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Combining ability and heterosis for different agronomic traits in maize (*Zea mays* L.) under drought stress in the Sudan Savanna of Borno State, Nigeria

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Combining ability variances were estimated for grain yield and its related traits in maize (*Zea mays* L.). Nine maize varieties consisted of five IITA open pollinated varieties (OPVs) and four local varieties were crossed in line x tester mating design. During the 2007 cropping season to determine the general combining ability (GCA), specific combining ability (SCA) effects and heterosis. Parents and hybrids were evaluated in Damboa during the cropping seasons of 2008/2009. Significant level of genetic variability among the parental lines and their hybrids for 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 relatively smaller proportion of GCA to SCA ratio indicated that the predominance of non-additive genetic effects with respect to all the traits except number of cobs per plant and number of cobs per plot. This suggests that high performing hybrids such as EVDT-99WSTRC0 x EX-DAMBOA WHITE, EVDT-99WSTRC0 x EX-BIU WHITE, EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW and TZECOMP$_3$DTC$_1$ x EX-BIU YELLOW may be used to develop potential varieties. Grain yield superiority of some hybrids over the higher parents was recorded suggesting the possibility of their commercial exploitation. The parents: EVDT-99WSTRC0, TZE-WDTSTRQPMC0, and EX-DAMBOA WHITE were identified as the best combiners in terms of GCA for days to tasseling, days to silking, number of cobs/plant, number of cobs/plot, dehusked cobs and grain yield.

Key words: Combining ability, heterosis, Nigeria maize, drought.

INTRODUCTION

Maize (*Zea mays* L.) is the most important cereal crop in Sub-Sahara Africa (SSA) and an important stable food for more than 1.2 billion people in SSA and Latin America. Globally, maize is ranked the third most important cereal

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crop, after wheat and rice. It is one of the widely cultivated cereal crops due to its adaptation to a wide range of environments and considered as major staple food crop in Nigeria and receiving much attention in industrial development. 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, 2013). However, according to IITA, (2011), 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. Drought stress is one of the most important environmental stresses affecting agricultural productivity worldwide particularly in the study area (Sudan savanna). It is a major abiotic constraint to maize production. A lack adequate rainfall can lead to decrease in yield and trigger famines. It is the most devastating maize production constraints in Sudan Savanna of Nigeria. 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 high yielding and drought tolerant hybrids. Information about combining ability and heterotic patterns among maize gene pools and populations should assist research programmes in their hybrid development activities (Beck et al., 1991). The needs for breeding maize crop tolerance important for increasing adaptability under stress conditions. The choice for selection and breeding procedure to be used for genetic improvement of crop plants therefore 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). To establish a sound basis for any breeding programme, aimed at achieving higher yield, breeders must have information on the nature of combing 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-Filho, 1988).

This study aimed to improve maize varieties depending on their great diversity which has yield potential and drought tolerance traits. Estimate of the general and specific combining ability effects and determine the high parent heterosis existing among the traits.

MATERIALS AND METHODS

Five maize lines (EVDT-99WSTRC0, TZE-WDTSTRQPMC0, EVDT-99WSTRQPMC0, TZECOMP$_3$DTC$_1$ and BG9TZECOMP$_{3x4}$) were selected and classified as drought tolerant genotypes and open pollinated varieties (OPVs), developed in International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria from diverse sources of germplasm. The second set of parents consisted of four local cultivars (EX-BIU WHITE, EX-BIU YELLOW, EX-DAMBOA WHITE and EX-DAMBOA YELLOW) susceptible to drought predominantly growing by the farmers in the study areas. The materials were crossed in line x tester mating design at the Faculty of Agriculture, Teaching and Research Farm, University of Maiduguri, Nigeria, to generate for the initial breeding population (F$_1$ hybrids) during the rainy season of 2007 under manual irrigation to generate a total of 20 hybrids. The hybrids produced together with their parents were evaluated during the two rainy seasons of 2008 and 2009 in Damboa. Damboa is located in Sudan Savanna with an average annual rainfall of 500 – 1000 mm distributed within the rainy season period of 100 – 120 days the soil type is sandy loam. The treatments were laid out in a randomized complete block design (RCBD) replicated three times. Each plot size was 5 x 2.75 m, with four rows spaced of 75 x 40 cm intra-row spacing. The sowing was done in (15th August) in order to subject the genotype to moisture stress.

