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RESEARCH ARTICLE

Studies on estimation of heterosis for striga resistance in maize test crosses in Mali

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Abstract

Heterosis for yield, secondary traits and *Striga* resistance was estimated in maize test crosses generated from fifteen inbred lines and three testers using line by tester analysis. Hybrids, testcrosses and parents were evaluated for two years at Agricultural Research Institute, Sotuba and Sanankoroba, to identify combinations expressing high hybrid vigor in Mali under *Striga- infested* and *Striga-free* conditions. Under *Striga-free* condition TZISTR106 /TZISTR1230, TZISTR106/TZISTR1223 and TZISTR1033/ TZISTR1223 appeared as the best hybrids combinations with respect to grain yield, while combinations TZISTR1207/ TZISTR1226, TZISTR106 /TZISTR112, TZISTR106 / TZISTR113 and TZISTR106/ TZISTR1028 showed positive mid parent heterosis for grain yield and negative mid parent heterosis for *Striga* related traits under *Striga* infestation. These hybrids are worthy for further utilization.

Key words: Heterosis, lattice design, genotypes, Striga related traits, maize.

Introduction

Maize occupied the second place with 28.27% after rice 31.36% in term of production in Mali l'Enquête Agricole de Conjoncture EAC, 2016/2017. The crop is now an important cereal in both rural and urban areas because of its economic profitability and its use in food and feed (60 to 70% of the poultry ration) conferred an important role in food security. The industrial use of maize represents another particularly important outlet. National companies canned, biscuits, but also batteries, pharmaceuticals or paint and beverages have significant needs for starch or corn flour. The total production is 8 964 829 tones, the area planted in maize in Mali from the last five years varied from 579 396 ha in 2013 to 1031 522 ha in 2017 according to EAC, 2017, this evolution indicates that maize have seen very high superficies' growth almost the double of the area planted in five years, while average yield remain almost static (2.35t/ha to 2.85t/ha) FAO, 2015. The demand for food and feed is increasing due to the development of poultry industry, the pisciculture and fattening cattle. To meet the increasing demand hybrid maize can be successfully used.

Out of the maize varieties grown, hybrids occupied 2.27% while OPV gained 97.5% **(**PLAN DE CAMPAGNE AGRICOLE CONSOLIDE ET HARMONISE 2018/ 2019**)**. Among these hybrid just few are resistant to *Striga hermonthica*. Heterosis has been exploited for hybrid production and it play an important role in achieving successful hybrid production. As reported by researchers, heterosis occurred in quantities in maize grain yield, plant height, ear height, days to maturity and 1000 seeds weight Coulibaly *et al.,* 2015. It is helful in identification of parental lines performance in hybrid combination. Little emphasis has been addressed to *Striga* resistance in heterosis study in maize in Mali. Heterosis in maize hybrids has been subjected to grain yield in drought prone area Coulibaly, 2013 but information on heterosis for *Striga* resistance traits in crosses between inbred lines with different patterns of *Striga hermonthica* is yet to be done. Therefore, the present study was undertaken to estimate the heterosis for grain yield, plant and ear height, days to maturity and *Striga* resistance traits in crosses using fifteen inbred lines and three testers in line by tester design.

Materials and methods

The experiment was carried out in the rainy season from 2014 to 2015 at Regional Centre for Agronomic Research (CRRA) station in Sotuba (12°39’47’’ North 7°54’50’’ West) and Sanankoroba (12° 23’51.67’’ North and 7° 56’22.10’’ West) in southern Mali. The hybrid trial was composed of 48 entries made up of forty five (45) experimental hybrids originated from a line by tester cross among the fifteen inbred lines and three inbred testers (TZSTRI106, TZSTRI1207 and TZSTRI1033) and two checks (Farako and Mata). The F_1 crosses, two checks and the parental lines were planted separately. The F_1 hybrids were planted in 6x8 alpha lattice design, while the parental lines were planted in randomize completed block design. The parental lines were all obtained from IITA and derived from various source populations. The list of fifteen inbred lines plus three inbred testers used in this study are described in table 1. The pedigree of these lines indicated the presence of *Zea diploperennis* an African landraces and elite tropical germplasm which contained an excellent source of resistance to *Striga hermonthica*. Seeds were sown in single row plot, 5 m long with spacing of 0.75 m between rows and 0.25 m between hills on the same row. Under both *Striga-infested* and *Striga-free* condition, all agronomic practices were kept constant except for hand weeding under *Striga-infested* condition for whole of the experiment.

