700	0.7700	337.7300

NSP, Number of stands per plot; ASI, anthesis silking interval; NCPL, number of cobs per plant; DC, dehusked cobs; DTT, days to 50% tasseling; PHT, plant height; NCPT, number of cobs per plot; HSW, 100 seed weight; DTS, days to 50% silking; EHT, ear height; WC, weight of cobs; GRY, grain yield; *Significant; **Highly significant (P< 0.05).

(2013). TZE-WDTSTRQPMC0 is the third highest general combiner after line TZE-COMP$_3$DTC$_1$ exhibiting positive significant effects in number of stands per plot, days to tasseling, plant height, ear height and 100-seed weight. The result also shows that EVDT-99WSTRQPMCO exhibited negative significant GCA effects for number of stands per plot, ASI and 100-seed weight.

In the case of testers, EX-BIU WHITE revealed superior positive significant GCA effects for number of cobs per plot, weight of cobs and grain yield. However, negative significant GCA effects were observed for number of stands per plot, days to 50% tasseling, days to 50% silking, plant height and ear height. Therefore, EX-BIU WHITE was the highest general combiner tester. EX-DAMBOA WHITE expressed positive significant GCA effects for the ASI, number of cobs per plant and 100-seed weight. It was the second highest general combiner tester.

The parents with a high GCA effects for traits could produce superior segregants in the F$_2$ as well as in later generations. The line EVDT-99WSTRCO and tester EX-BIU WHITE had high GCA effects for most of the traits. Therefore, these parents could be utilized in a hybridization programme for selection of superior recombinants. These results are supported by Premlatha and Kalamani (2010) and Kanta et al. (2005), who have also identified good combiners and superior hybrids in maize.

Specific combining ability effects of hybrids

Estimates of specific combining ability for twelve agronomic traits in 20 hybrids in maize combined across years are presented in Table 3. EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE exhibited the highest positive and significant SCA effects for grain yield. Hybrid EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW was the only one that exhibited positive and significant SCA effects for both number of stands per plot and grain yield. Therefore, these hybrids had the highest and significant specific combining ability effects among the hybrids and can be used for further selection.

The EVDT-99WSTRC0 x EX-DAMBOA WHITE hybrid exhibited significant and negative SCA effect for both days to 50% tasseling and silking. TZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE had the highest positive and significant SCA effects for ASI. Eight hybrids showed significant SCA effect for plant height, being EVDT-99WSTRQPMC0 x EX-BIU WHITE and EVDT-99WSTRQPMC0 x EX-BIU YELLOW those that express the highest

Table 3. Estimate of specific combining ability effect for the hybrids for 12 agronomic traits in maize combined across years.

