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Estimates of Combining Ability and Heterosis for Yield and Yield Traits in Maize Population (*Zea mays* L.), under Drought Conditions in the Northern Guinea and Sudan Savanna Zones of Borno State, Nigeria

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Abstract – **Combining ability variances and effects were estimated for grain yield and other agronomic traits in maize (*Zea mays* L.). Nine parental maize varieties consisted of five IITA open pollinated varieties (OPVs) drought tolerant used as lines and four local varieties used as testers with various level of susceptibility to drought. These materials were crossed in a line x tester mating design during the 2007 cropping season to determine the GCA, SCA effects and the level of heterosis. Parents and crosses were evaluated in Biu and Damboa during the cropping season of 2009. Results from analysis of variance and combining ability showed that there were high and significant level of genetic variability among the parental lines used and their hybrids for almost all the traits study, thus suggesting the possibility for genetic improvement. The study also 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 indicated the predominance of non-additive genetic effects with respect to most of the traits. That is, estimates of GCA were consistently lower than SCA effects in most of the traits evaluated. This suggests that high performing hybrids such as EVDT-99WSTRC0 x EX-DAMBOA WHITE, TZE-WDTSTRQPMC0 x EX-DAMBOA YELLOW, EVDT-W99STRQPMCO x EX-DAMBOA WHITE, EVDT-W99STRQPMCO x EX-DAMBOA YELLOW and TZECOMP$_3$DTC$_1$ 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 more prevalence. 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-DAMBOA WHITE were identified as the best general combiners in terms of GCA for days to 50% tasseling, for days to 50% silking, anthesis silking interval, plant height, number of cobs per plot, weight of cobs, 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.**

Keywords – **Gene Action, Hetorosis, Traits, Yield, Maize, Drought.**

I. Introduction

Maize (*Zea mays* L.) production in the savanna regions of Nigeria is facing a lot of problems ranging from low soil nutrients status, drought and susceptibility to pests and diseases as well as poor adaptation to the agro-ecologies (Olaoye *et al*., 2004). Maize breeders have therefore devoted effort to developing superior genotypes for grain yield and adaptation to the different stress factors (Bello and Olaoye, 2009). Early maturing maize hybrids are essential for successful production in short growing season areas. Because maturity and yield are usually positively correlated (Hallauer and Miranda, 1981), breeders need to develop a clearer understanding of how maturity influences agronomic traits in order to combine high yield potential and early maturity into the same hybrids.

Maize 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. All parts of the crop can be used for food and non-food products. Globally, maize is ranked the third most important cereal crop, after wheat and rice. It is one of the most widely cultivated cereal crops due to it adaptation to a wide range of environment. It is also a 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).

The global production has increased due to high consumption coupled with increased in human population. However, yield is reduced as a result of drought which is one of the most important environmental stresses affecting agricultural productivity worldwide particularly in the study areas. It is a major abiotic constraint to maize production which is mostly rain fed in Africa. Lack of adequate rainfall can lead to decrease in yield and trigger famines. It is the most devastating maize production constraints in savanna region 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).

Breeding strategies based on selection of hybrids require expected level of heterosis as well as the specific combining ability. In breeding high yielding varieties of crop plant, the breeders often face with the problem of selecting parents and crosses. Combining ability analysis is one of the powerful tools available to estimate the combining ability effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis. 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). Line x tester analysis provides information about general combining ability (GCA) and specific combining ability (SCA) effects of parents and is helpful in estimating various types of gene actions (Rashid *et al*., 2007). The improved varieties use in this study was due to their great diversity which has yield potential and drought tolerance traits. Therefore, the study was conducted to estimates the general combining ability effect of parents, specific combining effect of hybrids and to determine the high parent heterosis existing among the traits.

II. Materials and Methods

The parental materials used in this study comprised of five maize lines that are drought tolerant and open pollinated varieties (OPVs), developed at International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria from diverse sources of germplasm through evaluation and selection at multiple locations were used as lines *vis* EVDT-99WSTRC0, TZE-WDTSTRQPMC0, EVDT-99WSTRQPMC0, TZECOMP$_3$DTC$_1$ 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. 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 to generate a total of 20 hybrids. The resultant hybrids were harvested, processed and stored in the cold and dry room prior to field evaluation. Later, the hybrids produced together with their parents were evaluated during the rainy seasons of 2009 in Biu and Damboa respectively. 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^{l}N and longitude 13^0 2^{l}E), the soil type is clay or black cotton vertisols. On the other hand, Damboa is located in Sudan Savanna (latitude 11^o.10.5'N and longitude 12^0 46.3^{l}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. 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/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/plant, number of cobs/plot (g), 100 seed weight (g) and grain yield (kg/ha).

