

## HETEROSIS OF SOME TROPICAL MAIZE GENOTYPES DERIVED FROM TWO DIFFERENT MAIZE BREEDING ERAS

Ige Ayodele Sunday

Landmark University, Omuaran, Nigeria

Corresponding author: [ige.sunday@lmu.edu.ng](mailto:ige.sunday@lmu.edu.ng)

### Abstract

Heterosis for maize grain yield was studied to identify cross combinations that may be useful sources for inbred line extraction, recurrent selection and, to estimate changes in the maize grain yield heterosis across two breeding eras in the tropics. Field studies were conducted at the International Institute of Tropical Agriculture (IITA), Ibadan during the cropping seasons of 2010, 2011 and 2012, with 10 open pollinated maize varieties (OPVs) derived two breeding eras (1 and 2). The ten OPVs and the crosses generated from them were evaluated under stem borer infested and non-infested, high-N versus low-N and natural conditions. Mid and High-heterosis (MPH and HPH) were estimated from grain yield data from the tested environments. MPH and HPH under natural, optimum N-Fertilizer application, and borer infested environments were 37.20 and 25.38%, 19.85 and 12.3%, 30.98 and 18.94% respectively. Cross combination DMR-LSR-W (Era 1) x TZSR-Y-I (Era 1) expressed the highest magnitude of (MPH & HPH) (97.70 and 87.15%) for grain yield across the tested environments except low-N. It suggest the suitability of the hybrid for cultivation only in environments with high productivity index. Hybrid ACR99TZLCOMP4-DMRSR (Era 1) x BR9928DMRSR (Era 2) had highest HPH under low-N environments. This combination could be used as a good source of genes for the development of low nitrogen tolerance maize varieties in the tropics. Cross combinations that expressed better (HPH) under borer infestation are good gene pools for the development of stem borer tolerance maize varieties in stem borer endemic zone. These crosses hold promise as future candidates for commercial exploitation of heterosis or for the extraction of inbred lines in the tropics. Better (HPH) were derived from the crosses between Era 1 and & 2, indicates the older and newer maize varieties complement each other for (HPH) across environments.

### Key words:

### Introduction

An important aspect of hybrid maize breeding programme is the extraction of an elite group of inbred lines or identification of specific set of lines that maximize expression of heterosis in hybrid combinations. The concept of heterosis in maize improvement began with the studies reported by Shull (1908). Heterosis and hybrid vigour are nearly synonymous. In quantitative genetic terminology, heterosis is interpreted as the superiority of a hybrid or  $F_1$  over the mean of its parents, which is referred to as the mid-parent (MP) heterosis or superiority of the  $F_1$  or hybrid over the better parent which is referred to as high-parent (HP) or better parent (BP) heterosis. In practical plant breeding, the superiority of  $F_1$  over the mid-parent is not utilizable, because it does not offer the hybrid any advantage over the better parent. However, the commercial usefulness of a hybrid would also depend on its performance in comparison to the best commercial variety, referred to as economic heterosis. The development of hybrid combinations with high heterosis can be achieved through identification of good progenitors, or parents with desirable agronomic traits, and high general and specific combining ability. This has necessitated the grouping of various germplasms into distinct

heterotic groups. Various heterotic pairs have been identified in various parts of the world for the development of hybrid combinations with high heterosis.

In an attempt to identify appropriate heterotic combination to maximize vigour in hybrids, Kim and Ajala, (1996) conducted an experiment to study the combining ability for grain yield and agronomic traits of some tropical versus tropical x temperate inbred lines of maize in the forest and savanna zones of West Africa. Forty-five F<sub>1</sub> hybrids generated from crosses involving five tropical inbred lines and another five from temperate x tropical origin, were evaluated in each of the three environments of first and second seasons in the forest ecology of Ikenne and the third planting in the northern Guinea savanna ecology of Samaru in 1985 and 1986. Result from the study showed that for the forest ecology, yield of crosses made from tropical maize inbred lines (Tropical x Tropical) were significantly higher than those of tropical versus Temperate x Tropical maize inbred lines. Conversely, crosses between tropical and Temperate x Tropical maize inbred lines performed better in savanna environments than Tropical x Tropical cross which in turn showed superiority over those of temperate x temperate crosses. The authors succeeded in identifying a white grain tropical versus temperate x tropical cross as the best hybrid for the savanna ecologies of West Africa which was eventually released with commercial hybrid name (Oba Super1).