Entry	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
EVDT-99WSTRC0 x EX-DAMBOA WHITE	-4.40	-8.10**	-6.98**	-2.93	-40.09**	-38.23*	-4.25	-3.17	-100.78	276.05	2.79	88.60
EVDT-99WSTRC0 x EX-DAMBOA YELLOW	2.20	1.83	0.68	1.60	-0.74	-7.08	1.01	-0.50	-982.18	-1332.68	-0.06	-642.38
EVDT-99WSTRC0 x EX-BIU WHITE	2.67	4.43	4.82	0.40	27.62*	23.03	2.09	1.37	1297.15	1253.32	1.76	524.41
EVDT-99WSTRC0 x EX-BIU YELLOW	-0.47	1.83	2.48	0.93	13.21	22.29	1.15	2.30	-214.18	-196.68	1.11	29.38
TZE-WDTSTRQPMC0 x EX-DAMBOA WHITE	-3.82	-3.02	-2.73	-3.35**	-20.92	-18.56	-4.02	-8.75*	-3099.95	-3148.95*	-4.21*	-1970.80*
TZE-WDTSTRQPMC0xEX-DAMBOA YELLOW	-0.55	-3.42	-3.40	1.85	-25.90*	-38.42*	1.11	-0.75	1078.65	1402.32	2.19	740.65
TZE-WDTSTRQPMC0 x EX-BIU WHITE	0.92	2.18	2.07	1.32	7.79	21.36	1.09	3.12	1384.65	1034.98	0.33	1049.26
TZE-WDTSTRQPMC0 x EX-BIU YELLOW	3.45	4.25	4.07	0.18	39.05*	35.62*	1.82	6.38	636.65	711.65	1.69	180.89
EVDT-99WSTRQPMC0 x EX-DAMBOA WHI	6.52	1.15	0.10	-4.68	73.00*	28.09	-2.70*	10.42*	4626.72**	3936.05**	1.54	2262.54*
EVDT-99WSTRQPMC0xEX-DAMBOAYELOW	7.45*	2.08	0.43	-0.15	34.01**	68.90**	1.32	5.08	2635.32**	2510.65**	0.94	2018.83*
EVDT-99WSTRQPMC0 x EX-BIU WHITE	-1.75	-4.32	-3.77	1.65	-56.47**	-54.53**	0.58	-5.72	-3712.02**	-3063.35**	-0.93	-1971.96*
EVDT-99WSTRQPMC0 x EX-BIU YELLOW	-12.22**	1.08	3.23	3.18	-50.54**	-42.47*	0.80	-9.78*	-3550.02**	-3383.35**	-1.56	-2309.41*
TZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE	-0.73	12.15**	10.60**	15.65**	-3.33	32.76*	14.96**	-1.25	-2044.37**	-1902.53	8.75**	-695.59
TZE-COMP$_3$DTC$_1$ x EX-DAMBOA YELLOW	-6.13	-5.58*	-5.40*	-5.48	-1.35	-23.16	-4.72**	-1.25	-902.10	-734.27	-2.02	-765.63
TZE-COMP$_3$DTC$_1$ x EX-BIU WHITE	3.33	-2.32	-1.93	-5.68**	21.84	8.08	-5.43**	2.28	440.57	158.40	-5.55*	-88.54
TZE-COMP$_3$DTC$_1$ x EX-BIU YELLOW	3.53	-4.25	-4.27	-4.48**	-17.16	-17.69	-4.81**	0.22	2504.90*	2478.40*	-1.18	1549.76*
BG97TZECOMPO$_{3X4}$ x EX-DAMBOA WHITE	2.43	-2.18	-0.98	-4.68**	-8.66	-4.06	-4.00*	2.75	618.38	839.38	-3.29	315.26
BG97TZECOMPO$_{3X4}$ x EX-DAMBOA YELLOW	-2.97	5.08*	6.68*	2.18	-6.01	-0.25	1.29	-2.58	-1829.68	-1846.02	-1.06	-1351.47
BG97TZECOMPO$_{3X4}$ x EX-BIU WHITE	-5.17	0.17	-1.18	2.32	-0.78	2.06	1.68	-1.05	589.65	616.65	4.41*	486.83
BG97TZECOMPO$_{3X4}$ x EX-BIU YELLOW	5.70	2.92	-4.52	0.18	15.45	2.25	1.04	0.83	621.65	389.98	-0.06	549.38
SE (±)	3.5200	-2.6100	2.6000	1.3300	11.8800	13.8000	0.9200	4.0400	962.8200	1134.9400	1.5700	675.4700

NSP = Number of stands per plot; ASI = anthesis silking interval; NCPL = number of cobs per plant; DC = dehusked cobs; DTT = days to 50% tasseling; PHT = plant height; NCPT = number of cobs per plot; HSW = 100 seed weight; DTS = days to 50% silking; EHT = ear height; WC = weight of cobs; GRY = grain yield; *Significant; **highly significant ($P < 0.05$).

negative and significant SCA effects for this traits. These two hybrids also expressed the highest negative and significant SCA effects for ear height. EVDT-99WSTRQPMC0 has been identified in this study as one of three best combining parents. A similar result was reported by Aminu and Izge (2013). TZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE hybrid showed the highest positive and significant SCA effects for number of cobs per plant and 100-seed weight, while EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE had the highest positive and significant SCA effects for number of cobs per plot and dehusked cobs. In most of the hybrids that had the highest SCA effects for drought tolerant traits such as days to 50% tasseling, days to 50% silking, plant height, ear height and ASI one of the parents was EX-DAMBOA WHITE, which is the best general combining parent, and therefore, the combination of favourable genes from the parents for the corresponding traits could have resulted in high and desirable SCA effects.

