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GENE ACTION AND HETEROSIS FOR YIELD AND OTHER AGRONOMIC TRAITS IN MAIZE (*ZEA MAYS* L.), UNDER DROUGHT CONDITIONS IN THE NORTHERN GUINEA AND SUDAN SAVANNAS ZONES OF BORNO STATE, NIGERIA

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ABSTRCT
Combining ability variances and effects were estimated for grain yield and other agronomic traits in maize *(Zea mays* L.). Results from analysis of variance and combining ability showed that there was high and significant level of genetic variability among the parental lines used and their hybrids for days to tasseling, days to silking, anthesis silking interval, plant height, ear height, weight of cobs, dehusked cobs and grain yield, thus suggesting the possibility for genetic improvement. The study revealed the significant differences of general combining ability (GCA) effects of parents and that of specific combining ability (SCA) effects of hybrids. The relatively smaller proportion of GCA to SCA ratio in most of the traits indicated the predominance of non-additive genetic effects with respect to some traits. In this study, estimates of GCA were consistently lower than SCA effects in most of the traits evaluated. This suggests that high performing hybrids such as EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE, EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW, EVDT-99WSTRQPMC0 x EX-BIU YELLOW and EVDT-99WSTRC0 x EX-BIU YELLOW may be used to develop potential varieties. Both additive and non-additive gene effects controlled most traits, but non-additive genetic effect was the most important. These hybrids also revealed high parent heterosis in terms of grain yield. Very high level of higher parent heterosis is considered advantageous for drought tolerance and yield improvement. Hence yield superiority of some hybrids over the higher parents suggested the possibility of their commercial exploitation. The parents: EVDT-99WSTRC0, TZE-WDTSTRQPMC0 and EX-BIU WHITE were identified as the best general combiners in terms of GCA for days to 50% tasseling, days to 50% silking, anthesis silking interval, plant height, ear height, dehusked cobs and grain yield. 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 have genes that can be introgressed in to other promising lines in further developing high yielding and drought tolerant genotype.

KEY WORDS: Combining ability, heterosis, non additive, maize, drought.

INTRODUCTION
Maize (*Zea mays* L.) is believed to native to the Americas was introduced to the West Coast of Africa in the early 16th century from where it might have got to Nigeria (Obi, 1991). It is very adaptable and versatile in both its cultivation and consumption. It is viable crop for Nigeria and a major staple food in many developing countries, currently receiving attention in industrial development (Omueti, 1999). Globally, maize is ranked the third most important cereal crop, after wheat and rice. Africa harvests 29 million hectares, with Nigeria, the largest producer harvesting 3% (FAO, 2009). World maize production was estimated to be 950 million tonnes, for the 2012/2013 season, an increase of 9% from 2011/2012 (Brandt 2012). However, according to IITA, (2011), worldwide maize production is 785 million tonnes with the largest producer, the United States, producing 42%. Africa produces 6.5% and the largest African producer is Nigeria with nearly 8 million tonnes, followed by South Africa. 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 are 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 adequate rainfall can lead to decrease in yield and trigger famines. 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 unpredictable in terms of establishment (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 had been successfully studied in this work for the production of drought tolerant hybrids. The need for breeding maize crop tolerance 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 in identifying traits that are most vital in selection in order to improve crop yield and other yield attributes (Hallauer and Miranda, 1988). Therefore, the 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 & METHODS

