Genetic correlation and hybrid vigor for physiological traits of *Zea mays*

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Abstract: Present study was conducted in the glasshouse of Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan during 2012. The experimental material was comprises of 10 inbred lines, 2 varieties and 36 F_1 hybrids of maize. It was concluded that higher heritability and genetic advance was found for photosynthetic rate, chlorophyll contents, water use efficiency and sub-stomata CO_2 concentration. Significant genotypic and phenotypic correlation was found for photosynthetic rate with water use efficiency, transpiration rate and stomata conductance while negatively and significantly correlated with leaf temperature and sub-stomata CO_2 concentration. It was concluded that B-336 × B-316, EV-1097Q × EV-340, EV-1097Q × E-322, B-336 × Pop/209, B-336 × F-96, B-327 × F-96, B-327 × EV-340, B-327 × Pop/209, B-327 × E-322 showed higher heterosis and heterobeltiosis for all traits. Higher values of heritability, genetic advance, heterosis and heterobeltiosis indicated that selection of higher grain yielding maize genotypes of batter photosynthetic rate may be made on the basis of physiological traits of maize.

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1. Introduction

Maize (*Zea mays* L.) is an important cereal food crop in world and Pakistan where rapidly increasing population has run short of food supplies. Maize is the third very important cereal in Pakistan after wheat and rice. Maize contributes 5.67 % of GDP of agriculture products. It was grown on 1083 thousands hectares with annual production of 4271 thousands tons (Anonymous, 2011-12). Maize is used as food for human while feed for livestock and also used as industrial raw material to produce a large number of maize by-products. Its grain constitutes about 9.7396 % grain protein, 4.85% grain oil, 9.4392% grain crude fibre, 71.966% grain starch, 11.77% embryo while fodder contains 22.988% acid detergent fibre, 51.696% neutral detergent fibre, 28.797% fodder cellulose, 40.178% fodder dry matter, 26.845% fodder crude fibre, 10.353% fodder crude protein and 9.095% fodder moisture [Ali *et al.*, 2014ab]. Production of Pakistan is very low than other maize producing countries due to non-availability of potential germplasm and resources. Grain yield of maize is associated with different morphological, physiological and agronomic traits. By improving these traits production of maize may be improved. Genetic correlation provides a chance to a plant breeder to select genotypes on the basis of strong correlation among grain yielding contributing traits as reported by Mehdi and Ahsan (2000); Grzesiak *et al.* (2007); Ali *et al.* (2011a, b) and Ali *et al.* (2012). The present study was conducted to evaluate maize accessions for physiological seedling traits.

Materials and methods

The present study was carried out in the glasshouse of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad to evaluate maize genotypes for seedling traits for the period of the crop season in February 2012. The experimental material comprised of 10 inbred lines, 2 varieties and 36 crosses as given below (Table 1):

The seeds of all parents and F_1 hybrids were sown in iron trays filled with sand following a completely randomized design (CRD) with three replications at the depth of 2.5 cm and twenty seedlings of each parents and F_1 hybrids were established in each replication. The data of 5 plants was recorded for physiological traits including chlorophyll contents measured with the help of Chlorophyll Meter and leaf temperature, stomata conductance, transpiration rate, photosynthetic rate, sub-stomata CO_2 concentration, water use efficiency help of

IRGA (Infrared Gas Analyzer). The data was statistically analyzed by using analysis of variance technique (Steel *et al*. 1997). The genotypic and phenotypic correlations were calculated by Kwon and Torrie (1964) technique. The genetic advance was calculated by using Falconer (1989) formula. Heritability was recorded by using Burton, (1951) technique.

Table 1: Experimental germplasm

Sr. No.	Genotypes	Sr. No.	Genotypes	Sr. No.	Genotypes
1	Pop/209 (**Variety**)	17	B-11× F-96	33	B-327× EV-340
2	B-316 (**Inbred Line**)	18	B-11× EV-347	34	B-327× E-322
3	EV-340(**Inbred Line**)	19	B-336× Pop/209	35	B-327× F-96
4	E-322(**Inbred Line**)	20	B-336× B-316	36	B-327× EV-347
5	F-96(**Inbred Line**)	21	B-336× EV-340	37	Raka-poshi× Pop/209
6	EV-347(**Inbred Line**)	22	B-336× E-322	38	Raka-poshi× B-316
7	B-11(**Inbred Line**)	23	B-336× F-96	39	Raka-poshi× EV-340
8	B-336(**Inbred Line**)	24	B-336× EV-347	40	Raka-poshi× E-322
9	EV-1097Q(**Inbred Line**)	25	EV-1097Q× Pop/209	41	Raka-poshi× F-96
10	B-327(**Inbred Line**)	26	EV-1097Q× B-316	42	Raka-poshi× EV-347
11	Raka-poshi (**Variety**)	27	EV-1097Q× EV-340	43	Sh-139× Pop/209
12	Sh-139(**Inbred Line**)	28	EV-1097Q× E-322	44	Sh-139× B-316
13	B-11× Pop/209	29	EV-1097Q× F-96	45	Sh-139× EV-340
14	B-11× B-316	30	EV-1097Q× EV-347	46	Sh-139× E-322
15	B-11× EV-340	31	B-327× Pop/209	47	Sh-139× F-96
16	B-11× E-322	32	B-327× B-316	48	Sh-139× EV-347