Table 1: **Origin and reaction to *Striga hermonthica* of inbred used as parents**

Genotypes	Types	Reaction to Striga	Origin
TZSTRI110	Line	SR	IITA
TZSTRI112	Line	SR	IITA
TZSTRI113	Line	SR	IITA
TZISTR1028	Line	SR	IITA
TZISTR1211	Line	SR	IITA
TZISTR1214	Line	SR	IITA
TZISTR1218	Line	SR	IITA
TZISTR1222	Line	SR	IITA
TZISTR1223	Line	SR	IITA
TZISTR1226	Line	SR	IITA
TZISTR1227	Line	SR	IITA
TZISTR1230	Line	SR	IITA
TZISTR1235	Line	SR	IITA
TZISTR1237	Line	SR	IITA
TZISTR1238	Line	SR	IITA
TZSTRI106	Tester	SR	IITA
TZISTR1207	Tester	ST	IITA
TZISTR1033	Tester	SS	IITA

Where SR= *Striga* resistant line and ST= *Striga* tolerant line

Data for all traits were on a per plot basis for each experiment at each location. Under both *Striga-free and Striga-infested*, data on traits including grain yield (Yield), anthesis-silking interval (ASI) and plant height (PLHT) were collected in addition *Striga* related traits such as *Striga* damage rating 8 and 10 weeks after planting and Striga emergence count at 8 and at 10 weeks after planting collected under *Striga-infested* environments. The differences between the days to 50% silking and 50% anthesis is called anthesis-silking interval. Plant height the distance from the base of the plant to the height of the first tassel branch was collected from an average of five random plants. However, *Striga* damage rating was scored on a scale of 1 - 9 as described by Kim, 1994. *Striga* emergence count was counted, while ASI are observed. Grain yield was calculated in kilogram per hectare and was estimated based on 80% shelling percentage and adjusted to 15% moisture. Grain yield under *Striga-infested* environment was calculated as follows

$$GY = \text{fwt} \times \frac{(100 - m)}{85} \times \frac{1000}{(8 \times \phi)} \times 0.8$$

Where,

GY = grain yield (kg ha-1), Fwt = field weight of harvested ears per plot (kg), m = moisture content grain at harvest, 10,000 = land area per hectare (m^2), 8 = land area per plot (0.75 m x 0.25 m), ϕ = number of hills/plot (20) and 0.80 = 80 % shelling percentage.

The mid parent heterosis (MPH) were calculated in terms of percent increase (+) or decrease (-) of the F_1 hybrids against its mid-parent value as suggested by Fehr, 1987.

$$MPH\ (\%) = \frac{(F_1 - MP)}{MP} \times 100$$

Where,

F_1=Mean value of a cross, MP = mid parent value of the particular F1 cross [(P1 + P2)/2].

Test of significance for percent heterosis was made using the t-test.

$$SEentry = \sqrt{(MSE/s*y*r)},$$

Where,

MSE = mean square error; S = number of site, Y = number of year the trial were conducted, r = number of replications; 2- the “t” for each entry, hybrid was calculated as follow

t = Entry heterosis/SEentry

The t calculated value was tested against the t value at degree of freedom for error

Analysis of variance for grain yield, *Striga* resistance and secondary traits were performed in SAS 9.3 software using the model described by Kempthorne, 1957. Genotypes were considered fixed effects, while replications and environments were considered random effects.

Results and discussions

The analysis of variance revealed that there is significant ($P < 0.05$) difference for all traits among genotypes under *Striga-infested* and *Striga-free* conditions (Table 2). Under *Striga-infested* conditions the Genotypes by environment mean squares was significant for most traits except for *Striga* damage rating at 8 and 10 weeks after planting. Significant positive mid-parent heterosis were observed for all hybrids for grain yield under *Striga-infested* and *Striga-free* conditions. The mid-parent heterosis values for grain yield were higher under *Striga-free* conditions than *Striga-infested* conditions (Table 4). Mid-parent heterosis ranged from 105.8% (TZISTR106/ TZISTR110) to 259.5% (TZISTR106/ TZISTR1230) for grain yield under *Striga-free* conditions and from 100 %