The combining ability analysis and the estimates of GCA and SCA effects were done using line x tester method 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).

III. Results and Discussions

Analysis of combining ability

Combining ability variance and variance components for twelve agronomic traits in line x tester design in maize across locations in 2009 are presented in Table 1. The results showed that there was statistical significant difference among the lines in their variances in days to 50% tasseling, days to50% silking, anthesis silking interval, number of cobs per plant, number of cobs per plot, weight of cobs and grain yield. The results for testers showed highly significant differences in all the traits between locations. However, significant differences existed among the line x tester interaction in anthesis silking interval, number of cobs per plot, weight of cobs, dehusked cobs and grain yield. The results showed additive and non additive effects were both significant ($P < 0.05$) and responsible for the genetic expression. These results are in agreement with that of Joshi *et al*. (2002), Asif *et al.* (2007) 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 (2005) and Aminu and Izge (2013).

The estimates of variance component showed that ear height had the highest value among the lines. However, 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 in all the traits, and more than one for all the traits studied. This revealed the preponderance of non-additive genetic effect over 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 results of the interaction between line x tester were higher for all the traits except plant height and ear height. The GCA/SCA ratio shows that, high values were obtained in respect to anthesis silking interval, plant height and ear height. 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 grain weight in maize.

General combining ability effects of parents

Estimates of general combining ability effects of parents for twelve agronomic traits in maize across locations in 2009 are presented in Table 2. Parent EVDT-W99STRC0 expressed highly significant GCA values effects for almost all the traits except for number of stands per plot and anthesis silking interval. Traits such as days to 50% tasseling, for days to 50% silking, plant height and ear height, negative GCA effects are desirable, while in case of other characters positive GCA effects are most desirable. Minimum days to 50% tasseling, days to 50% tasseling, plant height and ear height are needed for crop early maturing and lodging. Hence, it is the highest general combiner. Similarly, TZEWDTSTRQPMC0 is the second highest general combiner with negative significant GCA effects for days to 50% tasseling and for days to 50% silking, positive significant GCA effects for plant height, number of cobs per plot, weight of cobs, dehusked cobs, 100-seed weight and grain yield. Therefore, EVDT-99WSTRC0 and TZE-WDTSTRQPMC0 had exhibited highly significant GCA effects in desirable direction for most of the traits. These findings are in accordance with Izge and Dugje (2011) and Aminu and Izge (2013).

The results for testers indicated that EX-DAMBOA WHITE had the highest significant GCA effects. These were due to the adaptation of the tester which was originated from the study area. Anthesis silking interval is a trait used mostly in screening genotypes for tolerance to stresses (EL-Hosary *et al*., 1994). It is a measure of nicking (synchronization) of pollen shed with silking as reported by Paul and Debenth (1999). Maize breeders have therefore, devoted effort to developing superior genotypes for grain yield and adaptation to different stress factors (Olaoye *et al.,* 2005).

Specific combining ability effects of hybrids

The estimates of specific combining ability effects for twelve agronomic traits in maize across locations in 2009 are presented in Table 3. These estimates are used to identify the best cross-combinations for hybrids production (Izge *et al*., 2007). The specific combining ability (SCA) effects were significant or highly significant in the twenty hybrids studied for the different agronomic traits, such as anthesis silking interval, plant height, ear heights, cobs per plant, cobs per plot, dehusked cobs and grain yield. The study revealed that hybrids with high SCA effects involved at least one or two of the several higher general combiners as parent namely: the IITA (OPVs) and EX-DAMBOA WHITE. Gama *et al.* (1995) and Kadams *et al*. (1999) reported similar result where a hybrid with high SCA effects involved one or both of the good general combiners as parents.

Hybrids EVDT-99WSTRC0 x EX-DAMBOA WHITE and TZE-WDTSTRQPMCO x EX-DAMBOA WHITE expressed negative and significant SCA effects for days to 50% tasseling, days to 50% silking, plant height and ear height. 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 anthesis silking interval, EVDT-99WSTRC0 x EX-DAMBOA WHITE and TZECOMP$_3$DTC$_1$ x EX-DAMBOA WHITE had the highest positive and significant SCA effects. Anthesis silking interval 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) and Paul and Debenth (1999).