Results and discussions

It was found from table 2 that significant differences were recorded for all traits. The heritability was found from 60.708-99.796% while genetic advance was found from 8.287-185.379%. Highest heritability and genetic advance were recorded for water use efficiency while lower for stomata conductance. Higher heritability and genetic advance indicated that selection of higher grain and fodder yielding maize genotypes may be helpful to improve crop yield. Similar results were obtained by Mehdi and Ahsan (2000); Grzesiak *et al.* (2007); Ali *et al.* 2014abc; Ali *et al.* (2011a, b) and Ali *et al.* (2012). It was found from figure 1 that highest photosynthetic rate was reported for B-336 × Pop/209 while lowest for B-327. Highest leaf temperature was recorded for EV-1097Q × Pop/209 while lowest for B-336 × F-96 (Figure 2). The highest chlorophyll contents were recorded for B-11 × EV-347 while lowest for EV-340 (Figure 3). Highest stomata conductance was recorded for B-11 × EV-347 while lowest for B-11 × Pop/209 (Figure 4). Figure 5 indicated that transpiration rate was found higher for B-11 × EV-347, B-336 × Pop/209 while lowest for B-327 × Pop/209 and Raka-poshi. It was suggested from figure 6 that highest sub-stomata CO_2 concentration was found for Sh-139 while lowest for B-336 × Pop/209. Highest water use efficiency was found for B-336 × EV-347 while lowest for EV-347 and Sh-139 × EV-347 (Figure 7). Similar results were reported by Ali *et al.* (2012). It was persuaded from table 3 that significant genotypic and phenotypic correlation of chlorophyll contents was found photosynthetic rate while negatively and significantly correlated with stomata CO_2 concentration and water use efficiency. Photosynthetic rate was positively and significantly correlated with chlorophyll contents, transpiration rate, stomata conductance and water use efficiency while negatively correlated with stomata CO_2 concentration and leaf temperature at genotypic and phenotypic levels. Leaf temperature was positively and significantly correlated with transpiration rate, stomata CO_2 concentration and water use efficiency at genotypic and phenotypic levels. Significant and positive genotypic and phenotypic correlations indicated that selection of higher yielding maize genotypes for photosynthetic rate, chlorophyll contents and water use efficiency may be help to improve maize production. Similar results were obtained by Mehdi and Ahsan (2000a); Grzesiak *et al.* (2007); Ali and Ahsan (2011); Ahsan *et al.* (2011); Ali *et al.* (2011a, b); Ali *et al.* (2012) and Tariq *et al.* (2014).

It was persuaded from table 4 that higher heterosis and heterobeltiosis for photosynthetic rate was recorded for B-11 × EV-340 (356.288, 161.068), B-327 × EV-340 (226.419, 135.593), B-327 × E-322 (647.867, 311.712), Raka-poshi × B-316 (651.886, 624.561) and Raka-poshi × EV-340 (635.724, 594.236) respectively, while lower for B-336 × EV-347 (-93.237, -89.306) and B-336 × EV-347 (-87.666, -89.306) respectively.

Table 2: Genetic components for various physiological traits of maize

Traits	M.S	G.M	GV	GCV %	PV	PCV %	EV	ECV %	h2bs%	GA%
Photosynthetic rate	105.520*	68.103	35.050	71.740	35.420	72.118	0.370	7.371	98.955	95.039
Leaf Temperature	4.217**	33.892	1.399	20.315	1.419	20.461	0.020	2.441	98.576	26.913
Chlorophyll contents	0.624**	0.366	0.206	75.042	0.211	76.002	0.005	12.044	97.489	99.413
Stomata conductance	0.00048**	0.034	0.00013	6.255	0.00021	8.028	0.00008	5.032	60.708	8.287
Transpiration rate	0.514**	0.671	0.171	50.497	0.172	50.587	0.001	3.015	99.645	66.897
Sub-Stomata CO2 concentration	154893*	274.930	51578	1369.685	51737	1371.795	159.000	76.048	99.693	144.75
Water use efficiency	865.800*	16.061	288.403	423.749	288.993	424.182	0.590	19.166	99.796	185.379

Table 3: Genotypic and phenotypic correlation for various physiological traits of maize

Traits	r	Photosynthetic rate	Chlorophyll contents	Sub-Stomata CO_2 concentration	Transpiration rate	Leaf Temperature	Water use efficiency
Chlorophyll contents	g	0.4569*					
	p	0.3867**					
Sub-Stomata CO_2 concentration	g	-0.5236*	-0.2165**				
	p	-0.2314**	-0.0342				
Transpiration rate	g	0.3125**	-0.1228	0.0551			
	p	0.3451**	-0.1086	0.0453			
Leaf Temperature	g	-0.2459**	-0.1205	0.3697**	0.4608*		
	p	-0.2133**	-0.0754	0.4563*	0.5764*		
Water use efficiency	g	0.4948*	-0.2365**	0.1815	0.4074*	0.2537**	
	p	0.5643*	-0.3213**	0.1886	0.4352*	0.2876**	
Stomata conductance	g	0.2077**	0.0036	-0.2196**	0.178	0.0891	-0.0465
	p	0.2412**	0.0564	-0.3421**	0.1902	0.0987	-0.0036