Five maize lines that are drought tolerant and open pollinated varieties (OPVs), developed at International Institute of Tropical Agriculture in Ibadan (IITA), Nigeria from diverse sources of germplasm through evaluation and selection at multiple locations were used as lines *vis* EVDT-99WSTRC0, TZE-WDTSTRQPMC0, EVDT-99WSTRQPMC0, TZECOMP3DTC1 and BG9TZECOMP$_{3x4}$. The second set of parents consisted of four local cultivars susceptible to drought predominantly growing by the farmers in the study areas. The local cultivars formed the testers, *vis* EX-BIU WHITE, EX-BIU YELLOW, EX-DAMBOA WHITE and EX-DAMBOA YELLOW. A nursery experiment was conducted at the Faculty of Agriculture, Teaching and Research Farm, University of Maiduguri (latitudes 11^o 14$^|$N and longitude 13^0 04$^|$E on an altitude of 354 m above sea level) for the initial breeding population (F_1 hybrids). The materials were crossed in line x tester mating design during the rainy season of 2007 to generate twenty F_1 hybrids. The hybrids produced together with their parents were evaluated during the rainy seasons of 2008 in Biu and Damboa. Biu is located in Northern Guinea Savanna and is characterized by a rainy season period of 130–160 days with range of average annual rainfall of 900– 1400 mm (latitude 11^0 2$^|$N and longitude 13^0 2$^|$E), the soil type is clay or black cotton soil. Damboa on the other hand is located in Sudan Savanna (latitude 11^o.10.5'N and longitude 12^0 46.3$^|$E on an altitude of 291m above sea level). It has an average annual rainfall of 500–1000 mm distributed within the rainy season period of 100–120 days. The parental lines and crosses were laid-out in a randomized complete block design (RCBD) with three replications. The sowing was carried out in mid and end of August (15th-30th August) in Sudan and Northern Guinea savanna respectively in order to subject the entries to moisture stress. Each plot size was 5 x 2.75 m, with four rows spaced of 75 x 40 cm intra-row spacing. The planting was done in August ending to subject the genotype to moisture stress. NPK (15:15:15) fertilizer at the rate of 333.3kg/ha was applied 10 days after planting and urea was applied at the rate of 110kg/ha four weeks after planting. Data were recorded on number of stands per plot, days to 50% tasseling, days to 50% silking, anthesis silking interval (ASI), plant height (cm) and ear height (cm). Other parameters recorded include; number of cobs per plant, number of cobs harvested per plot (g), 100 seed weight (g) and grain yield (kg/ha) on all the plants/plot. The combining ability analysis and the estimates of GCA and SCA effects were done 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 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 & DICUSSIONS

The analysis of variance for combining ability and variance in a line x tester for twelve agronomic traits in maize combined across locations are presented in Table 1. The results indicated that mean squares due to lines were significant for days to 50% tasseling, days to 50% silking and ear height. The results also revealed that the mean squares were significant in testers for days to 50% tasseling and days to 50% silking. However, the analysis of variance for combining ability showed that the mean squares due to line x tester interaction were significant ($p < 0.05$) in days to 50% tasseling, days to 50% silking, anthesis silking interval, plant height and ear height. This suggests differential response of population to environment. Similar result was reported by Bello and Olaoye (2009). Therefore, the result showed that both additive and non-additive gene actions were important and responsible in the genetic expression. These results are in agreement with those of Kadams *et al*. (1999), 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 Olaoye *et al.* (2005) and Izge *et al.* (2007). Even though, additive and non additive gene actions were responsible in the genetic control of most traits. 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 except number of stand per plot, number of cobs per plot, Dehusked cobs and grain yield, and most of the ratios were less than unity. However, the results were agreements with that of Sharma *et* *al.* (2004) and Aminu and Izge (2013) 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.

The estimate of general combining ability of effects of lines and testers in maize combined across locations are presented in Table 2. Line EVDT-99WSTRCO and TZE-WDTSTRQPMC0 expressed positive significant GCA effects for almost all the traits. Therefore, TZE-WDTSTRQPMC0 is the highest general combiner. Similarly, TZE-COMP$_3$DTC$_1$ exhibited positive GCA effects for almost all the traits. However, it expressed negative significant GCA effects for number of stand per plot and plant 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 (2013). In the case of testers, EX-DAMBOA YELLOW revealed superior positive significant GCA effects for number of stands per plot, ear height, and number of cobs per plant, weight of cobs, dehusked cobs and grain yield. Therefore, EX- DAMBOA YELLOW is the highest general combiner tester. EX-DAMBOA WHITE expressed positive significant GCA effects for anthesis silking interval, number of cobs per plant and 100-seed weight. This report is in line with earlier studies by Shanghai *et al*. (1983) who reported that GCA effects were significant for anthesis silking interval and that additive gene action play a major role in the inheritance of the traits. It is 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- DAMBOA YELLOW had high GCA effects for most of the traits. Therefore, these parents could be utilized in a hybridization programme for selection of superior recombinants. Premlatha and Kalamani (2010) and Paul and Debenth (1999) have also identified good combiners and superior hybrids in maize. Estimates of specific combining ability for twelve agronomic traits in twenty hybrids in maize combined across locations are presented in Table 3. EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE and EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW exhibited the highest positive and significant SCA effects for grain yield. However, these hybrids appeared to have genes that can be introgressed to exploit high grain yield. These results are in line with studies of Kumar *et al.* (1998). Hybrids EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE was superior with higher significant SCA effects for grain yield. Therefore, these hybrids had the highest and significant specific combining ability effects among the hybrids and can be used for further selection. Similar result was obtained by Aminu and Izge (2013). The EVDT-99WSTRC0 x EX-DAMBOA WHITE and TZE-COMP$_3$DTC$_1$ x EX-BIU YELLOW hybrids exhibited negative significant SCA effect for both days to 50% tasseling and silking, plant height, ear height and grain yield. TZECOMP$_3$DTC$_1$ x EX-DAMBOA WHITE hybrid showed the highest positive and significant SCA effects for days to 50% tasseling, anthesis silking interval and number of cobs per plant, days to 50% tasseling, anthesis silking interval, while TZECOMP$_3$DTC$_1$ x EX-BIU YELLOW had the highest negative and significant SCA effects for almost all the traits except number of stands per plot, ear height, number of cobs per plot and 100 seed weight. These hybrids therefore, could have the potential to escape drought stress in drought prone areas (Izge and Dugje 2011, and Aminu and Izge 2013). This study revealed hybrids that were found with significant and highly desirable SCA effects for different traits. Similar results have been reported by Ahmed-Amal and Mekki (2005). Some 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. Similar findings have been reported by other workers like Asif *et al.* (2007) and Premlatha and Kalamani (2010).