In another experiment conducted by Han *et al.*, (1991) to examine the combining ability effects of inbred lines derived from maize population at CIMMYT. Fifty S<sub>3</sub> lines selected from different populations based on *per se* performance were divided into six sets to make six diallel crosses. Each diallel included 8 to 11 lines derived from 2 or 3 populations and crosses in each diallel set were evaluated in 3 to 4 locations during the 1986 and 1987 growing seasons. The results from the study showed that inter-population crosses were superior by between 4 and 16 percentage (%) over the intra-population crosses for grain yield. The authors also observed that while means of all inter-population crosses had positive SCA estimates, the intra-population line crosses gave negative SCA estimates for grain yield. The authors therefore concluded that on the average, inter-population crosses expressed greater heterosis for grain yield than intra-population crosses. This study was therefore carried out (i) to assess the heterosis of maize for grain yield in two breeding eras in order to identify the possible changes in maize grain yield heterosis across the two breeding eras. (ii) to compare cross combinations within and between maize breeding eras in order to determine which of them will produce higher grain yield heterosis.

## **MATERIALS AND METHOD**

The plant materials used in this study comprised 10 open-pollinated varieties (OPVs) of maize which were developed for grain yield and adaptation to biotic and abiotic stress factors at the International Institute of Tropical Agriculture (IITA), Ibadan. They are late maturing white or yellow grained cultivars with maturity period of approximately 120 days. The characteristics of the 10 maize varieties are presented in Table 1. The materials were released in two different breeding Eras. Those varieties that were released and released before year 2000 were classified as belonging to the first era (Era1), while those that were released in year 2000 and above were considered as belonging to the second Era (Era 2).

The ten open-pollinated varieties were crossed in a partial diallel fashion to generate 45 F<sub>1</sub> hybrids during the 2011 cropping season at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The resultant hybrids were harvested, processed,

fumigated and stored in the cold room prior to field evaluation. The 45 F<sub>1</sub> hybrids, the ten parents were evaluated in eight environments in August, 2012. The first two environments were under artificial infestation with stem borer versus uninfested conditions, located at the IITA, Ibadan ( Latitude 7<sup>o</sup> 22<sup>1</sup>N, longitude 3<sup>o</sup> 58<sup>1</sup>E), while two other environments viz: Ikenne (Latitude 6<sup>o</sup> 53<sup>1</sup>N, Longitude 3<sup>o</sup> 42<sup>1</sup>E) and Ile-Ife ( Latitude 7<sup>o</sup> 18<sup>1</sup>N, Longitude 4<sup>o</sup> 33<sup>1</sup>E) (rain forest region) were regarded as stress-free environments. Mokwa ( Latitude 9<sup>o</sup> 18<sup>1</sup>N, Longitude 5<sup>o</sup> 4<sup>1</sup>E) and Zaria (Latitude 12<sup>o</sup> 00<sup>1</sup>N, Longitude 8<sup>o</sup> 22<sup>1</sup>E) (Guinea savanna) which were the last four for Nitrogen (N) study where the genetic materials were evaluated under high and low N conditions respectively. In all evaluations, two row plots were used. Each row was 6m in length, spaced at 0.75m between rows 0.25m within rows with four replications to give a population density of approximately 53,333 plants per hectare. Observed cultural practices included pre-emergence spray of gramoxone and primextra for weed control supplemented with hand weeding as necessary during the season. Fertilizer was also split applied using N-P-K 15:15:15 at 10 days after planting (DAP) at the rate of 30 kg N/ha and top dressed with urea six WAP at the same rate. However, the four locations at Mokwa and Zaria were the low and high-N environment with two different levels of nitrogen application (30kgha<sup>-1</sup> and 90kgha<sup>-1</sup>) respectively. Trials at Ibadan were separated into two equal halves of 3m with a space of 1m in the middle. One half of each row was artificially infested with egg masses of *Sesamiacalamists* at three weeks after emergence while the other half was not infested. Similarly, one half of the same trials previously infested with *Sesamia* was again infested at flowering stage with egg masses of *Eldanasacharina* while the second half remained uninfested. Larvae of *Sesamiacalamists* cause damage to maize plants by feeding on the leaves of young plants, causing deadheart if the growing point is destroyed. Stem tunneling also occurs when the larvae continue their feeding activities within the stem. Larvae of *Eldanasacharina* will usually attack maize after flowering, causing damage to the cobs and cause stalk breakage. The ten open-pollinated varieties were crossed in a partial diallel fashion to generate 45 F<sub>1</sub> hybrids while S<sub>1</sub> progenies were also generated by selfing 35-50 plants in each population during the 2011 cropping season at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Mid-Parent heterosis (MP) was measured as the superiority of the hybrid over the mean of its parents. High-Parent heterosis (HP) or Better-Parent heterosis (BP) was measured as the superiority of the hybrid over the better parent. Mid -Parent (MP) and high-parent (HP) heterosis were estimated as follows:

$$\text{MP Heterosis} = 100 [(F_1 - \text{MP}) / \text{MP}]$$

$$\text{HP Heterosis} = 100 [(F_1 - \text{HP}) / \text{HP}]$$

## RESULTS

Table 1 showed the mid- and high-parent heterosis for grain yield under stressed free environments. Highest and positive mid- and high-parent heterosis (67.87% and 63.49%) for grain yield were exhibited by hybrid DMR-LSR-Y (era1) x BR9928DMRSR (Era 2) under stress free environment, while hybrids BR9922DMRSR x TZBRELD.4C<sub>0</sub>W and ACR99T2LCOMP4-DMRSR x DMR-LSR-Y had the least positive mid- and high-parent heterosis (2.67% and 0.98%) for grain yield respectively under the same environment. Highest but negative mid- and high-parent heterosis (-19.81% and -23.75%) were observed in hybrids DMR-LSR-W x TZSR-Y-1 and BR9922DMRSR x TZSR-W-1 respectively under stress-free environment.

**Table 1. Mid-Parent heterosis (Upper diagonal) and high-Parent heterosis (lower diagonal) for Optimum environment at Ife and Ikenne, 2012**

	TZSR-W-1	DMR-	DMR-	TZSR-Y-1	ACR9922TZ	BR9922	BR9928	BR9943	AMATZBR-WC2B	TZBRELD
		LSR-W	LSR-Y		LCOMP4-DMRSR	DMRSR	DMRSR	DMRSR		.4C <sub>0</sub> -W
TZSR-W-1	–	27.5	40.63	24.34	18.86	-7.4	67.17	42.06	12.45	29.71
DMR-LSR-W	18.16	–	-7.68	-19.82	-11.16	18.45	19.95	-0.14	-11.32	22.85
DMR-LSR-Y	33.29	17.6	–	53.89	26.22	-2.32	67.87	55.35	17.49	16.53
TZSR-Y-1	22.54	17.88	43.86	–	27.85	10.86	37.52	37.37	11.73	28.44
ACR99TZLCO										
MP4-DMRSR	-0.75	-5.05	0.98	8.04	–	-7.46	34.7	16.92	-5.92	10.54
BR9922DMRSR	-23.73	5.72	-22.85	-7.61	-9.03	–	20.56	19.1	37.57	2.67
BR9928DMRSR	62.8	34.35	63.24	32.04	10.11	-2.74	–	55.4	-3.01	13.65
BR9943DMRSR	32.44	42.24	37.81	29.84	3.77	4.14	31.03	–	16.9	7.68
AMATZBR-WC2B	-4.33	-6.54	-4.34	-3.77	35.55	32.25	24.06	10.88	–	0.59
TZBRELD.4C0W	11.33	19.7	-4.35	11.61	6.95	-2.29	-4.59	5.31	-0.46	–

**Table 2. Mid-Parent heterosis (upper diagonal) and high-parent heterosis (lower diagonal) for Low-N environment at Mokwa and Zaria, 2012**