(TZISTR1033 / TZISTR1218) to 228.2% (TZISTR1033 / TZISTR1223) for grain yield under *Striga-infested* conditions. Mid-parent heterosis for plant height ranged from -0.7% (TZISTR1207/ TZISTR1237) to 44.9% (TZISTR1033 /TZISTR1227) under *Striga-free* conditions and from -6.7% (TZISTR1207/ TZISTR1235, TZISTR1207 / TZISTR1237) to 40.1% (TZISTR1033 / TZISTR1222) under *Striga-infested* conditions. Crosses TZISTR1207 / TZISTR1237 exhibited significant negative heterosis for plant height under both conditions. Some crosses also exhibited significant positive heterosis for plant height under both conditions. Anthesis-silking interval showed values ranging from -100% to 122.2% under *Striga-free* conditions and from -52.1% to 107.7% for grain yield under *Striga-infested* conditions. The range is wider under *Striga-free* conditions than *Striga-infested* conditions for anthesis-silking interval. The mean value range was wider for grain yield than for the others traits under both conditions. *Striga* damage rating at 8 and 10 WAP exhibited the highest number of negative mean values compare to *Striga* emergence count at 8 and 10 WAP under *Striga-infested* conditions. Significant negative heterosis were found for five hybrids for the same trait under *Striga-free* conditions, with heterosis value ranging from -100 to 122.2. Among the forty five hybrids, cross TZISTR1033/ TZISTR1227 exhibited significant negative heterosis for ASI under *Striga-infested* conditions, heterosis were found in a range from -2, 2 to 107.7. The heterosis estimates for plant height were positive for most hybrids except six crosses. The mid-parent heterosis estimate, in percentage was found in a range of -0.7 to 44.9 under *Striga-free* conditions and -6.7 to 40.1 under *Striga-infested*. Their magnitude is lower under *Striga-infested* compare to *Striga-free*. The estimate heterosis for grain yield was positively significant with high magnitude. Similar result was found by Tonette and Carena, 2014 enabling plant breeder to select good lines and their promising hybrids. Three out of the twenty hybrids exhibited negative mid parent heterosis for anthesis silking interval in both conditions indicating that theses crosses could be tolerant to *Striga*. This finding agree with Lu *et al*., (2010) who reported that low anthesis silking interval is mostly used to screen genotypes for stresses tolerance. Lesser difference between anthesis and silking is desirable for grain sitting. The finding also corroborate with those of Iqbal *et al*., (2010) who fund negative mid parent over, reported that these crosses could be either due to dominance at the same locus or different dominant genes which are closely linked and /or pleiotropic in their action. Hybrid TZISTR1207/TZISTR1238 exhibited negative mid parent heterosis for plant height under both conditions, indicating that they have not been affected by the effect of the parasite. This is desirable because dwarf plant can reduce the final yield of maize crop while high plant height could also cause plant lodging as reported by Ali *et al*., (2011b). According to Scapim *et. al*., (2006) reported that when the level of heterosis is low the choice of parental line for hybrid development should be based on their means. Similarly, hybrids TZISTR1207/ TZISTR110, TZISTR1207 /TZISTR112 and TZISTR1207/ TZISTR113 exhibited positive mid parent heterosis for plant height. This finding corroborate with Uzarowska *et al*., (2007) who observed substantial mid-parent heterosis for plant height in field environment. For the entire hybrids mentioned above the heterosis was in desirable direction. TZISTR1207/TZISTR1238 exhibited significant and negative mid parent heterosis under *Striga-infested* condition indicating the availability of variability for hybrid for this trait. The level of heterosis observed for *Striga* related traits was lower than for grain yield and plant height. This is in agreement with study undertake by Solomon *et al*., (2012) on sweet corn who found that quality related traits exhibited mean value mid parent heterosis lower than for most agronomic trait. There is lack or lesser significance for *Striga* related traits, this finding agree with Kvitschal *et al*., (2004) who reported that this absence could be explained by the lack of difference in among the degrees of complementation with each other, in relation to the frequency of alleles at loci with some dominance and predominating additive effects.

Conclusion

In this study, the mid-parent heterosis for grain yield were noted for all crosses under *Striga-infested* and *Striga-free* conditions. Under *Striga-free* condition test crosses TZISTR106/ TZISTR1230, TZISTR106 / TZISTR1223 and TZISTR1033/TZISTR1223 appeared as the best hybrids combinations with respect to grain yield, while combinations TZISTR1207 /TZISTR1226, TZISTR106/ TZISTR112, TZISTR106/ TZISTR113 and TZISTR106 /TZISTR1028 show positive mid parent heterosis for grain yield and negative mid parent heterosis for *Striga* related traits under *Striga* infestation. Amongst tester TZISTR106 and TZISTR1033 contributed a lot toward the exposure of *Striga* related traits. Hybrids exceed the best parent in yield and productivity.