* = Significant at 1% level, ** = Significant at 5% level

Higher heterosis and heterbeltiosis suggested that the hybrids may be developed fro the improvement of green fodder yield on the basis of higher photosynthetic rate (Khan *et al.* (2001); Akhtar (2002); Alvi *et al.* (2003) and Vafias *et al.* 2005; Ali *et al.* 2013abc). It was suggested from table 4 that higher heterosis and heterobeltiosis for leaf temperature was recorded for B-336 × B-316 (6.315, 5.424), EV-1097Q × EV-340 (6.746, 6.268) and EV-1097Q × E-322 (6.905, 6.746) respectively, while lower for B-336 × E-322 (-7.121, -7.396) and B-336 × F-96 (-9.244, -9.960) respectively. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). It was shown from table 5 that higher heterosis and heterobeltiosis for chlorophyll contents was recorded for B-336 × Pop/209 (6525.53, 6387.50), B-336 × E-322 (3020.56, 1911.45), B-336 × F-96 (7197.62, 6285.42), EV-1097Q × EV-340 (2067.13, 1328.11) and B-327 × F-96 (2116.49, 1172.43) respectively, while lower for EV-1097Q × B-316 (-96.06, -97.90), EV-1097Q × EV-347 (94.58, 97.10) and B-336 × B-316 (-93.79, -96.85) respectively. Higher heterosis and heterobeltiosis for chlorophyll content suggested that the hybrid vigor will be higher that caused to improve photosynthetic rate to enhance of accumulation of organic compounds. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). It was persuaded from table 5 that higher heterosis and heterobeltiosis for stomata conductance was recorded for B-327 × Pop/209 (183.333, 183.333), B-327 × E-322 (142.857, 112.50), B-327 × EV-340 (209.091, 183.333), B-327 × B-316 (100.00, 66.667) and EV-1097Q × Pop/209 (110.00, 75.00) respectively, while lower for B-11 × Pop/209 (-60.00, -71.429), B-11 × F-96 (-51.724, -53.333) and B-336 × F-96 (-53.333, -53.333) respectively. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). It was found from table 6 that higher heterosis and heterobeltiosis for transpiration rate was recorded for Raka-poshi × Pop/209 (264.602, 145.238), Raka-poshi × E-322 (125.225, 29.534), Raka-poshi × EV-347 (553.521, 452.381), Raka-poshi × B-316 (523.881, 450.00) and Raka-poshi × EV-340 (369.880, 261.11) respectively, while lower for B-336 × E-322 (-54.351, -66.587), B-336 × F-96 (-69.464, -73.317) and Sh-139 × EV-347 (-65.482, -78.065) respectively. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). It was persuaded from table 6 that higher heterosis and heterobeltiosis for sub-stomata CO_2 concentration was recorded for B-336 × B-316 (680.00, 380.698), EV-1097Q × E-322 (705.536, 465.049), Raka-poshi × EV-347 (404.444, 247.893) and EV-1097Q × EV-347 (657.295, 437.374) respectively, while lower for B-336 × EV-340 (-89.364, -93.987), B-327 × E-322 (-86.732, -92.852) and Sh-139 × EV-340 (-95.915, -97.401) respectively. Higher sub-stomata CO_2 concentration suggested that the amount of organic compounds may be increased due to higher photosynthetic rate. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). It was suggested from table 7 that higher heterosis and heterobeltiosis for water use efficiency was recorded for B-336 × EV-347 (1572.04, 850.998), EV-1097Q × B-316 (727.10, 423.553), EV-1097Q ×

B-316 (304.56, 288.418) and Raka-poshi × EV-347 (290.80, 133.109) respectively, while lower for B-327 × E-322 (-95.93, -97.135), B-327 × EV-340 (-68.06, -76.056), Sh-139 × F-96 (-82.94, -90.579) and Sh-139 × EV-347 (-96.27, -98.078) respectively. Similar results were found by Khan *et al.* (2001); Akhtar (2002); Desai and Singh (2001); Alvi *et al.* (2003) and Vafias *et al.* (2005). Higher heterosis and heterobeltiosis indicated that selection may be helpful for the development of hybrids for higher grain and fodder yield of maize.

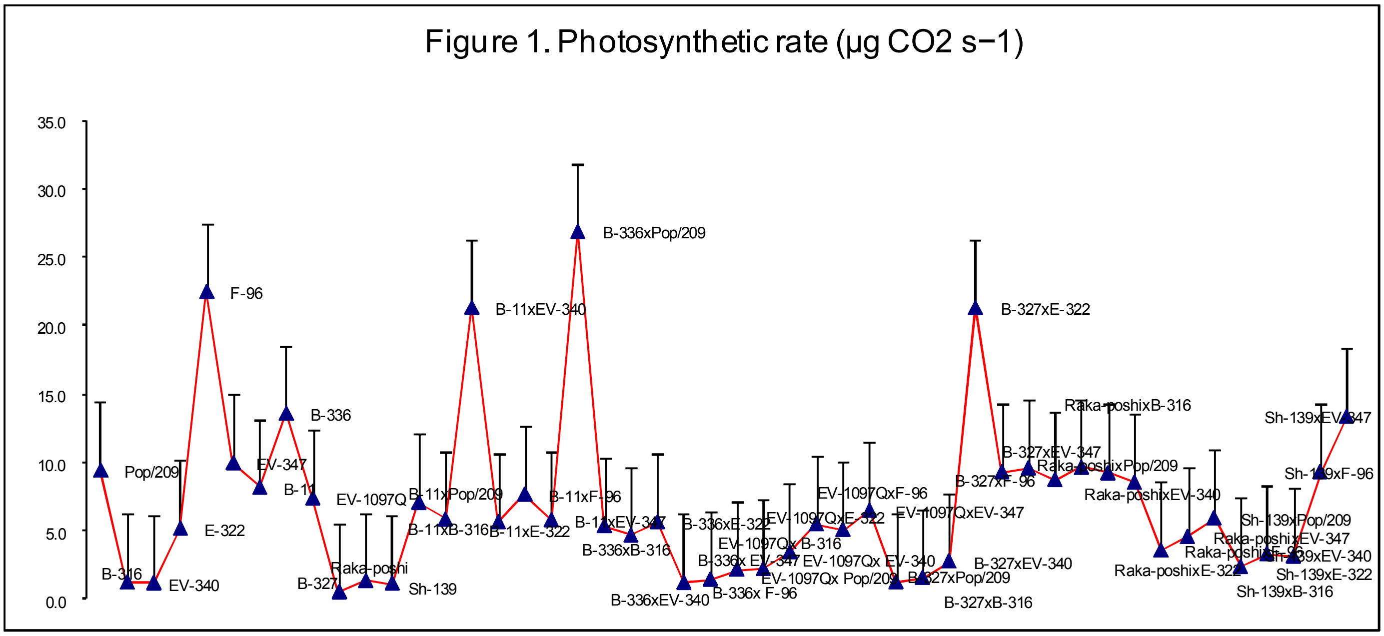
Figure 1. Photosynthetic rate (µg CO2 s−1)