	TZSR-W-1	DMR-LSR-W	DMR-LSR-Y	TZSR-Y-1	ACR9922TZ LCOMP4-DMRSR	BR9922DMRSR	BR9928DMRSR	BR9943DMRSR	AMATZBR-WC2B	TZBRELD .4C0-W
TZSR-W-1	–	-0.46	9.40	9.58	19.51	-9.03	53.71	21.55	26.36	11.9
DMR-LSR-W	-2.76	–	14.91	9.26	22.79	23.62	75.97	24.82	8.96	11.45
DMR-LSR-Y	5.29	13.17	–	30.53	23.79	19.03	37.28	16.65	2.85	24.85
TZSRY1	7.74	4.99	23.6	–	61.05	4.40	33.25	50.17	31.1	17.57
ACR99TZLCOMP4-DMRSR	11.5	17.2	19.92	48.01	–	20.03	70.41	34.06	45.28	23.25
BR9922DMRSR	-4.56	15.48	9.63	1.38	7.39	–	52.88	15.56	28.99	68.28
BR9928DMRSR	34.16	56.77	53.78	14.64	55.48	12.25	–	55.55	56.17	42.17
BR9943DMRSR	8.9	14.24	26.44	32.56	28.25	-12.72	51.01	–	37.21	40.91
AMATZBR-WC2B	20.71	1.79	-5.27	27.31	40.23	15.41	31.1	18.07	–	31.49
TZBRELD.4C0W	10.92	9.81	21.18	14.61	16.00	41.71	36.5	27.23	24.57	–

Mid-and high-parent heterosis across Low-N environment are present in Table 2. The most positive percentages of mid-and high-parent heterosis (75.97% and 56.77%) were observed in hybrids DMR-LSR-W (Era 1) x BR9928DMRSR (Era 2) across low-N environment. However, hybrids DMR-LSR-Y (Era 1) x AMATZBR-WCZB (Era 2) and BR9922DMRSR (Era 2) x TZSR-Y-1 (Era 1) exhibited the least positive mid-and high-parent heterosis for grain yield under the same environments. Meanwhile, the highest negative mid-and high-parent heterosis (-9.03 and -12.72) were recorded by hybrids TZSR-W-1 (Era 1) x BR9922DMRSR (Era 2) and BR9943 DMRSR (Era 2) x BR9922DMRSR (Era 2).

Table 3: showed the mid-and high-parent heterosis for high-N environment. The most positive values of mid-and high-parent heterosis (97.7 and 87.15%) was manifested by hybrid. DMR-LSRW (Era 1) x TZSR-Y-1 (Era 1) under high-N environment. However, the lowest positive percentages of mid-and high-parent heterosis (0.16% and 1.5%) were recorded by hybrids ACR9922TZLCOMP-DMRSR x TZBRELD.4.C0W and TZBRELD.4.C0W x BR 9943 DMRSR under high-N environment. Hybrids DMRLSR-W (Era 1) x AMATZBR-WC2B(Era 2) recorded the highest negative percentages of mid-and high-parent heterosis (-14.96 and -27.81) under low-N environment.

Mid-and high parent heterosis for grain yield under stem borer infested environment are presented in Table 4. The highest percentages of mid- and high-heterosis (82.62 % and 60.16%) for grain yield were observed in hybrids TZSR-Y-1 x BR9928DMRSR under stem borer infested environment. The least positive values of mid-and high-parent heterosis (6.29% and 0.31%) for grain yield were recorded by DMR-LSR-Y x TZSR-Y-1 and DMR4SR-W x TZBRELD.4C<sub>0</sub>W respectively under the same environment. The most negative values of mid-and high parent heterosis (-20.49% and -23.095) for grain yield were recorded by TZSR-Y-1 x AMATZBR-WC2B under stem borer infested environment.