NPK (15:15:15) fertilizer at the rate of 333.3 kg/ha was applied 10 days after planting and urea was applied at the rate of 110 kg/ha four weeks after planting. Growth data were recorded on number of stands/plot, days to 50% tasseling, days to 50% silking, anthesis silking interval (ASI), plant height (cm) and ear height (cm). Harvest data recorded include; number of cobs/plant, number of cobs/plot (g), 100 seed weight (g) and grain yield (kg/ha). The combining ability analysis and the estimates of general combining ability (GCA) and specific combining ability (SCA) effects were done based on the procedures described by Kempthorne (1957) and Singh and Chaudhary (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 AND DISCUSSION

Analysis of combining ability

Analysis of combining ability variance and variance components for twelve agronomic traits in line x tester design in maize are presented in Table 1. The results showed that there were statistical significant differences among the lines in their variances in plant height, ear height and number of cobs per plot. Similarly, the results for testers indicated that mean squares due to ear height, number of cobs per plant and dehusked cobs expressed significant differences. In another development, the results indicated that, the variance for line x tester interaction were highly significant for days to tasseling, days to silking, plant height and ear height among all the other traits. The results showed additive and non additive effects were both significant ($P < 0.05$) and responsible

Table 1. Analysis of general combining ability (GCA) and specific combining ability (SCA) variance for twelve agronomic traits combined years.

Source of variation	DF	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
Line	4	29.270	29.425	27.175	0.321	825.300*	959.26**	0.480	89.533*	511734.167	794620.00	15.978	138476.014
Tester	3	20.911	21.964	21.564	0.097	324.243	1125.373**	1.318*	32.62	718411.11	1134960.833**	4.402	688938.326
Line x Tester	12	102.960*	44.908*	43.536*	0.465	1082.056**	1082.056**	0.407	16.511	513315.278	558837.222	8.084	443865.929
Error variance component estimates	56	52.436	19.608	18.656	0.603	383.66	413.66	0.576	42.618	561726.332	590952.808	6.830	387721.082
Line		-3.070	-0.645	-0.682	-0.006	7.408	-5.117	0.003	0-537	-65.880	9824.282	0.329	-12724.579
Tester		2.735	-0.765	-0.732	-0.012	-10.775	1.444	0.034	0.262	6836.528	19204.120	-0.123	8169.080
σ^2 gca		0.415	-0.100	-0.101	-0.001	-0.199	-0.277	0.002	0.339	467.714	2051.845	0.016	-373.535
σ^2 sca		0.184	2.016	1.951	-0.050	16.121	74.426	0.037	4.183	2770.151	37701.468	0.428	6380.03
σ^2gca/sca		2.26	-0.050	-0.052	0.02	0.012	-0.004	0.054	0.081	0.169	0.054	0.037	-0.059
Proportional contribution to total variation													
Line		8.27	16.229	15.62	17.93	27.41	19.00	17.84	54.75	19.75	23.92	36.71	6.97
Tester		4.43	9.12	9.30	4.07	8.08	16.72	36.75	14.96	20.80	25.62	7.58	26.01
Line x Tester		87.30	74.59	75.08	78.00	64.51	64.29	45.41	30.29	59.45	50.46	55.71	61.02
GCA (Line + Tester)		1`2.70	25.41	14.92	22.00	35.49	35.72	53.59	69.71	40.55	49.54	44.29	32.98
GCA/SCA		0.146	0.341	0.199	0.282	0.550	0.557	1.180	2.301	0.682	0.982	0.795	0.540

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.

for the genetic expression. These results are in agreement with that of Kadams et al. (1999), Izge et al. (2007), Premlathan 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 Bello and Olaoye (2009) and Aminu and Izge (2013). The results for the variance component estimates showed that dehusked cobs had the highest value among the lines. However, the variance component estimates for testers also expressed the highest value for weight of the cobs, dehusked cobs and grain yield. The estimate of SCA variance was higher than the GCA variance. However, in few cases the estimates of GCA were higher than SCA indicating that additive gene effect was in controlled while, non-additive genetic effect was more important than the additive gene effect as most of the GCA/SCA ratios were less than unity. These results are in agreement with Rojas and Sprague (1952) and Gama et al. (1995) who worked on millet and maize respectively. These results showed that parental lines would be utilized in the development of maize hybrids.