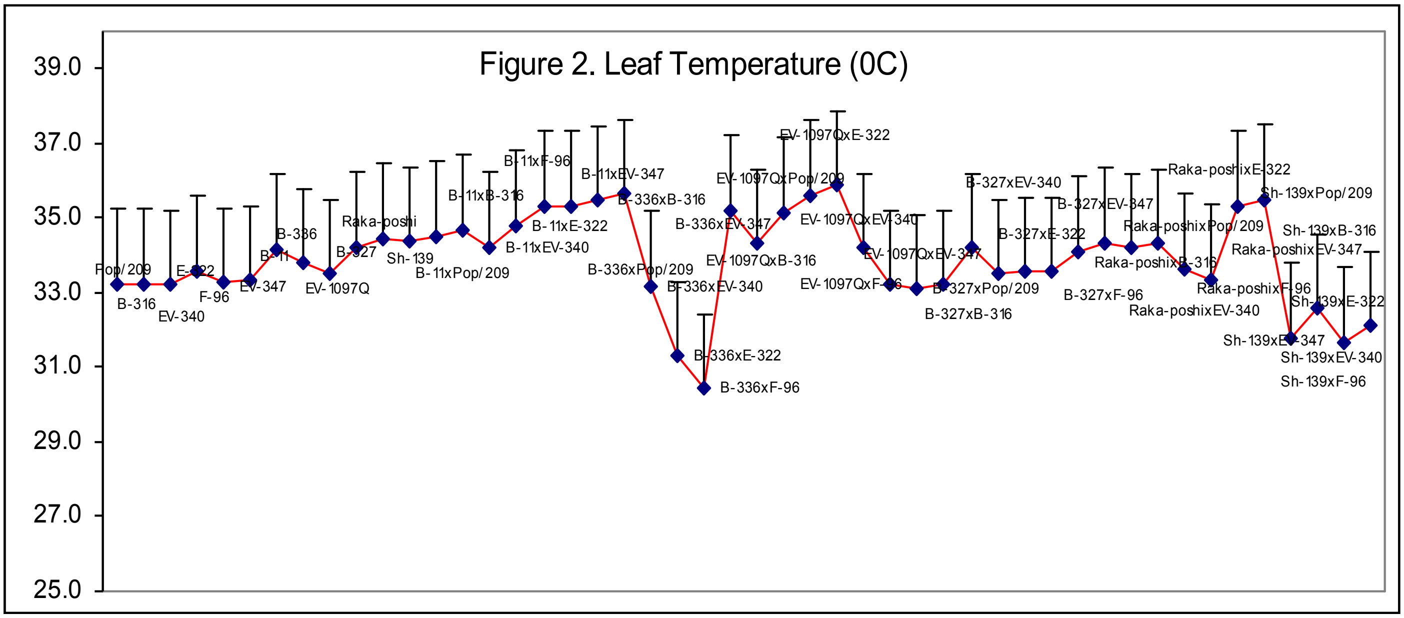
Figure 2. Leaf Temperature (0C)

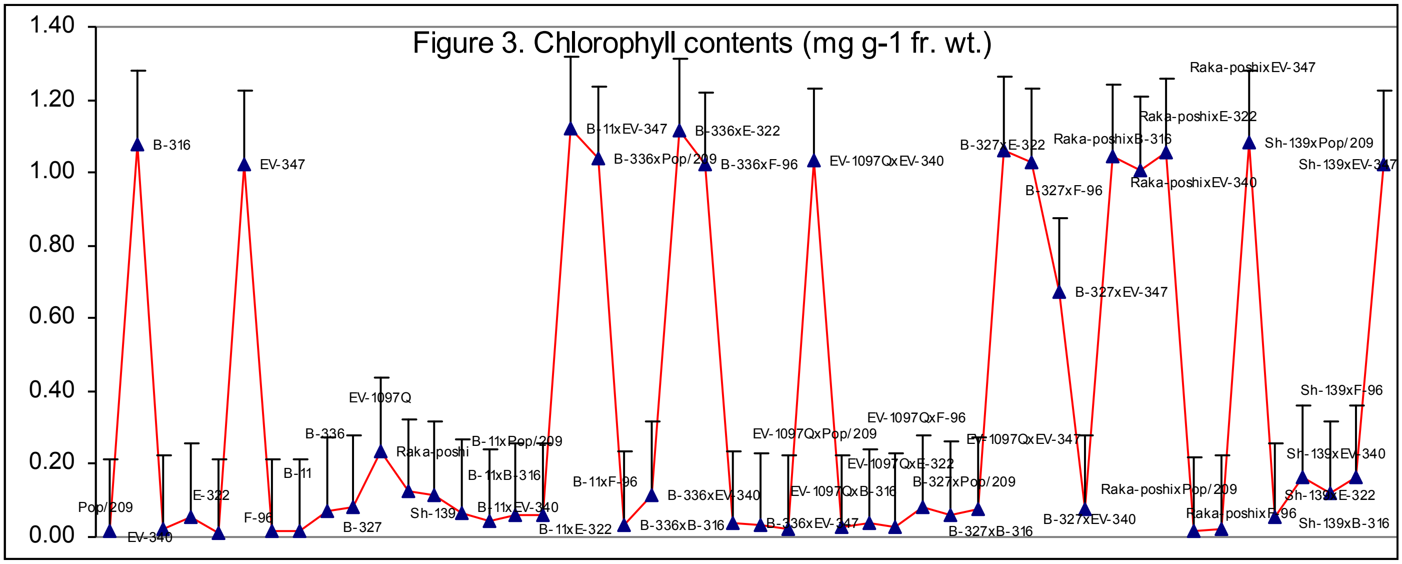
Figure 3. Chlorophyll contents (mg g-1 fr. wt.)