## DISCUSSION

Heterosis for grain yield being the most important economic traits of maize was studied in other to identify populations that may be useful sources for inbred line extraction and base populations for recurrent selection. According to Robinson *et al.* (1965), greater success should be expected when inbred lines are developed from populations which show substantial heterosis in crosses. Under Low-N condition, mid and high parent heterosis for grain yield were 29.14 and 19.81% respectively, which is similar to values obtained by Fakorede (1984), who reported 35 and 19% for grain yield mid and high-parent heterosis in the study conducted in 20 different stress-free environments in Nigeria. Furthermore, mid and high-parent heterosis for hybrids under high, stress free, optimum N-Fertilizer and borer infested environments were 37.20 and 25.38%, 19.85 and 12.3%, 30.98 and 18.94% respectively. These results except values obtained under optimum N condition still fell within the same range with the earlier report by Fakorede (1984). Cross combination DMR-LSR-W (Era 1) x TZSR-Y-I(Era 2) expressed the highest magnitude of mid and high-parent heterosis (97.70 and 87.15%) for grain yield under high-N and across the other four test environments. However, the same hybrid expressed very low mid and high-parent heterosis (9.26 and 4.99%) under low-N environment, which suggest that the suitability of the hybrid for cultivation only in environments with high productivity index.

**Table 3. Mid-Parent heterosis (upper diagonal) and high-parent heterosis (lower diagonal) for high-N environment at Mokwa and Zaria, 2012**

	TZSR-W-1	DMR-LSR-W	DMR-LSR-Y	TZSR-Y-1	ACR992TZ LCOMP4-DMRSR	BR9922DMRSR	BR9928DMRSR	BR9943DMRSR	AMATZBR-WC2B	TZBRELD .4C0-W
TZSR-W-1	–	24.6	51.15	41.19	3.98	3.52	56.24	59.01	7.49	19.12
DMR-LSR-W	20.7	–	53.59	97.7	27.91	42.27	71.18	61.57	-14.96	42.73
DMR-LSR-Y	48.79	51.11	–	52.61	21.97	9.68	70.67	15.76	6.36	20.92
TZSR-Y-1	29.72	87.15	42.27	–	39.87	50.24	77.1	47.06	40.39	17.02
ACR99TZ LCOMP4-DMRSR	-3.77	14.99	11.27	19.7	–	32.12	60.5	38.48	31.42	0.16
BR9922DMRSR	-2.81	26.42	-1.12	27.28	30.41	–	46.3	46.04	9.35	47.85
BR9928DMRSR	38.18	55.78	53.05	69.83	32.76	19.77	–	96.47	30.01	8.41
BR9943DMRSR	53.9	51.65	10.34	31.15	32.22	37.72	68.89	–	16.28	11.65
AMATZBR-WC2B	-6.26	-27.81	26.95	13.95	-3.75	3.75	2.19	4.38	–	40.7
TZBRELD.4C0W	5.15	22.58	5.29	-3.98	-4.87	42.15	13.65	1.5	42.7	–

**Table 4. Mid-Parent heterosis (Upper diagonal) and high-parent heterosis (lower diagonal) for borer infestation environment at Ibadan, 2012**

	TZSR-W-1	DMR-LSR-W	DMR-LSR-Y	TZSR-Y-1	ACR9922TZLCOMP4-DMRSR	BR9922DMRSR	BR9928DMRSR	BR9943DMRSR	AMATZBRWC2B	TZBRELD
	TZSR-W-1									.4C0-W
TZSR-W-1	–	19.69	54.15	12.54	63.55	21.02	44.3	42.9	23.53	64.9
DMR-LSR-W	0.31	–	28.23	25.09	28.82	-3.52	53.2	27.27	-7.48	13.53
DMR-LSR-Y	38.95	-1.08	–	6.29	29.87	14.28	43.24	10.49	70.16	53.82
TZSR-Y-1	-4.82	23.71	-17.36	–	15.79	26.33	82.62	40.72	-20.49	-6.34
ACR99TZLCOMP4-DMRSR	49.55	16.97	8.13	6.22	–	32.34	49.32	37.00	35.55	16.05
BR9922DMRSR	4.07	-6.45	-9.83	23.84	23.66	–	58.11	26.18	20.62	34.75
BR9928DMRSR	38.33	33.08	24.34	60.16	42.11	41.11	–	31.03	24.06	-5.76
BR9943DMRSR	29.9	16.24	-8.48	29.84	36.12	18.61	23.95	–	62.26	33.53
AMATZBRWC2B	7.48	-11.48	35.63	-23.09	28.31	18.97	12.09	54.54	–	36.39
TZBRELD.4C0W	52.52	1.95	29.36	-15.05	14.62	24.47	-9.23	36.11	45.78	–