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Table 2: Mean squares of grain yield and other measured traits under *Striga-infested* and *Striga- free* conditions

		***Striga- free* condition**			***Striga-infested* condition**						
Sources of variation	**DF**	**GY**	**ASI**	**PLHT**	**GY**	**ASI**	**PLHT**	**STRA**	**STRA**	**STRC8**	**STR**
Year	1	124,670,669**	26.69**	22,052.46*	7,342,057**	7.33*	285,700.60**	14.55*	3.39ns	61.40*	2.88ns
Site (Year)	1	176,203,399**	0.44ns	85,439.70*	122,943,633**	84.65**	110,992.80**	58.95**	41.23**	1,269.82**	834.49**
Genotypes	47	3,233,749**	2.69**	1,261.18**	1,892,330**	1.46*	1,564.22**	2.36*	2.89*	58.41**	88.77**
REP (Site)	2	1,136,944ns	1.42ns	351.23ns	2,522,438*	0.04ns	3,545.41**	12.44*	11.55*	293.24**	636.74**
Block (REP)	15	541,929ns	2.20*	270.73ns	145,676ns	0.46ns	414.87ns	1.02ns	0.91ns	17.04ns	35.24ns
Year*Site*Genotypes	141	2,517,653**	1.95**	841.59**	1,295,991**	1.86**	726.07**	1.54ns	1.44ns	25.25**	42.29**
Error	365	645,650	365.00	101,332.59	380,019	1.09	319.17	1.47	1.84	12.85	22.20

Where, *, **, Significant at 0.05 and 0.01 levels of probability, respectively, ns = non-significance, GY = Grain Yield, ASI = anthesis silking- interval, STRA 8 WAP = *Striga* damage rating at 8 WAP, STRA 10 WAP = *Striga* damage rating at 10 WAP, STRC 8 WAP = *Striga* emergence count at 8 WAP STRC 10 WAP = *Striga* emergence count at 10 WAP and WAP = Weeks after Planting.

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Table3: Performance of best fifteen and worst five hybrids evaluated for two years under Striga-free and Striga-infested condition

Genotypes	*Striga-free*			*Striga-infested*							
	GY	ASI	PLHT	GY	ASI	PLHT	STRA8	STRA10	STRC8	STRC10	Base index
TZISTR106/TZISTR1028	5515	1	183	2851	2	121	1.7	2.0	1.6	0.9	1.4
TZISTR1207/TZISTR1222	5027	1	168	3558	2	179	4.1	3.1	3.8	6.6	-0.4
TZISTR1207/TZISTR1214	5001	1	173	4155	2	175	4.0	3.6	2.7	5.9	1.6
TZISTR106/TZISTR1230	4942	1	177	3704	2	192	2.9	3.5	4.4	8.5	0.4
TZISTR1207/TZISTR1028	4897	1	168	3725	2	167	4.2	3.7	4.6	5.7	2.8
TZISTR106/TZISTR1223	4867	0	181	3846	1	205	2.5	3.1	5.5	7.6	2.4
TZISTR1033/TZISTR1223	4691	2	187	4076	1	141	2.4	2.5	5.5	9.0	5.6
TZISTR1207/TZISTR1218	4677	1	168	3789	1	178	3.8	3.0	2.8	5.5	2.5
TZISTR1033/TZISTR1214	4661	1	193	2833	2	185	3.2	4.0	9.3	12.3	-5.4
TZISTR1207/TZISTR113	4572	1	162	3757	2	171	4.5	3.2	1.4	4.4	0.4
TZISTR1207/TZISTR112	4547	1	169	3759	2	180	3.4	3.6	4.8	8.6	0.5
TZISTR1207/TZISTR110	4468	1	172	3166	1	170	4.0	3.8	1.8	5.5	-2.4
TZISTR106/TZISTR112	4436	1	180	3545	2	136	1.6	1.6	0.7	3.4	5.2
TZISTR106/TZISTR1226	4407	1	185	3470	1	199	2.5	3.5	4.8	8.1	-0.4
TZISTR1207/TZISTR1211	4346	2	165	3270	2	169	4.2	3.4	3.6	6.6	1.5
TZISTR1207/TZISTR1238	3231	1	167	3568	2	188	3.5	3.8	5.6	8.0	2.6
TZISTR106/TZISTR110	3175	2	180	3218	1	178	2.7	3.1	4.9	7.6	-0.3
TZISTR1033/TZISTR1230	3112	1	174	3280	2	132	2.5	2.8	2.5	6.2	1.7
TZISTR1207/TZISTR1226	3030	1	172	3589	2	179	3.7	3.5	2.1	4.1	3.3
TZISTR1033/TZISTR110	3008	2	169	3430	1	180	3.8	4.7	9.5	13.3	-4.8
Mean	3980	1	179	3452	2	180	3.1	3.4	5.2	5.4	
Minimum	3008	0	161	2237	1	154	2.3	2.3	1.6	1.6	
Maximum	5515	2	219	4211	2	217	5.1	4.5	10.6	11	
SE ±	93	0.1	2.0	72.3	0	4.0	0.1	0.1	0.4	0.4	