Estimates of heterosi for twelve agronomic traits in maize combined across locations are presented in Table 4. The results revealed that hybrid EVDT-WDTSTRC0 x EX-BIU WHITE, TZE-WDTSTRQPMC0 x EX-BIU WHITE and EVDT-WDTSTRQPMC0 x EX-BIU WHITE had the highest positive heterotic effect for anthesis silking interval. Positive high value heterosis is actually desirable for anthesis silking interval, implying that these hybrids could tolerate drought. Most of the hybrids indicated negative higher parent heterosis for days to 50% tasseling, days to 50% silking, plant height and ear height. Since drought stress has been reported to be more detrimental on maize crop during tasseling (Gant *et al*., 1989), hybrids which tassels and produce silks early in the season will be of utmost advantage in a drought endemic environments because they could escape drought (Izge *et al*., 2007 and Izge and Dugje 2011). Hybrids EVDT-W99STRCO x EX-DAMBOA WHITE, TZE-WDTSTRQPMC0 x EX-DAMBOA WHITE, EVDT-99WSTRQPMC0 x EX-BIU WHITE and TZE-COMP$_3$DTC$_1$ x EX-DAMBOA YELLOW had the highest negative higher parent heterosis for plant height and ear height. Negative heterosis for plant height and ear height are also desirable these hybrids would mature earlier and could escape drought. This result is in agreement with that reported by Sodangi *et al*. (2011). TZE-WDTSTRQPMC0 x EX-DAMBOA YELLOW and EVDT-99WSTRQPMC0 x EX-BIU WHITE hybrids recorded the highest exhibited positive higher parent heterosis for number of cobs per plant. In respect to number of cobs per plot and weight of cobs, EVDT-99WSTRC0 x EX-BIU YELLOW and TZE-WDTSTRQPMC0 x EX-DAMBOA YELLOW exhibited the highest positive higher parent heterosis effects. Hybrids EVDT-99WSTRC0 x EX-BIU WHITE and EVDT-99WSTRC0 x EX-BIU YELLOW recorded the highest positive higher parent heterosis for dehusked cobs.

TABLE 1: Combining ability analysis of variance for twelve agronomic traits in maize, combined locations in 2008