This study reveals hybrids with significant and highly desirable SCA effects for different traits such as days to 50% tasseling, days to 50% silking, plant height, ear height, ASI dehusked cob and grain yield which were found. Some of the superior hybrids were from either one of the parents with high GCA effect or parents that are low x low general combiners. It therefore, means that the parents with either high GCA or low SCA would have a higher chance of having excellent complementary with other parents that have high GCA. Similar findings have been reported by Asif et al. (2007), Premlatha and Kalamani (2010) and Aminu and Izge (2013).

Heterosis

Estimates of heterosis for 12 agronomic traits in maize combined across years are presented in

Table 4. Heterosis of the hybrids over higher parents for twelve agronomic traits in maize combined across years.

Entry	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
EVDT-99WSTRC0 x EX-DAMBOA WHITE	0.53	-3.50	-2.65	-12.20	4.43	1.95	9.90	13.45	3.20	5.62	-2.46	-2.19
EVDT-99WSTRC0 x EX-DAMBOA YELLOW	-4.16	-17.06	-13.42	-1.18	-22.86	-37.87	-11.79	-19.97	-22.09	-20.03	-7.69	-23.02
EVDT-99WSTRC0 x EX-BIU WHITE	-4.59	-15.67	-12.39	7.32	-38.33	-55.52	-22.12	-31.13	-43.33	41.09	-13.85	-44.15
EVDT-99WSTRC0 x EX-BIU YELLOW	1.56	-310.76	-640	-2.38	-38.27	-46.10	-11.52	-18.35	-43.54	-41.58	-10.15	-45.20
TZE-WDTSTRQPMC0 x EX-DAMBOA WHITE	1.93	-6.15	-4.27	-1.27	0.45	18.28	11.27	5.44	-2.45	-1.01	1.92	-2.50
TZE-WDTSTRQPMC0 x EX-DAMBOA YELLOW	-1.04	-17.65	-13.42	-2.44	-30.96	-55.80	-16.98	-28.84	-47.73	-48.52	-4.49	-52.78
TZE-WDTSTRQPMC0 x EX-BIU WHITE	0.51	-9.54	-4.56	13.12	-34.96	-46.90	-20.35	-23. 64	-50.56	-52.46	-14.91	-55.54
TZE-WDTSTRQPMC0 x EX-BIU YELLOW	-12.99	-13.54	-8.55	-20.99	-27.27	-52.35	-17.05	-20.80	-41.85	-40.88	-10.19	-44.39
EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE	-0.76	1.55	0.86	14.88	3.89	13.80	12.75	14.43	3.00	27.71	30.64	54.88
EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW	-9.39	-15.59	-10.14	13.18	-31.52	-48.03	11.60	10.07	4.23	39.30	20.41	44.00
EVDT-99WSTRQPMC0 x EX-BIU WHITE	-8.88	-6.83	-3.14	-17.07	-29.47	-37.43	-17.70	12.01	-43.29	-43.83	-14.29	-41.65
EVDT-99WSTRQPMC0 x EX-BIU YELLOW	-8.12	-6.21	-1.71	9.05	-27.36	-42.67	-14.22	-15.98	-47.52	-48.,32	-15.29	-52.03
TZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE	-2.91	1.00	0.29	8.43	5.27	2.93	4.81	13.16	-6.1	-4.62	0.64	-5.66
TZE-COMP$_3$DTC$_1$ x EX-DAMBOA YELLOW	-2.60	-15.29	-12.60	-16.28	-34.32	-57.60	-16.04	-27.18	-45.32	-44.18	-10.90	-44.73
TZE-COMP$_3$DTC$_1$ x EX-BIU WHITE	-2.04	-11.29	-6.05	-3.61	-31.86	-41.78	-10.62	-22.09	-42.97	-42.99	-11.18	-49.90
TZE-COMP$_3$DTC$_1$ x EX-BIU YELLOW	-2.08	-13.88	-11.56	1.18	-33.93	-53.77	4.60	7.67	-23.75	-33.22	-3.82	43.62
BG97TZECOMP$_{3X4}$ x EX-DAMBOA WHITE	-2.19	-5.41	-4.13	6.17	-0.56	10.80	3.70	13.20	-6.29	-3.72	-6.54	-2.39
BG97TZECOMP$_{3X4}$ x EX-DAMBOA YELLOW	-5.45	-14.71	-8.49	-19.05	-32.14	-51.41	0.93	10.25	-20.95	-10.65	-12.15	34.51
BG97TZECOMP$_{3X4}$ x EX-BIU WHITE	-7.65	-12.54	-8.07	3.70	-35.19	-44.71	-22.12	-26.54	-46.94	-48.58	-16.77	-54.38
BG97TZECOMP$_{3X4}$ x EX-BIU YELLOW	-2.86	-13.61	-11.05	-3.61	-23.14	-49.47	20.74	-16.32	-50.89	-51.93	-14.95	-52.58