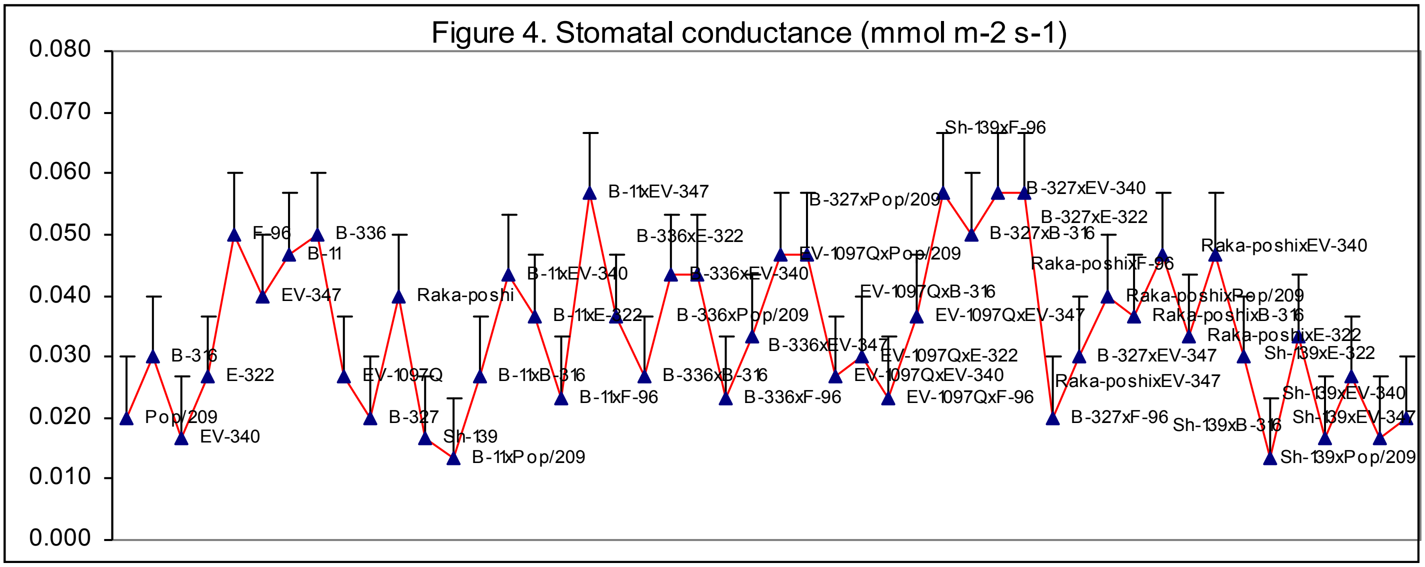
Figure 4. Stomatal conductance (mmol m-2 s-1)

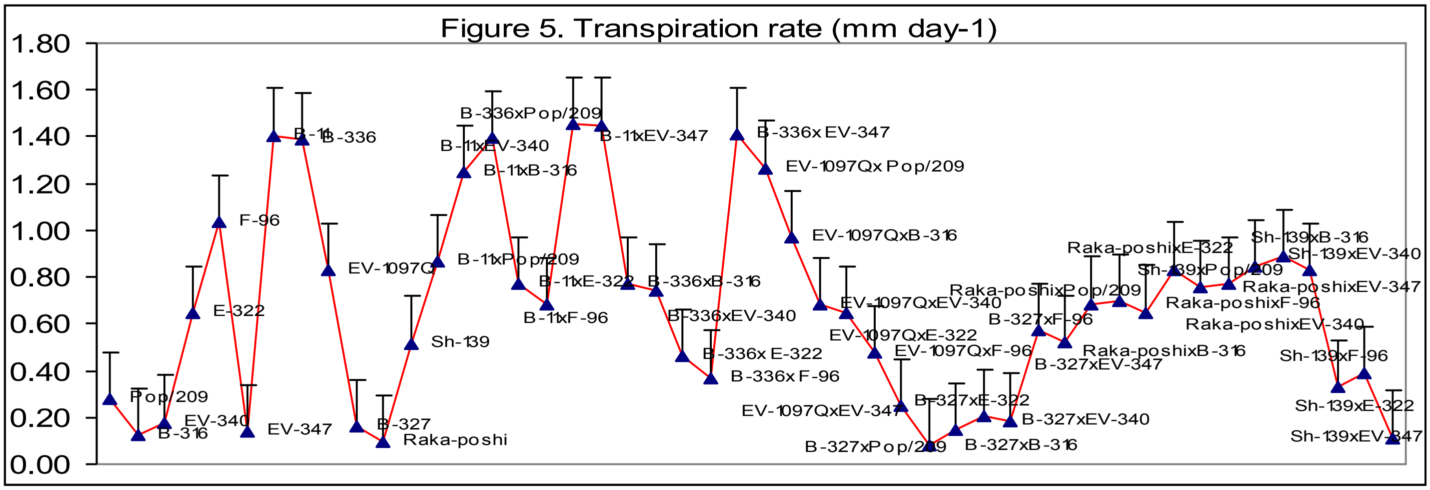
Figure 5. Transpiration rate (mm day-1)