Source of variation	DF	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
Line	4	52.721	27.804*	21.971*	1.000*	565.446	1`327.970*	0.675	15.271	817664.583	1570066.956	9.271	517764.904
Tester	3	26.589	26.711*	26.186*	0.422	416.389	359.709	0.127	17.222	4489914.167	4686914.167	2.883	1426842.681
Line x Tester	12	37.221	32.954*	29.082*	0.950*	898.146*	1631.130*	0.338	46.3426	2527877.361	2482493.333	2.657	1006453.242
Error	56	38.719	12.99	6.00	0.431	312,477	481.661	0.339	37.890	3293967.931	3017035.345	4.635	1063911.632
Variance Component Estimates													
Line		0.646	0.465	0.296	0.002	13.863	-12.632	0.014	-1.294	-71258.866	-38017.778	0.276	-20362.014
Tester		-0.354	0.208	0097	-0.018	16.059	-42.381	-0.007	-0.970	65401.227	73480.694	0..08	14012.981
δ^2 gca		0.023	0.049	0.029	-0.001	-2.132	-3.861	0.001	-0.163	-733.288	2276.157	0.021	-535.707
δ^2 sca		0.002	1.650	1.914	0.061	54.500	41.903	0006	-1.774	112958.250	-19589.038	0.029	-12838.074
δ^2gca/sca		11.5	0.030	0.015	0.016	-0.039	-0.092	0.167	0.092	0.007	0.116	0.724	0.042
Proportional contribution to total variance													
Line		28.60	15.50	17.05	24.00	15.83	20.46	37.82	9.14	6.95	12.53	47.78	11.24
Tester		10.82	14.24	15.24	7.60	8.74	4.16	5.32	7.73	28.61	28.05	11.14	23.23
Line x Tester		60.58	70.26	67.71	68.40	75.43	75.39	56.86	83.14	64.44	59.42	41.08	65.53
GCA (Line + Tester)		29.42	29.74	32.29	31.60	24.57	24.62	43.14	16.87	25.56	40.58	58.92	34.47
GCA/SCA		0.651	0.423	0.477	0.462	0.326	0.327	0.759	0.203	0.397	0.683	1.434	0.526

KEYS

NSP =Number of stands per plot ASI=Anthesis silking interval NCPL = Number of cobs per plant WDC = Dehusked cobs
DTT =Days to 50% tasseling PHT = Plant height NCPT = Number of cobs per plot HSW= 100seed weight
DTS =Days to 50% silking EHT = Ear height WC = Weight of cobs GRY = Grain yield
* = Significant ** = Highly significant

TABLE 2: Estimate of general combining ability effect for male and female parents for twelve agronomic traits in maize combined locations in 2008

Line entries	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPLT	WC	DC	HSW	GRY
EVDT-W99STRCO	12.567**	3.300*	1.900*	-1.667**	-2.833	26.805*	-0.655*	11.300**	5487.017**	4912.850**	5.082**	2573.108**
TZEWDTSTRQPMCO	12.983**	-2.117	-0.683	-0.917*	20.667**	30.805**	-0.422	10.883**	5452.850**	5101.183**	45.498**	2702.805**
EVDTW99STRQPMCO	-4.433	-2.950*	-1.933*	-1.167**	-10.250	-2.895	-0.930	-2.200	21.183	-23.817	-1.418	-7.498
TZE-COMP$_3$DTC$_1$	-12.100**	3.550*	2.317*	5.083**	-10.917	-17.603*	4.087**	-9.783**	-5910.567**	-5491.400**	-2.560*	-2897.885**
BG97TZECOMP$_{3\ x4}$	-9.017**	-1.783	-1.600	-1.333*	3.333	-37.112**	-2.080**	10.200**	-5050.483**	-4498.817**	-6.602**	-2370.529**
SE±	2.07	1.20	0.80	0.20	5.89	7.32	0.19	2.05	709.61	604.98	0.72	343.82
Testers Entries												
EX-DAMBOA WHITE	2.583	-0.033	0.283	3.750**	-12.217*	-11.195	3.853**	1.767	838.783	791.450	3.990**	371.465
EXDAMBOAYELLOW	5.650*	0.767	0.483	-1.317*	1.717	18.098*	-1.527**	4.567*	1581.517*	1417.517*	-0.463	914.077*
EX-BIU WHITE	-5.617*	-1.767	-1.250	-1.050*	1.083	-8.695	-1.040*	-5.167*	-761.817	-855.817	-1.717*	-480.347
EX-BIU YELLOW	-2.617	1.033	0.483	-1.383*	11.583	1.792	-1.287*	-1.167	-1658.483*	-1353.150*	-1.810*	-805.195*
SE±	1.80	1.04	0.71	0.19	5.10	6.34	0.17	1.78	614.54	523.93	0.62	297.76

KEYS

NSP =Number of stands per plot ASI=Anthesis silking interval NCPL = Number of cobs per plant WDC = Dehusked cobs
DTT =Days to 50% tasseling PHT = Plant height NCPT = Number of cobs per plot HSW= 100seed weight
DTS =Days to 50% silking EHT = Ear height WC = Weight of cobs GRY = Grain yield
* Significant ** = Highly significant

TABLE 3: Estimate of specific combining ability effect for twelve agronomic traits in maize, combined locations in 2008