Seventeen hybrids expressed significant SCA effect for plant height and ear height. However, nine and eight of them expressed negative and significant SCA effects with TZE-WDTSTRQPMC0 x EX-DAMBOA YELLOW had the highest negative and significant SCA effects for both plant height and ear height. Negative plant height and ear height are desirable especially in drought prone and windy areas against drought and lodging (Sodangi *et al*., 2011 and Aminu and Izge, 2013).

For 100-seed weight, hybrid EVDT-W99STRQPMCO x EX-DAMBOA WHITE and EVDT-W99STRQPMCO x EX-DAMBOA YELLOW had the highest positive and significant SCA effects. Variation among the hybrids in 100seed weight, could be ascribed to the impairment of many important metabolic and physiological processes in plants during moisture stress. Similar results have been reported by Ahmed-Amal and Mekki (2005). Hybrids EVDT-99WSTRC0 x EX-DAMBOA WHITE, TZE-WDTSTRQPMC0 x EX-DAMBOA YELLOW, EVDT-W99STRQPMCO x EX-DAMBOA WHITE, EVDT-W99STRQPMCO x EX-DAMBOA YELLOW 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 hybrid varieties, as well as for inclusion in breeding programmes, 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 Joshi *et al*. (1998) who reported that maize grain yield and flowering traits were under the control of non-additive (SCA effects) type of gene action.

Heterosis

Percentages of heterosis for twelve agronomic traits in maize across locations in 2009 for yield and yield components 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. Farshad *et al.* (2008) and Aminu and Izge (2013) reported significant and positive level of heterosis for 1000 seed weight and grain yield for these traits in maize. The negative heterosis recorded for traits like days to 50% tasseling, days to 50% silking, plant height and ear height are desirable in breeding for earliness and short stature hybrids that could resist lodging particularly in windy environment like the study areas. But for the rest of the traits positive heterosis were more desirable. Hybrids EVDT-99WSTRC0 x EX-BIU YELLOW, EVDT-99WSTRQPMC0 x EX-BIU YELLOW and BG97TZECOMP$_{3x4}$ x EX-BIU YELLOW expressed positive and significant higher parent heterosis for number of stands per plot. For days to 50% tasseling and days to 50% silking, hybrids EVDT-99WSTRC0 x EX-BIU WHITE, TZE-WDTSTRQPMC0 x EX-DAMBOA YELLOW, TZE-WDTSTRQPMC0 x EX-BIU YELLOW and TZE-COMP$_3$DTC$_1$ x EX-BIU YELLOW expressed high negative and significant higher parent heterosis. In respect to anthesis silking interval, TZE-WDTSTRQPMC0 x EX-BIU WHITE, EVDT-99WSTRQPMC0 x EX-DAMBOA YELLOW and EVDT-99WSTRQPMC0 x EX-BIU YELLOW has the highest positive and significant level of higher parent heterosis. These traits could be recommended for environment with low and erratic rainfall, because it is one of the drought tolerant traits. This result is in agreement with that of Izge *et al.* (2007).

This study indicated tremendous level of higher parent heterosis in grain yield. EVDT-99WSTRC0 x EX-BIU YELLOW, TZE-WDTSTRQPMC0 x EX-BIU WHITE, TZE-WDTSTRQPMC0 x EX-BIU WHITE and EVD-99WSTRQPMC0 x EX-DAMBOA 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.

These hybrids which featured prominently in the expression of higher level heterosis could form an initial gene pool for further breeding programme in developing high yielding varieties for cultivation in the Nigerian savannas. These results are in line with earlier independent studies of Kumar *et al.* (1988), Joshi *et al.* (1998), Perez-Velasquez *et al.* (1996), Bello and Olaoye (2009) and Aminu and Izge (2013) who reported that maize grain yield and flowering traits were under the control of non-additive (SCA effect) type of gene action.