The results for the proportional contribution of lines to total variation are higher than the testers in most of the traits. The lowest contribution to total variations among the lines was given by grain yield. The results of the interaction between line x tester were higher for all the traits except number of cobs per plant and number of cobs per plot. The GCA/SCA ratio shows that, high values were obtained in respect to number cobs per plant, number of cobs per plot, dehusked cobs and 100-seed weight. However, the low and moderate values were obtained in the remaining traits. The lower proportion of GCA/SCA also indicated that additive x non additive and non additive interactions were not significant among hybrids. However, the importance of additive genetics effects was reported by Alamnie et al. (2006) and Aminu and Izge (2013) in respect of

Table 2. Estimate of general combining ability (GCA) effect for male and female parents for twelve agronomic traits combined years.

Line entries	STD	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
EVDT-99WSTRC0	0.650	-2.200	-1.783	-1.200*	77.612**	54.522**	0.217	26.833**	3139.683**	2807.017**	4.518**	2227.241**
TZE-WDTSTRQPMC0	4.067	-3.200*	-4.033*	2.817**	88.028**	38.822**	-0.042	29.333**	3539.683**	3181.183**	4.943**	2331.483**
EVDT-99WSTRQPMC0	1.733	-2.700	-2.450	-1.533**	1.528	-12.487	-1.308*	1.417	303.017	363.683	-0.998	159.665
TZE-COMP$_3$DTC$_1$	-3.267	7.217**	6.550**	-1.117*	-79.497**	-31.770*	3.308**	-26.500*	-3853.733**	-3557.233*	-1.648*	-2345.509**
BG97TZECOMP$_{3\ x4}$	-3.183	0.883	1.717	-1.367*	-87.672**	-47.087**	-2.175**	-31.083**	-3128.650**	-2794.650**	-6.815**	-2374.880**
SE (±)	2.414	1.52	1.48	0.26	7.48	6.78	0.25	2.17	249.83	256.25	0.83	207.56
Male Entries												
EX-DAMBOA WHITE	1.117	0.133	0.050	1.617**	11.872	4.793	4.532**	7.767**	761.283*	612.450*	3.478*	312.992
EX-DAMBOA YELLOW	3.183	-1.867	0.517	-1.283*	33.645**	16.693**	1.662*	4.833*	668.017*	727.850**	-0.648	439.798*
EX-BIU WHITE	-1.750	1.200	-1.417	-1.550*	-29.762**	-8.167	-1.128*	-6.100*	-424.650*	-367.483	-1.495	-382.214*
EX-BIU YELLOW	-2.550	0.533	0.850	-1.350*	-15.755*	-13.320*	-1.742*	-6.500*	-1004.650**	-972.817**	-1.335	-370.577*
SE (±)	2.09	1.31	1.28	0.22	6.48	5.87	0.22	1.89	216.36	221.92	0.75	179.75

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.

grain weight in maize.

General combining ability effects

Estimates of general combining ability effects for twelve agronomic traits in maize are presented in Table 2. Among the parents, TZE-WDTSTRQPMC0 expressed positive significant GCA values effects for all the traits except for days to tasseling expressed negative GCA effects, while in case of other characters positive GCA effects are desirable. Similarly, EVDT-99WSTRC0 is the second highest general combiner with positive significant GCA effects for number of cobs per plot, weight of cobs, dehusked cobs, 100-seed weight and grain yield. Therefore, TZEWDTSTRQPMC0 and EVDT-99WSTRC0 had exhibited highly significant GCA effects in desirable direction for almost all the traits. These findings are in accordance with Bello and Olaoye (2009) and Aminu and Izge (2013).

The results for testers indicated that EX-DAMBOA WHITE and EX-DAMBOA YELLOW had the highest significant GCA effects. These were due to the adaptation of the testers which were originated from the study area. Maize breeders have therefore, devoted effort to developing superior genotypes for grain yield and adaptation to different stress factors (Olaoye et al., 2005). The results also indicated that, EX-BIU WHITE and EX-BIU YELLOW had negative significant GCA effects for almost all the traits.