Hybrids Entries	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
EVDT-W99STRCO x EX-DAMBOA WHITE	-6.500	-6.300*	-5.700*	3.333*	-16.033	-32.972*	-4.212**	-2.433	182.950	1228.550	-3.282*	2303.080*
EX-DAMBOA YELLOW	1.433	2.567	1.767	1.733	16.033	-0.598	1.368	3.233	-995.683	-1360.850	-0.995	-772.865
EX-BIU WHITE	4.700	3.100	2.833	0.467	28.833*	17.862	1.815	0.500	1477.650	579.150	2.592	621.559
EX-BIU YELLOW	0.367	0.633	1.100	1.133	-8.833	15.708	1.028	7.167	-399.017	-446.850	1.685	-151.774
TZE-WDTSTRQPMCO x EX-DAMBOA WHITE	-5.917	-1.217	-1.450	-3.750*	3.133	-13.305	-3.978**	-8.017*	-3082.117*	-3196.450*	-4.698*	-1756.314*
EX-DAMBOA YELLOW	-1.317	-2.683	-2.317	1.983	-29.133	-31.932*	1.468	-0.483	1665.150	374.150	1.255	610.165
EX-BIU WHITE	2.950	0.850	0.083	1.383	-11.000	16.195	0.815	2.250	1565.150	360.817	1.175	1146.408
EX-BIU YELLOW	4.283	3.050	3.683*	0.383	27.000	29.042*	1.695	7.250	451.817	461.483	2.268	-0.259
EVDT-W99STRQPMCO x EX-DAMBOA WHITE	8.500*	-2.050	-2.533	-4.167*	31.050	-2.938	-2.870*	8.733*	5756.217**	581.883	3.552*	2772.171**
EX-DAMBOA YELLOW	10..767*	-2.183	-2.400	0.900	-15.217	39.102	1.477	7.933	3733.483**	775.817	2.505	2683.498**
EX-BIU WHITE	-8.967*	0.350	1.000	1.967	-24.417	-34.905*	0.790	-5.333	-4993.517**	-4694.183**	-2.842	-2596.623**
EX-BIU YELLOW	-10.300*	3.883	-3.933*	1.300	8.585	-1.258	0.603	-10.333**	-4496.517**	-4263.517**	-3.215*	-2359.047**
TZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE	5.500	10.117**	9.883	14.917**	-16.283	50.170**	15.113**	-1.017	-1735.700	-1480.867	9.293**	-968.079
EX-DAMBOA YELLOW	-6.900	-1.683	-0.983	-5.683	-0.883	-21.190	-5.373	-4.483	-1738.100	-1629.933	-4.720*	-635.206
EX-BIU WHITE	-1.300	-2.817	-2.250	-5.283	29.250*	0.703	-5.393	2.583	1138.567	840.067	-3.567*	284.067
EX-BIU YELLOW	2.700	-5.617*	-6.650**	-3.950*	-22.083*	-29.683	-4.347**	-0.083	535.233*	270.733	-1.007	319.218
BG97TZECOMPO$_{3X4}$ x EX-DAMBOA WHITE	-1.583	-0.550	-0.200	-3.667*	-1.867	-0.955	-4.053**	-1.267	-855.450	-733.117	4.865*	-350.850
EX-DAMBOA YELLOW	-3.983	3.983	3.933*	1.067	9.200	14.6128	1.060	-4.733	-2664.850*	-2159.183*	1.955	-1385.592*
EX-BIU WHITE	2.617	-1.483	-1.667	1.467	27.333*	0.145	1.973	0.000	911.817	914.150	2.642	544.589
EX-BIU YELLOW	2.950	-1.950	-2.067	1.133	-14.667	-13.808	1.020	7.000	2008.483	978.150	0.268	1191.862
SE±	3.59	2.08	1.42	1.41	10.21	12.67	1.10	3.55	1229.08	647.85	1.24	595.51

KEYS

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= 100seed weight, DTS =Days to 50% silking, EHT = Ear height, WC = Weight of cobs, GRY = Grain yield, Significant ** = Hghly significant

TABLE 4: Heterosis of the hybrids over the parents for twelve agronomic traits in maize, combined locations in 2008