IV. Conclusion

The present study identified parents: EVDT-99WSTRC0, TZE-WDTSTRQPMC0 and EX-DAMBOA WHITE as the best general combiners among the nine parents. The study also identified the following hybrids: EVDT-99WSTRC0 x EX-BIU YELLOW, TZE-WDTSTRQPMC0 x EX-BIU WHITE, TZE-WDTSTRQPMC0 x EX-BIU WHITE and EVD-99WSTRQPMC0 x EX-DAMBOA YELLOW as the best among the 20 hybrids evaluated across locations since they have the best level of high parent heterosis in days to 50% tasseling, days to 50% silking, anthesis silking interval, weight of cobs dehusked cobs and grain yield. The desirable heterotic levels in days to 50% tasseling, days to 50% silking, anthesis silking interval and plant height are desirable in areas with marginal rainfalls and windy environment like the study areas.

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Table 1: Combining ability analysis of variance for twelve agronomic traits in maize at Biu and Damboa in 2009 combined locations

Source of variation	DF	NSP	DTT	DTS	ASI	PH	EHT	NCPL	NCPT	WC	DC	HSW	GRY
Line	4	17.946	54.096*	65.417*	1.67\88*	1024.323	987.337	1.718*	163.883*	2105611.250*	1750555.417	17.752	1009754.656*
Tester	3	165.722*	378.022*	259.856**	5.278**	3238.359**	1157.178*	16.228**	5131.533**	124792521.11*	109973069.722**	558.291**	36236016.713**
Line x Tester	12	83.118	17.779	25.022	1.349*	682.965	350.997	0.529	122.422*	2358519.028**	2243812.083*	17.055	1122977.870*
Error	56	55.519	24.48	26.744	0.713	588.084	517.323	0.582	61.793	1001491.759	1023515.304	10.693	505390.377
Variance Component Estimates													
Line		-2.716	1.096	0.850	-0.036	14.223	26.514	0.008	-0.773	-10537.824	-20552.361	0.029	-4717.634
Tester		2.754	12.008	7.828	0.124	85.180	26.873	0.523	166.970	4081133.403	3590975.255	18.041	1170434.628
δ²gca		0.010	0.911	0.604	0.06	6.937	3.813	0.037	11.485	281329.013	246708.715	1.249	80557.776
δ²sca		5.578	19.460	12.289	0.293	169.807	48.610	0.837	275.874	6732680.771	5914229.692	29.919	1966807.675
δ²gca/sca		0.002	0.047	0.045	0.205	0.041	0.078	0.044	0.042	0.042	0.417	0.042	0.041
Proportional contribution to total variance													
Line		31.74	14.00	23.80	42.60	44.14	29.84	10.97	8.50	6.88	7.40	10.49	10.68
Tester		4.58	11.58	23.80	7.40	18.64	33.95	4.96	2.40	2.05	1.92	3.64	3.20
Line x Tester		63.68	74.42	61.80	50.00	37.24	36.21	84.07	89.09	91.07	90.68	85.87	86.12
GCA (Line + Tester)		36.32	25.58	38.20	50.00	62.76	63.83	15.93	10.764	8.93	9.32	14.13	13.88
GCA/SCA		0.570	0.344	0.618	1.00	1.685	1.763	0.190	0.122	0.098	0.103	0.156	0.161

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 at Biu and Damboa in 2009 combined locations

Lines entries	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPLT	WC	DC	HSW	GRY
EVDT-W99STR CO	5.183	-7.450**	-5.533*	-0.150	18.375*	17.152*	0.395	27.117**	4544.850**	4303.683**	7.525**	2559.483**
TZE-WDTSTRQPM CO	5.183	-7.617**	-5.367*	-0.567	19.342*	8.735	0.320	27.867**	4574.850**	4308.683**	7.192**	2405.241**
EVDT-W99STRQPM CO	-1.150	-2.867	-3.533	-1.567*	1.442	-10.523	-1.455*	-0.300	-407.650	-395.483	0.267	-176.880
TZE-COMP$_3$DTC$_1$	-3.65	12.133**	9.633**	4.433**	-15.492	-0.023	3.122**	-25.050	-4718.567**	-4489.733**	-4.642**	-2378.236**
BG 97 TZECOMP$_{3x4}$	-5.567	5.800*	4.800*	-2.150**	-23.667*	-15.340	-2.372**	-29.633**	-3993.483**	-3727.150**	-9.808**	-2409.608**
SE±	2.48	1.64	1.72	0.28	8.08	7.28	0.26	2.62	333.58	337.23	1.09	236.97
Testers Entries												
EX-DAMBOA WHITE	3.133	-1.150	-1.867	4.267**	-5.737	0.047	4.262**	6.833*	941.117**	947.283*	4.292**	1422.023**
EX-DAMBOA YELLOW	4.000	0.050	0.200	-1.067	22.777**	20.533*	-1.245*	4.683	482.517	486.683	-0.108	270.526
EX-BIU WHITE	-3.800	-0.217	-0.333	-2.000*	-19.237*	-14.160	-1.645*	-5.317*	-404.817	-441.983	-1.875	-203.365
EX-BIU YELLOW	-3.333	1.317	2.000	-1.200*	2.197	-6.420	-1.372*	-6.250*	-1018.817**	-991.983**	-2.308*	-14389.183**
SE±	2.15	1.42	1.49	0.24	7.00	6.57	0.22	2.27	288.89	292.05	0.94	205.22