Specific combining ability effects of hybrids

The estimates of specific combining ability for twelve agronomic traits in maize evaluated are presented in Table 3. Specific combining ability effects are used to identify the best cross-combinations for hybrids production (Izge et al., 2007). These studies identified a number of desirable hybrids for some of the agronomic traits such as anthesis silking interval, plant height, ear heights, cobs per plant, cobs per plot, dehusked cobs and grain yield. The SCA effects were significant or highly significant in the twenty hybrids studied for the different agronomic traits. The study revealed that hybrids with high SCA effects involved at least one or two of the several higher general combiners as parent namely: EVDT-99WSTRC0, EVDT-99WSTRQPMC0, EX-BIU WHITE and EX-DAMBOA WHITE. Gama et al. (1995) reported similar result where a hybrid with high SCA effects involved one or both of the good general combiners as parents. Hybrid EVDT-99WSTRC0 x EX-DAMBOA WHITE expressed negative and significant SCA effects for days to tasseling and days to silking.

Table 3. Estimate of specific combining ability (SCA) effect for the hybrids for twelve agronomic traits combined years.

Entries	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
EVDT-99WSTRC0 x EX-DAMBOA WHITE	5.117	-6.617*	-7.983*	4.467*	-39.538*	-37.802*	3.428*	15.650*	2917.060**	2705.050**	-2.578	2220.038**
EX-DAMBOA YELLOW	-5.517	0.133	0.650	1.200	-15.645	5.568	1.437	-9.167*	-1059.683*	-1053.683*	1.082	-839.798*
EX-BIU WHITE	6.417	3.533	3.250	-3.267*	41.428*	37.258*	4.503*	28.583**	3210.317**	3156.317**	1.028	2415.656**
EX-BIU YELLOW	4.217	1.467	-0.350	0.600	13.755	6.112	0.850	13.167*	679.650	583.650	0.468	523.305
TZE-WDTSTRQPMC0 x EX-DAMBOA WHITE	-8.533*	-0.800	0.300	-4.350*	-6.955	0.798	-4.698*	-9.267*	-1052.950*	1179.117*	-4.870*	-739.659*
EX-DAMBOA YELLOW	-3.600	-1.867	4.33	2.117	-37.395*	-31.002*	1.762	-5.000	-459.683	-361.183	1.723	-156.162
EX-BIU WHITE	5.333	-0.133	0.833	1.383	16.678	-9.908	1.562	7.267*	699.650	867.483*	0.470	699.789
EX-BIU YELLOW	6.800	2.800	2.900	0.850	27.672*	40.112*	1.375	7.000*	812.983	672.817	2.677	196.032
EVDT-99WSTRMC0 x EX-DAMBOA WHITE	0.800	-5.300*	5.2317*	-3.600*	81.878**	30.040*	-2.232	-7.100*	-7.100	-871.617*	3.238*	-625.720
EX-DAMBOA YELLOW	2.067	-4.033	-4.350	1.200	50.772**	14.673	3.790*	13.100*	1132.983*	1341.650*	4.898*	1942.214**
EX-BIU WHITE	-10.333*	2.700	2.917	0.800	-81.255**	-31.800*	0.228	-18.483**	-2863.683**	-	-0.488	-
EX-BIU YELLOW	7.467	6.633*	6.650*	1.600	-51.395**	-12.913	-0.225	-25.750**	-3263.683**	2795.017**	-	2106.574**
TZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE	17.467**	-7.450*	-8.450*	4.317*	-22.997	23.257*	4.752*	-1.433	-1276.533*	-	7.648**	-
EX-DAMBOA YELLOW	3.733	0.050	0.650	-5.217*	-9.137	-5.577	-5.455*	-6.167	-912.933*	3066.350**	9.522**	2529.120**
EX-BIU WHITE	-7.000	-3.883	4.417	-5.283*	36.170*	7.150	-5.388*	-0.233	903.067*	-871.033*	-5.018*	-818.939*
EX-BIU YELLOW	4.200	-5.113*	-3.355*	4.817*	-4.037	-29.830*	3.908*	9.833*	1286.400*	-962.767*	-4.838*	-1045.048*
BG97TZECOMPO$_{3X4}$ x EX-DAMBOA WHITE	-4.617	0.783	0.383	-4.100	-12.388	-26.293*	-4.032*	2.150	165.383	529.233*	2.335	175.994
EX-DAMBOA YELLOW	3.317	5.717*	6.483*	0.700	11.405	27.473*	0.028	-8.250*	-778.017	1304.567	-5.312*	1687.994**
EX-BIU WHITE	5.583	-2.217	2.583	1.633	-13.022	-2.700	2.095	8.350*	127.983	216.717	-2.685	-35.720
EX-BIU YELLOW	-4.283	-4.283	3.517	1.767	14.005	-8.840	1.908	-2.250	484.650	-778.683	3.828*	-374.647
SE ([illegible])	4.18	2.61	2.56	1.48	12.96	11.74	1.44	3.77	432.72	56.650	4.168*	288.577
										505.317	1.51	121.789
										443.83		359.50