NSP, Number of stands per plot; ASI, anthesis silking interval; NCPL, number of cobs per plant; DC, dehusked cobs; DTT, days to 50% tasseling; PHT, plant height; NCPT, number of cobs per plot; HSW, 100 seed weight; DTS, days to 50% silking; EHT, ear height; WC, weight of cobs; GRY, grain yield; *Significant; **Highly significant (P< 0.05).

in Table 4. The results reveal that hybrid TZE-WDTSTRQPMC0 x EX-DAMBOA WHITE had the highest positive heterotic effect for number of stands per plot. All the hybrids indicated negative higher parent heterosis for days to 50% tasseling and days to 50% silking, except, EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE and TZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE.

Hybrids EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE, EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW and TZE-WDTSTRQPMC0 x EX-BIU WHITE had the highest positive higher parent heterosis for ASI. Positive high value heterosis is actually desirable for ASI, implying that these hybrids could tolerate drought. EVDT-99WSTRC0 x EX-BIU WHITE and EVDT-99WSTRC0 x EX-BIU YELLOW had the highest negative higher parent heterosis for plant height. While, TZE-COMP$_3$DTC$_1$ x EX-DAMBOA YELLOW had the highest negative higher parent heterosis for ear height. Negative heterosis for plant height and ear height are also desirable implying that these hybrids would mature earlier and could escape drought respectively.

BG9TZECOMP$_{3x4}$ x EX-BIU YELLOW hybrid recorded the highest exhibited positive higher parent heterosis for number of cobs per plant. With respect to number of cobs per plot, EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE exhibited the highest positive higher parent heterosis effects. Hybrids EVDT-99WSTRC0 x EX-DAMBOA WHITE and EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW recorded the highest positive higher parent heterosis for weight of cobs. EVDT-99WSTRC0 x EX-BIU WHITE exhibited the highest positive higher parent heterosis for dehusked cobs.

Four hybrids expressed positive higher parent heterosis for 100-seed weight, being EVDT-99WSTRC0 x EX-DAMBOA WHITE, the hybrid with the highest higher parent heterosis. Hybrids EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE and EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW expressed the highest positive higher parent heterosis for grain yield. High heterotic values in grain yield have also been reported in maize by Joshi et al. (2002) and Aminu and Izge (2013).

It is noteworthy that these hybrids EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE, EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW, TZE-C0MP$_3$DTC$_1$ x EX-BIU YELLOW and BG97TZE-COMP$_{3x4}$ x EX-DAMBOA YELLOW appeared to have genes that could be introgressed to exploit heterosis for earliness and high grain yield. These results are in line with earlier independent studies of Bello and Olaoye (2009), Kumar et al. (1998), Joshi et al. (1998)

Conclusion

The present study identifies parents: EVDT-99WSTRC0, EVDT-99WSTRQPMC0, TZE-COMP$_3$DTC$_1$ and EX-BIU WHITE as the best general combiners, and hybrids EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE and EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW as the best among the 20 hybrids evaluated since they have the best level of high parent heterosis in ASI, number of cobs per plot, 100 seed weight and grain yield. Desirable heterotic levels in days to tasseling, days to silking, ASI and plant height are of tremendous advantage in areas with marginal rainfall like the study area.

REFERENCES

Alabi SO, Obilana AB, Nwasike CC (1987). Gene action and combining ability for quantitative characters in upland cotton. Samaru J. Agric. Res. 5(1-2):59-64.

Aminu D, Izge AU (2013). Gene action and heterosis for yield and yield traits in maize (*Zeamays*L.), under drought conditions in Northern Guinea and Sudan Savannas of Borno State. Peak J. Agric. Sci. 1(1):17-23.

Asif MI, Nehvi FA, Wani SA, Qadir R, Zahoor AD (2007). Combining ability for yield and yield related traits in maize *(Zea mays* L.). Int. J. Plant Breeding Genetics*.*1(2):101-105.