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

Table 3: Estimate of specific combining ability effect for twelve agronomic traits in maize, Biu and Damboa in 2009 combined locations

Hybrids Entries	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
EVDT-W99STRCO x EX-DAMBOA WHITE	9.283*	-4.683	-5.467*	8.517*	-25.522*	-25.005*	4.595*	-4.717	534.253 -	493.54 -	4.125*	2084.750*
EX-DAMBOA YELLOW	-6.250	2.450	2.800	2.150	-18.702	-14.358	1.045	-1.850	1270.850	1318.350*	0.725	-873.859*
EX-BIU WHITE	-0.783	4.717	4.667	1.750	28.245*	24.202*	2.645	-1.850	609.817	500.317	1.375	795.183
EX-BIU YELLOW	3.750	-2.483	-2.000	0.617	5.978	15.162	1.905	8.417	1290.483*	1203.650	3.475	163.426
TZE-WDTSTRQPMCO x EX-DAMBOA WHITE	-3.717	-1.183	-0.633	-4.433*	-2.222	29.912*	-4.520*	-12.800*	-1506.117	-1767.283*	-5.792*	-1083.235**
EX-DAMBOA YELLOW	-2.583	-1.383	-1.700	1.900	-50.33**	-37.275*	2.520	7.583	883.233	603.733	2.608	2103.414*
EX-BIU WHITE	3.883	-1.450	-1.500	0.500	27.345*	-14.615	1.520	11.400*	1436.483*	1658.650*	2.708	1081.547*
EX-BIU YELLOW	2.417	4.017	3.833	2.033	25.212*	28.978*	1.480	9.333	313.817	168.650	0.475	-101.726
EVDT-W99STRQPMCO x EX-DAMBOA WHITE	-8.983*	-7.933*	-6.800*	-2.100	17.912	-8.363	-2.145	15.033*	3606.383*	3476.883**	7.333**	2240.705**
EX-DAMBOA YELLOW	3.417	-9.133*	-8.867*	0.900	25.032*	-2.583	4.628*	23.900**	2834.983*	2637.483**	6.900**	1850.595**
EX-BIU WHITE	-5.783	6.133*	6.000	0.500	-37.688*	-6.023	2.162	-16.100*	-3037.683**	-2893.850**	-3.833	-1983.605**
EX-BIU YELLOW	10.750*	10.933*	9.667*	0.700	-5.255	9.970	-0.645	-22.833**	-3403.683*	-3220.517**	-10.400**	-2108.695**
TZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE	10.,450**	11.733*	11.367	7.233**	-5.388	28.003*	5.022*	-0.550	1456.367*	-1205.867	8.708*	-927.970*
EX-DAMBOA YELLOW	2.917	1.200	0.967	-5.433*	11.732	0.583	-5.338*	-6.017	-727.433	-721.600	-5.558*	-875.776*
EX-BIU WHITE	-4.950	-5.533	-5.500	-4.833*	20.645	3.143	-5.405*	-1.017	-244.183	-60.017	-4.458*	2002.855**
EX-BIU YELLOW	-13.417*	-7.400	-6.833	-4.967*	-21.988	-31.730*	-4.278*	-7.933	1360.567*	1323.733	1.308	1806.600**
BG97TZECOMPO$_{3X4}$ x EX-DAMBOA WHITE	-9.633*	2.067	1.533	-4.183*	5.220	-11.547	-3.762	3.033	-14.450	-118.117	-6.125*	-144.750
EX-DAMBOA YELLOW	2.500	6.867*	6.800	0.483	32.273*	33.638*	-2.145	-8.100	-592.517	-537.517	-3.225	-205.374
EX-BIU WHITE	9.633*	-3.867	-3.667	2.083	-33.547*	-6.707	-2.078	7.567	131.150	102.501	-4.208*	109.729
EX-BIU YELLOW	-3.500	-5.067	-4.667	1.617	-3.947	-15.380	1.538	-2.500	-629.450	-524.483	5.142*	-2240.39**
SE±	4.30	2.84	1.99	1.49	12.00	11.13	1.44	4.54	584.10	491.01	1.89	410.44