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.

Negativity of these traits is important, implying that these hybrids could mature earlier and could escape drought. Similar results were reported by Bello and Olaoye (2009) and Aminu and Izge (2013). With respect to ASI, TZECOMP$_3$DTC$_1$ x EX-DAMBOA WHITE had the highest positive and significant SCA effects. ASI is a trait used mostly in screening for tolerance to stresses. It is a measure of nicking (synchronization) of pollen shed with silking. This report is in accordance with finding of Shanghai et al. (1983), Paul and Debenth (1999) and Bello and Olaoye (2009). Nine hybrids expressed significant SCA effect for plant height and ear height. However, four and five of them expressed negative and significant SCA effects with EVDT-99WSTRQPMC0 x EX-BIU WHITE had the highest negative and significant SCA effects. Negative plant height is desirable especially in drought prone and windy areas against drought lodging (Izge et al., 2007; Aminu and Izge, 2013). For 100-seed weight, hybrid TZECOMP$_3$DTC$_1$ x EX-DAMBOA WHITE had the highest positive and significant SCA effects. The hybrids EVDT-99WSTRC0 x EX-DAMBOA WHITE, EVDT-99WSTRC0 x EX-BIU WHITE and TZECOMP$_3$DTC$_1$ x EX-BIU YELLOW exhibited positive and significant SCA effects for grain yield. These are good hybrids when breeding for drought stress and grain yield. These hybrids probably have potential as parents of

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

Entry	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
EVDT-99WSTRC0 x EX-DAMBOA WHITE	13.05	-4.86	-2.26	5.76	-2.82	-18.33	12.07	18.36	12.68	15.80	5.82	38.34
EX-DAMBOA YELLOW	14.72	-4.00	-3.41	6.26	5.05	14.88	14.29	6.78	-3.10	-4.72	-9.08	-16.24
EX-BIU WHITE	11.31	-6.30	-8.24	4.81	-5.48	-29.43	6.44	19.38	15.89	13.97	5.64	39.46
EX-BIU YELLOW	14.14	7.64	7.85	-10.29	9.18	13.42	3.97	5.88	3.79	7.46	-7..41	10.10
TZE-WDTSTRQPMC0 x EX-DAMBOA WHITE	8.65	-6.64	-4.24	-5.20	-11.73	-25.16	6.20	13.03	9.11	8.69	2.90	18.55
EX-DAMBOA YELLOW	6.34	-6.15	5.97	-4.76	8.38	12.68	3.10	3.17	13.69	9.34	1.93	11.62
EX-BIU WHITE	-13.26	-10.60	-8.78	3.06	-12.89	-32.87	7.36	12.50	4.22	4.58	14.86	11.17
EX-BIU YELLOW	-1.44	-2.17	-1.14	-5.26	-2.28	6.21	4.73	2.94	5.12	7.73	0.95	9.57
EVDT-99WSTRQPMC0 x EX-DAMBOA WHITE	3.66	-3.00	-1.12	2.26	6.78	-8.79	-3.73	1.52	5.60	0.76	2.75	-4.44
EX-DAMBOA YELLOW	13.96	-1.80	-2.23	5.81	-2.27	-18.86	17.86	21.31	19.17	18.86	7.88	40.76
EX-BIU WHITE	9.52	-14.33	-12.5	-14.29	-15.46	-32.90	5.58	12.50	10.60	-10.95	5.31	-31.96
EX-BIU YELLOW	-2.74	-10.51	-8.66	-4.76	-4.51	-33.38	13.57	27.94	12.09	23.07	4.01	21.12
TZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE	-9.27	-1.18	-1.09	-10.00	-1.99	-5.73	-9.54	-17.81	-32.23	-38.51	-18.88	-39.78
EX-DAMBOA YELLOW	-10.39	-5.60	-5.99	-4.76	-5.75	-23.59	1.30	-26.03	-14.59	-24.18	-5.79	-23.69
EX-BIU WHITE	-2.53	-3.15	-2.93	-4.76	-2.44	-25.23	4.23	-5.48	6.35	-3.52	-20.46	-1.16
EX-BIU YELLOW	13.93	-7.08	-5.18	4.76	-2.78	-23.94	16.78	23.70	21.55	15.12	7.27	41.72
BG97TZECOMP$_{3X4}$ x EX-DAMBOA WHITE	6.42	7.60	8.47	-19.05	2.78	22.03	-16.60	-7.58	0.58	-5.59	-1.01	-0.33
EX-DAMBOA YELLOW	12.92	-2.44	-1.69	-11.31	8.74	2.47	-2.16	-6.78	5.19	0.27	-6.93	1.60
EX-BIU WHITE	3.43	-4.58	-4.79	4.26	1.39	2.61	4.37	13.44	6.15	4..25	4.64	12.05
EX-BIU YELLOW	s8.62	-6.40	-5.65	-5.26	-1.84	-33.09	14.68	13.88	8.80	10.07	0.19	21.92