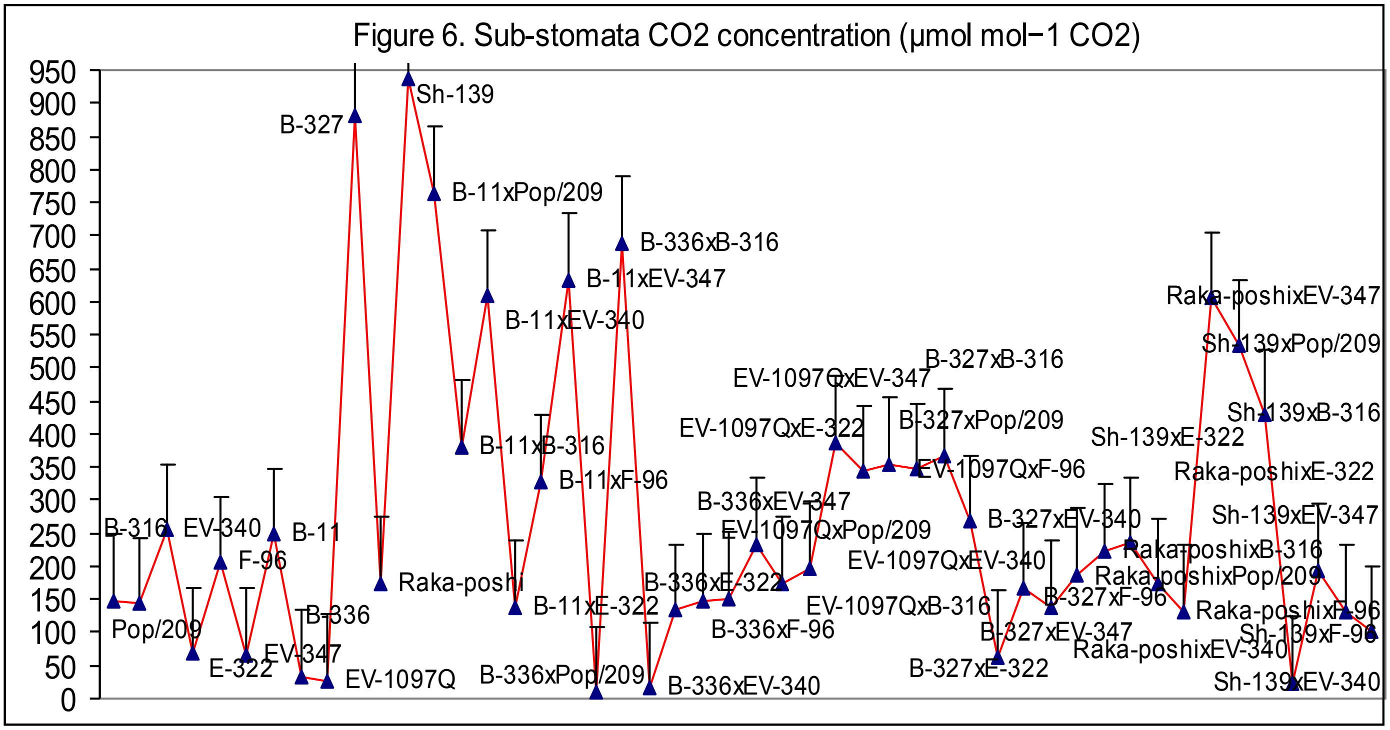
Figure 6. Sub-stomata CO2 concentration (μmol mol−1 CO2)

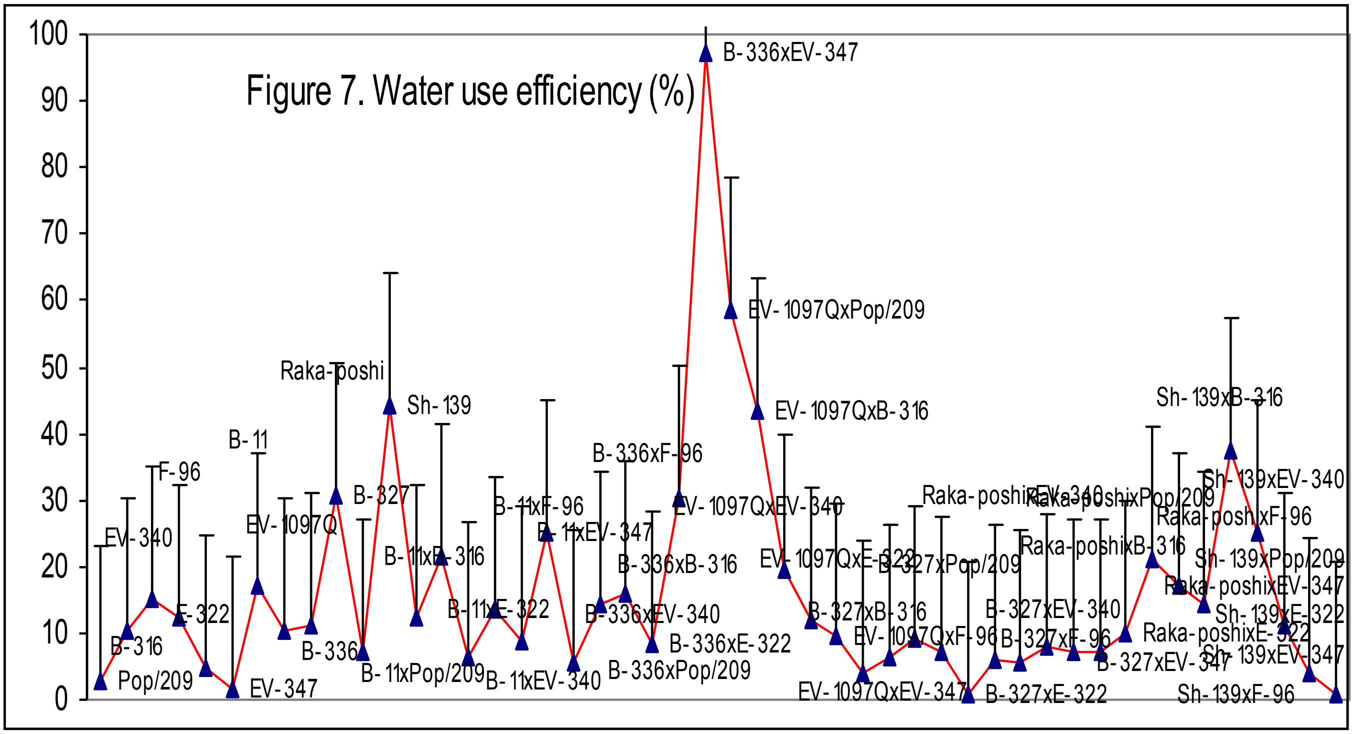
Figure 7. Water use efficiency (%)