Hybrids Entries	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
EVDT-W99STRCO x EX-DAMBOA WHITE	-10.63	-5.92	-4.29	10.53	-11.25	-10.16	3.59	3.40	10.14	9.76	-1.24	16.26
EX-DAMBOA YELLOW	2.42	1.31	1.19	-5.56	5.34	16.32	5.29	32.73	30.77	22,.01	-0.89	43.69
EX-BIU WHITE	-7.73	-8.41	-10.80	22.22	7.98	-22.85	5.59	30.00	26.36	25.30	-028	52.52
EX-BIU YELLOW	4.84	4.22	3.85	16.67	8.10	5.62	5.29	41.03	32.32	24.58	-3.37	57.74
TZE-WDTSTRQPMCO x EX-DAMBOA WHITE	-9.37	-5.61	-4.86	5.26	-16.01	-23.88	-0.28	-2.91	-17.13	-21.74	-2.78	-20.30
EX-DAMBOA YELLOW	-2.69	3.82	5.97	11.11	6.71	17.67	9.50	42.00	34.29	23.67	-2.43	37.15
EX-BIU WHITE	-3.24	-6.01	-4.71	22.22	-4.42	-6.53	0.80	27.62	21.47	14.17	-1.46	52.74
EX-BIU YELLOW	-6.72	-0.32	-1.48	11.76	3.82	-1.61	2.04	1.00	31.69	21.67	-1.73	44.45
EVDT-W99STRQPMCO x EX-DAMBOA WHITE	-6.58	-0.62	-1.14	5.26	-6.20	4.46	4.51	4.85	6.57	8.96	2.08	28.81
EX-DAMBOA YELLOW	-4.63	-1.25	-0.57	-22.22	-5.89	17.63	9.55	26.57	28.70	20.75	-3.01	-19.47
EX-BIU WHITE	-12.97	-11.71	-9.70	22.22	-13.40	-13.64	7.96	29.43	22,.24	20.63	2.22	50.58
EX-BIU YELLOW	-2.57	-10.31	-9.20	5.56	3.69	-25.70	-1.59	19.59	17.41	17.29	-0.07	69.16
TZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE	-3.80	3.09	2.28	-5.26	-1.23	5.14	-3.85	-9.,26	-23.97	-29.05	-3.26	-24.16
EX-DAMBOA YELLOW	-2.36	-5.86	-4.84	11.11	14.24	-20.37	-7.14	-16.67	-7.87	-12.01	1.74	-5.71
EX-BIU WHITE	-0.25	-3.00	-3.32	0.00	-2.00	-8.34	-3.19	-21.30	-2.17	-5.04	-2.76	-4.95
EX-BIU YELLOW	0.79	-4.01	-3.99	-5.56	-4.01	8.45	1.37	-19.44	-10.27	-10.99	-11.94	-10.62
BG97TZECOMP$_{3X4}$ x EX-DAMBOA WHITE	-7.59	4.64	4.57	-5.26	-6.20	12.45	-4.14	-7.77	-7.05	-9.95	1.00	-10.04
EX-DAMBOA YELLOW	-11.17	-2.48	-1.44	5.26	5.81	-5.67	-0.84	2.06	-13.32	-16.03	-0.81	-12.71
EX-BIU WHITE	-6.73	-1.80	-2.22	-22.22	0.64	8.11	-5.59	-8.57	-3.59	-4.29	9.51	-3.18
EX-BIU YELLOW	-4.43	-7.74	-5.76	11.76	4.26	-22.90	3.46	-1.55	21.00	25.79	-6.45	24.61

KEYS

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= 100seed weight , DTS =Days to 50% silking, EHT = Ear height, WC = Weight of cobs , GRY = Grain yield, * = Significant , ** = Highly significant

Five hybrids expressed positive higher parent heterosis for 100-seed weight, with EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE and EVDT-99WSTRQPMC0 x EX-BIU WHITE having the highest higher parent heterosis. Hybrids EVDT-99WSTRC0 x EX-BIU YELLOW and EVDT-99WSTRQPMC0 x EX-BIU 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-W99STRCO x EX-DAMBOA WHITE, TZE-WDTSTRQPMC0 x EX-DAMBOA WHITE, EVDT-99WSTRQPMC0 x EX-BIU WHITE, EVDT-99WSTRC0 x EX-BIU YELLOW and EVDT-99WSTRQPMC0 x EX-BIU YELLOW appeared to have genes that can 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*. (1988), Joshi *et al*. (1998).

CONCLUSION

The present study identified parents: EVDT-99WSTRC0, TZE-WDTSTRQPMC0, and EX-BIU WHITE as the best general combiners, while hybrids EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE, EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW, EVDT-W99STRCO x EX-BIU YELLOW and EVDT-99WSTRQPMC0 x EX-BIU YELLOW as the best among the 20 hybrids evaluated for SCA, have the best level of high parent heterosis for drought tolerant traits and grain yield.

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