Betran *et al.* (2003) in a study conducted to determine relationship between genetic diversity and heterosis in tropical maize under stress environment, observed that SCA had the strongest correlation with genetic diversity, and that the environment significantly affected the correlation between  $F_1$ , SCA, mid- and high-parent heterosis. In this study, cross combinations DMR-LSR-W (Era 1) x BR9928DMRSR (Era 2) and ACR99TZLCOMP4DMRSR (Era 1) x BR9928DMRSR (Era 2) under low-N, DMR-LSR-Y (Era 1) x BR9928DMRSR (Era 2) and BR9928DMRSR (Era 2) x BR9943DMRSR (Era 2) under stress-free condition and TZSR-Y-I (Era 1) x BR9928DMRSR (Era 2) and DMR-LSR-Y (Era 1) x AMATZBR-W2CB (Era 2) showed high heterosis over better parents for grain yield under borer infestation. Incidentally, these hybrids were derived mostly from crosses between Era 1 x Era 2 genotypes, which still show the extent of genetic diversity between the maize genotypes from the two breeding Eras. This result was in line with earlier findings of Moll *et al.* (1965) who reported that the heterosis manifested by crosses depends on genetic divergence of two parental varieties. Therefore, these crosses hold promise as future candidates for commercial exploitation of heterosis or for the extraction of inbred lines, to derive and isolate lines with gene combination for high grain yield. Moreover, the cross combinations DMR-LSR-W (Era 1) x BR9928DMRSR (Era 2) (under stress free), DMR-LSR-W (Era 1) x BR9928DMRSR (Era 2) (under low-N) and TZSR-Y-1 (Era 1) x BR9928DMRSR (Era 2) (under borer infested) that recorded excellent heterosis for grain yield could effectively be exploited in similar hybrid breeding programmes. As revealed in this study, in most cases inter-era cross combinations manifested better heterosis than cross combinations within maize breeding Eras. This is an indication that individual maize genotypes belonging to Eras 1 of maize breeding complement those in era two to produce better heterosis among the ten maize population. This also implies that changes in breeding objectives has also altered the magnitude of heterosis in newer maize varieties. Backcrossing to the older varieties is suggested for the restoration of original magnitude of heterosis in the modern maize varieties.

## CONCLUSION

Two hybrids DMR-LSR-Y (Era 1) x TZSR-Y-1 (Era 1) and DMR-LSR-W (Era 1) x BR9928DMRSR (Era 2) which expressed the highest magnitude of mid- and high-parent heterosis under high-N and stem borer infested conditions are good sources of genes for grain yield improvement programs, and could serve as base populations for future recurrent selection under adequate supply of nitrogen and in stem borer endemic environments. Moreover, the study revealed that the older maize varieties still appeared to complement the newer maize varieties to produce good maize grain yield heterosis.

## REFERENCES

- Fakorede, M.A. B. (1984). Concurrent population improvement and development of maize hybrids by recurrent selection. Paper presented at the inaugural Meeting of the Nationally Coordinated Maize Research Program 16-17 April, 1984. NCRI, badan
- Han, G.C., Vasal S.K., Beck D.L, and Elias, E. (1991) Combining ability of inbred lines derived from CIMMYT maize (*Zea mays* L.) germplasm. *Maydica*, 36: 57-64.
- Kim and Ajala, (1996)
- Moll, 1965

- Ojo, G.O.S., Adedzwa D.K. and Bello L.L, (2007). Combining ability estimates and heterosis for grain yield and yield components in maize (*Zea mays L*). *Journal of Sustainable Development in Agriculture and Environment* 3: 49-57.
- Robinson, H.F., Comstock R.E, Khalil, A., and P. H. Havey (1965). Dominance Versus Overdominance in heterosis: Evidence from crosses between open-pollinated varieties of maize. *American Naturalist* 9: 127-131.
- Shull, G. H (1908). The composition of field maize. *American Breeders Assoc. Rep.* 4: 296-301.