Table 4: Heterosis and heterobeltiosis for Photosynthetic rate and leaf temperature

	Photosynthetic Rate				Leaf Temperature			
Parents/Crosses	**Heterosis**	**Heterobeltosis**	**t_Hetr**	**t_Hetrb**	**Heterosis**	**Heterobeltosis**	**t_Hetr**	**t_Hetrb**
B-11xPop/209	-19.674	-25.000	-4.671	-5.505	2.374	0.976	9.181	3.313
B-11xB-316	24.478	-28.373	3.107	-5.420	2.967	1.561	11.476	5.301
B-11xEV-340	356.288	161.068	44.962	30.766	1.633	0.195	6.312	0.663
B-11xE-322	-15.248	-30.779	-2.747	-5.879	2.705	1.854	10.520	6.295
B-11xF-96	-49.935	-65.866	-20.654	-34.605	4.795	3.415	18.554	11.595
B-11xEV-347	-36.320	-42.065	-8.893	-9.804	4.691	3.415	18.171	11.595
B-336xPop/209	133.715	97.915	41.509	31.085	5.818	4.931	22.379	16.565
B-336xB-316	-27.592	-60.510	-5.516	-19.210	6.315	5.424	24.292	18.221
B-336xEV-340	-36.628	-65.563	-7.297	-20.814	-0.995	-1.874	-3.826	-6.295
B-336xE-322	-39.691	-58.352	-10.048	-18.525	-7.122	-7.396	-27.543	-24.847
B-336x F-96	-93.237	-94.575	-45.371	-49.688	-9.245	-9.961	-35.577	-33.461
B-336x EV-347	-87.666	-89.306	-27.865	-28.352	4.866	4.142	18.745	13.914
EV-1097Qx Pop/209	-74.252	-77.016	-16.855	-16.960	2.797	2.388	10.711	7.951
EV-1097Qx B-316	-48.205	-69.788	-5.615	-12.070	5.295	4.876	20.275	16.234
EV-1097Qx EV-340	-19.534	-53.354	-2.261	-9.227	6.747	6.269	25.822	20.872
EV-1097QxE-322	-12.689	-25.799	-2.154	-4.462	6.905	6.746	26.587	22.528
EV-1097QxF-96	-66.012	-77.412	-26.615	-40.671	2.446	2.090	9.372	6.957
EV-1097QxEV-347	-25.240	-34.881	-5.916	-8.130	-0.648	-0.896	-2.487	-2.982
B-327xPop/209	-74.807	-86.704	-10.039	-19.093	-1.877	-3.311	-7.268	-11.264
B-327xB-316	80.266	28.378	1.902	0.818	-1.581	-3.019	-6.121	-10.270
B-327xEV-340	226.419	135.593	5.202	3.738	1.434	-0.097	5.547	-0.331
B-327xE-322	647.867	311.712	49.835	37.720	-1.229	-2.142	-4.782	-7.289
B-327xF-96	-19.032	-58.574	-5.907	-30.774	-0.543	-1.947	-2.104	-6.626
B-327xEV-347	82.730	-3.842	11.716	-0.896	-0.641	-1.947	-2.487	-6.626
Raka-poshixPop/209	62.628	-7.214	9.086	-1.589	0.739	-1.064	2.869	-3.644
Raka-poshixB-316	651.886	624.561	22.537	19.405	1.428	-0.387	5.547	-1.325
Raka-poshixEV-340	635.724	594.236	21.521	18.463	1.084	-0.774	4.208	-2.650
Raka-poshixE-322	162.161	64.736	14.238	7.834	0.784	-0.484	3.060	-1.657
Raka-poshixF-96	-69.941	-84.082	-22.470	-44.175	-0.689	-2.418	-2.678	-8.282
Raka-poshixEV-347	-19.281	-54.260	-2.940	-12.646	-1.573	-3.191	-6.121	-10.933
Sh-139xPop/209	12.075	-36.987	1.726	-8.145	4.536	2.813	17.597	9.608
Sh-139xB-316	97.784	92.973	3.174	2.679	5.030	3.298	19.510	11.264
Sh-139xEV-340	181.020	180.226	5.746	4.968	-5.871	-7.468	-22.762	-25.510
Sh-139xE-322	-1.049	-39.318	-0.090	-4.758	-4.169	-5.238	-16.258	-17.890
Sh-139xF-96	-21.257	-58.574	-6.784	-30.774	-6.358	-7.856	-24.674	-26.835
Sh-139xEV-347	140.120	34.180	21.072	7.966	-5.170	-6.596	-20.084	-22.528

Table 5: Heterosis and heterobeltiosis for Chlorophyll contents and stomata conductance