Table4: Mid-parent heterosis of best fifteen and worst five hybrids over different characters in maize hybrids

Genotypes	*Striga-free*			*Striga-infested*						
	GY	ASI	PLHT	GY	ASI	PLHT	STRA 8WAP	STRA 10WAP	STRC 8WAP	STRC 10WAP
TZISTR106/TZISTR1028	233,7*	-23,1	15,4	112*	22	18*	-52,3	-42,6*	-38,8	-80,7
TZISTR1207/TZISTR1222	247*	-44,4	14,5	191,5*	64,8	5.3*	7,4	-22,7	12,6	21,4
TZISTR1207/TZISTR1214	216.9*	-56.5*	14.7	221.7*	37.1	12.4*	14.2	-0.7	-28.5	5.3
TZISTR106/TZISTR1230	259,5*	-33,3	19	181,7*	78,3	3,5*	-12,6	-1,5*	35,7	80,7
TZISTR1207/TZISTR1028	199.6*	-23.1	11.5	125.6*	14.4	9.2*	20	6.3	38.3	22.4
TZISTR106/TZISTR1223	246,7*	-100	21,8	193,2*	-3,3	12,1*	-37,9	-26,6*	97,1	70,6
TZISTR1033/TZISTR1223	234,5*	17,6	25	228,2*	6,4	22.2*	-36	-46,7*	147,2	152,6
TZISTR1207/TZISTR1218	208,9*	-63*	16,9	190,5*	-3,3	0.9*	-8,1	-19	-11,5	-3,6
TZISTR1033/TZISTR1214	196,3*	-47,4*	28,1	117,4*	22,7	32*	0,9*	-3,8*	259,7	170
TZISTR1207/TZISTR113	221.5*	-37.5	0.6*	219.6*	107.7	3.9*	28.6	-13.2	-59.1	-10.2
TZISTR1207/TZISTR112	185.8*	-23.1	5.8*	195.1*	16.7	0.5*	-10.1	-0.7	51.7	86.5
TZISTR1207/TZISTR110	219.8*	-33.3	5.3*	181.4*	21.9	4.9*	25.9	8.9	-46.7	14
TZISTR106/TZISTR112	166,6*	-16,7	12	140,6*	49,8	6,4*	-57,7	-55,6*	-72	-23,8
TZISTR106/TZISTR1226	229,6*	-41,2	23,6	170,4*	-6,2	9,4*	-30,8	-8*	30,2	49,3
TZISTR1207/TZISTR1211	173.2*	17.6	13.8	155.9*	107.4	9.1*	21.4	-2	0,1*	24.8
TZISTR1207/TZISTR1238	138,7*	25	0,4*	226,1*	69	-0.3*	-1,4*	7,3*	48	39,5
TZISTR106/TZISTR110	105,8*	81,8	12,4	155,5*	39	8.6*	-14,5	-10,9*	78,5	64,1
TZISTR1033/TZISTR1230	126,4*	-28,6	16,9	161,7*	24,5	7*	-19,6	-31,8*	-8,1	61,7
TZISTR1207/TZISTR1226	126,7*	-16,7	12,5	204,3*	79,3	2.3*	-0,3*	-7,5*	-52,7	-27,5
TZISTR1033/TZISTR110	142,7*	53,8	2,9*	177,2*	-3,8	8*	29,4	19,2*	340,2	255,7

*, **, Significant at 0.05 and 0.01 levels of probability, respectively