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.

hybrid varieties, as well as for inclusion in breeding programs, since they may contribute superior alleles in new populations for high grain yield and other abiotic stresses in maize production especially in Sudano-Sahelian zone. These results are in line with earlier independent studies of Perez-Velasquez et al. (1996), Kumar et al. (1998) and Bello and Olaoye (2009) who reported that maize grain yield and flowering traits were under the control of non-additive (SCA effects) type of gene action.

Heterosis

Estimates of heterosis for twelve agronomic traits in maize are presented in Table 4. The degree of heterosis varied from hybrid to hybrid and from traits to traits. This study showed that great potentials for increased maize yield exist because of the high level of heterosis observed. Both positive and negative heterotic values were recorded for all agronomic traits studied. However, the high positive higher parent heterosis observed for stands count, number of cobs/plant, cobs/plot, weight of cobs and dehusked cobs directly indicated their importance for total grain yield increased. Aminu and Izge (2013) reported significant and positive level of heterosis for 1000 for these traits in maize. The negative heterosis recorded for traits like days to tasseling, days to silking, plant height and ear height are desirable in breeding for earliness and short stature hybrids that could resist lodging particularly in windy environment. Hybrids EVDT-99WSDTRC0 x EX-

DAMBOA WHITE, EVDT-99WSDTRC0 x EX-DAMBOA YELLOW and EVDT-99WSTRQPMC0 x EX-DAMMBOA YELLOWH expressed positive and significant higher parent heterosis for ASI and could be recommended for environment with low and erratic rainfall, because it is one of the drought tolerant traits.

This study indicated tremendous level of higher parent heterosis in grain yield. EVDT-99WSTRC0 x EX-DAMBOA WHITE, EVDT-99WSTRC0 x EX-BIU WHITE, EVD-99WSTRQPMC0 x EX-DAMBOA YELLOW and TZE-COMP$_3$DTC$_1$ x EX-BIU YELLOW are among the hybrids that expressed the highest significant higher parent heterosis for grain yield. Low levels of heterosis were observed which could be attributed to narrow genetic base of the materials used in the development of some parents. It is noteworthy that these hybrids 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) and Perez-Velasquez et al. (1996) who reported that maize grain yield and flowering traits were under the control of non-additive (SCA effect) type of gene action.

Conclusion

The study identified parents: EVDT-99WSTRC0, TZE-WDTSTRQPMC0 and EX-DAMBOA YELLOW as the best general combiners, while hybrids EVDT-99WSTRC0 x EX-DAMBOA WHITE, EVDT-99WSTRC0 x EX-DAMBOA YELLOW 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/plant, cobs/plot, weight of cobs and dehusked cobs and grain yield. The desirable heterotic levels in days to tasseling, days to silking, plant height and ear height are desirable in areas with marginal rainfalls and windy environment like the study area.

Conflict of Interest

The authors have not declared any conflict of interest.

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