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

Table 4: Heterosis of the hybrids over the parents for twelve agronomic traits in maize at Biu and Damboa in 2009 combined locations

Hybrids Entries	NSP	DTT	DTS	ASI	PHT	EHT	NCPL	NCPT	WC	DC	HSW	GRY
EVDT-W99STRCO x EX-DAMBOA WHITE	-20.23	2.48	1.41	-21.74	14.59	8.35	-5.45	-15.79	-18.12	-18.87	-1.00	9.67
EX-DAMBOA YELLOW	-10.98	-18.49	-16.54	-13.04	-0.38	-30.33	-2.60	-8.91	12.42	14.84	-4.44	34.20
EX-BIU WHITE	5.04	-20.88	-16.94	4.35	-0.71	-8.03	-9.1	-11.46	29.93	35.70	-5.56	40.72
EX-BIU YELLOW	8.15	-15.57	-10.31	13.04	-3.93	-5.22	-8.60	-15.94	40.70	48.11	-2.22	48.64
TZE-WDTSTRQPMCO x EX-DAMBOA WHITE	-20.23	-12.46	-10.34	-10.00	-12.73	-30.40	-3.77	-39.02	-28.06	-31.74	-8.25	-15.54
EX-DAMBOA YELLOW	-7.98	-21.57	-18.35	10.00	14.15	-9.31	-11.50	-11.46	29.78	35.15	-3.61	29.45
EX-BIU WHITE	-6.55	-16.71	-11.14	33.33	4.73	9.78	-9.22	-11.95	32.71	38.00	-1.24	49.18
EX-BIU YELLOW	-2.85	-20.40	-14.85	-5.00	16.26	-9.56	-13.26	-11.95	44.51	56.75	5.36	51.89
EVDT-W99STRQPMCO x EX-DAMBOA WHITE	-6.07	3.88	3.60	5.00	15.20	4.52	-8.81	-13.16	-26.82	-3.56	-2.72	42.00
EX-DAMBOA YELLOW	-6.23	-19.61	-15.50	30.00	13.23	6.64	-15.64	-17.05	-57.42	6.26	-0.18	57.90
EX-BIU WHITE	-4.75	-11.76	-7.38	14.29	13.56	29.89	-7.44	-12.68	36.74	37.15	2.35	-4.43
EX-BIU YELLOW	8.68	-9.85	-4.71	30.00	19.64	22.07	-12.63	-19.21	36.85	45.14	1.14	-22.63
TZE-COMP$_3$DTC$_1$ x EX-DAMBOA WHITE	1.45	-4.26	-1.85	-34.78	-0.10	-1.85	-7.55	-18.42	-6.33	-3.72	-2.25	-23.64
EX-DAMBOA YELLOW	-6.82	-19.33	-17.57	0.00	8.15	-13.01	-11.73	-16.72	-46.68	36.25	0.52	-9.73
EX-BIU WHITE	-0.30	-19.60	-13.76	0.00	9.72	13.00	-9.10	-14.23	37.01	38.38	-8.24	-9.84
EX-BIU YELLOW	-1.61	-22.44	-19.05	17.39	7.28	-16.85	16.94	18.52	-38.04	14.10	1.59	-6.86
BG97TZECOMP$_{3X4}$ x EX-DAMBOA WHITE	-13.29	-3.11	-1.70	10.00	-11.74	-23.31	-24.60	11.32	-25.56	-6.56	5.26	-2.02
EX-DAMBOA YELLOW	0.00	-18.77	-13.70	25.00	12.19	-0.30	6.25	10.18	-18.85	9.33	-4.42	-5.37
EX-BIU WHITE	0.59	17.94	-12.84	9.52	4.35	14.30	5.98	6.60	-20.94	34.36	4-05	-6.65
EX-BIU YELLOW	10.61	18.26	-14.76	0.00	16.92	1.18	7.00	6.22	17.78	7.44	-4.68	14.32

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