Bello OB, Olaoye G (2009). Combining ability for maize grain yield and other agronomical characters in a typical Southern Guenea Savanna ecology of Nigeria. Afr. J. Biotechnol. 8(11):2518-2522.

Brandt L (2013). Absa Agribusiness Maize Outlook. *Farmersweekly.co.za/maizeoutlook 2012/1013.*

Chawla HS, Gupta VP (1984). Index India-Agric. Calcutta Agric. Society Indian. 28(4):261-265.

Cox DJ, Frey KJ (1984). Combining ability and the selection of parents for interspecific oat matings. Crop Sci. J. 24:963-967.

Fajemisin JY, Efron SK, Kim FH, Khadr ZT, Dabrowsk JH, Mareck M, Bjarnason V, Parkison LA, Evarett A, Diallo AO (1985). Population and varietal development in maize for tropical Africa through resistance breeding approach. In: A. Brondol in and F, Salamini (eds), Breeding strategies for maize production improvement in the tropics. FAO and Institutor Agronomico per L'ollremare, Florence. Italy. pp. 385-407.

FAO/UNESCO, (1998) World reference base for soil resources; World soil resources. 84 Rome. p. 91

Hallauer AR, Miranda-Filho JB (1988). Quantitative Genetics in Maize Breeding 2nd ed. Iowa State University Press Ames USA. p. 468.

IITA (2011). International Institute of Tropical Agriculture, Ibadan. Annual Report.

Izge AU, Dugje IY (2011). Performance of drought tolerance three-way and top cross maize hybrids in sudan savanna of North Eastern Nigeria. J. Plant Breeding Crop Sci. 3(11):269-275.

Izge AU, Kadams AM, Gungula DT (2007). Heterosis and inheritance of quantitative characters in diallel cross of pearl millet (*Pennisetum glaucam* L.). J. Agron. 62:278-285.

Jaliya MM, Babaji BA, Sani BM, Aminu D, Ibrahim A (2011). Effects of nitrogen and sulfur fertilizers on sulfur content in soil, ear leaf, flag leaf and grain of QPM maize varieties at Samaru, Zaria. J. Arid Agric*.* 20:140-144.

Joshi VN, Dubey RB, Marker S (2002). Combining ability for polygenic traits in early maturity hybrids of maize (*Zea mays* L.), Indian J. Genetic and Plant Breeding. 62:312-315.

Joshi VN, Pandiya NK, Dubey RB (1998). Heterosis and combining ability for quality and yield in early maturing single cross hybrids of maize. Indian J. Genetic Breeding. 58:519-524.

Kamara AY, Menkir A, Fakorede MAB, Ajala SO, Badu-Apraku B, Kure I (2004). Agronomic performance of maize cultivars representing three decades of breeding in the Guinea Savannas of West and Central Africa. J. Agric. Sci. 142:1-9.

Kanta G, Singh HB, Sharma JK, Guleri GK (2005). Heterosis and combining ability studies for yield and related traits in maize. Crop Res. J. 30:221-226.

Kempthorne O (1957). An introduction to quantitative genetics. Wiley Pub., New York.

Kumar A, Gangashetti MG, Kumar N (1998). Genetic effects in some metric traits of maize hybrids. Ann. Agric. Biology Res. 3:139-143.

Liang GH, Reddy CR, Dayton AD (1972). Heterosis, inbreeding depression and heritability estimates in a systematic series of grain sorghum genotype. Crop Sci. J. 12:409-411.

Ludlow MM, Muchow RC (1990). A critical evaluation of traits for improving crop yields in water-limited environments. Adv. Agron. 43:107-153.

Premlatha M, Kalamani A (2010). Heterosis and combining ability studies for grain yield and growth characters in maize (*Zea mays* L.). Indian J. Agric. Res*.* 44(1):62-65.

Sharma S, Narwal MS, Kumar R, Dass S (2004). Line x Tester analysis in maize (*Zea mays* L.). Forage Res*.* 30:28-30.

Singh RK, Chaudhary BD (1985). Analysis in Biometrical Genetics, Kalyani Publishers, New Delhi, India. p. 303.

Sodangi IA, Izge AU, Maina TY (2011). Change in Climate: Causes and effects on Afr. Agric. J. Environ. Issues Agricultural Development Countries 3(3):22-33.