	Chlorophyll contents				**Stomata Conductance**			
Parents/Crosses	**Heterosis**	**Heterobeltosis**	**t_Hetr**	**t_Hetrb**	**Heterosis**	**Heterobeltosis**	**t_Hetr**	**t_Hetrb**
B-11xPop/209	675.560	658.700	2.270	1.960	-60.000	-71.429	-3.527	-5.090
B-11xB-316	-87.560	-93.690	-10.720	-19.602	-30.435	-42.857	-2.057	-3.054
B-11xEV-340	123.010	82.610	0.519	0.369	36.842	-7.143	2.057	-0.509
B-11xE-322	68.570	6.630	0.538	0.071	0.000	-21.429	0.000	-1.527
B-11xF-96	332.500	293.180	0.993	0.834	-51.724	-53.333	-4.408	-4.072
B-11xEV-347	116.010	9.550	13.475	1.895	30.769	21.429	2.351	1.527
B-336xPop/209	6525.530	6387.500	22.903	19.828	4.762	-26.667	0.294	-2.036
B-336xB-316	-93.790	-96.850	-11.496	-20.261	-33.333	-46.667	-2.351	-3.563
B-336xEV-340	491.450	401.450	2.147	1.791	30.000	-13.333	1.763	-1.018
B-336xE-322	3020.560	1911.450	24.135	20.520	13.043	-13.333	0.882	-1.018
B-336xF-96	7197.620	6285.420	22.574	19.511	-53.333	-53.333	-4.702	-4.072
B-336xEV-347	-93.000	-96.450	-10.817	-19.130	-25.926	-33.333	-2.057	-2.545
EV-1097QxPop/209	-27.760	-56.220	-0.273	-0.789	100.000	75.000	4.114	3.054
EV-1097QxB-316	-96.060	-97.900	-12.381	-20.481	64.706	55.556	3.233	2.545
EV-1097QxEV-340	2067.130	1328.110	22.074	18.638	23.077	0.000	0.882	0.000
EV-1097QxE-322	-60.310	-64.980	-0.863	-0.912	12.500	12.500	0.588	0.509
EV-1097QxF-96	-2.770	-43.320	-0.026	-0.608	-39.130	-53.333	-2.645	-4.072
EV-1097QxEV-347	-94.580	-97.100	-11.597	-19.259	10.000	-8.333	0.588	-0.509
B-327xPop/209	67.470	-0.410	0.728	-0.007	183.333	183.333	6.465	5.599
B-327xB-316	-89.480	-94.340	-11.619	-19.737	100.000	66.667	4.408	3.054
B-327xEV-340	42.950	-8.230	0.500	-0.129	209.091	183.333	6.759	5.599
B-327xE-322	1455.990	1209.470	22.234	19.007	142.857	112.500	5.877	4.581
B-327xF-96	2116.490	1172.430	22.048	18.425	-42.857	-60.000	-2.645	-4.581
B-327xEV-347	22.360	-33.970	2.764	-6.738	0.000	-25.000	0.000	-1.527
Raka-poshixPop/209	-38.910	-67.470	-1.094	-3.085	33.333	0.000	1.763	0.000
Raka-poshixB-316	58.800	-3.250	8.655	-0.679	4.762	-8.333	0.294	-0.509
Raka-poshixEV-340	679.900	328.010	19.699	14.997	64.706	16.667	3.233	1.018
Raka-poshixE-322	626.920	348.800	20.435	15.948	0.000	-16.667	0.000	-1.018
Raka-poshixF-96	-86.000	-92.640	-2.386	-4.236	3.704	-6.667	0.294	-0.509
Raka-poshixEV-347	-96.290	-97.720	-13.568	-19.382	-25.000	-25.000	-1.763	-1.527
Sh-139xPop/209	1455.880	774.390	22.668	18.580	-27.273	-33.333	-0.882	-1.018
Sh-139xB-316	-90.460	-94.680	-12.180	-19.809	42.857	11.111	1.763	0.509
Sh-139xEV-340	120.910	31.000	1.986	0.744	0.000	0.000	0.000	0.000
Sh-139xE-322	33.330	-3.500	0.668	-0.084	23.077	0.000	0.882	0.000
Sh-139xF-96	138.820	31.000	2.110	0.744	-50.000	-66.667	-2.939	-5.090
Sh-139xEV-347	78.820	0.230	10.118	0.045	-29.412	-50.000	-1.469	-3.054

Table 6: Heterosis and heterobeltiosis for Transpiration rate and Sub-stomata CO_2 concentration

	Transpiration	Rate			Sub-Stomata	CO_2 Concentration		
Parents/Crosses	**Heterosis**	**Heterobeltosis**	**t_Hetr**	**t_Hetrb**	**Heterosis**	**Heterobeltosis**	**t_Hetr**	**t_Hetrb**
B-11xPop/209	2.372	-38.626	1.318	-31.017	286.678	209.030	73.324	57.935
B-11xB-316	63.043	-11.137	31.860	-8.943	95.051	54.043	24.024	14.979
B-11xEV-340	75.630	-0.948	39.550	-0.761	142.070	138.431	46.173	39.557
B-11xE-322	-24.878	-45.261	-16.809	-36.345	-12.658	-44.205	-2.588	-12.252
B-11xF-96	-44.065	-51.422	-35.485	-41.292	45.066	32.749	13.198	9.077
B-11xEV-347	88.362	3.555	45.043	2.854	304.468	156.199	61.722	43.292
B-336xPop/209	74.000	4.567	40.649	3.615	-90.809	-94.369	-10.654	-15.651
B-336xB-316	2.203	-44.231	1.099	-35.013	680.000	380.698	77.724	61.147
B-336xEV-340	-5.532	-46.635	-2.856	-36.915	-89.364	-93.987	-16.670	-26.857
B-336x E-322	-54.351	-66.587	-36.364	-52.709	162.745	95.146	10.740	7.321
B-336x F-96	-69.464	-73.317	-55.480	-58.037	24.581	-27.597	3.796	-6.350
B-336x EV-347	84.716	1.683	42.626	1.332	206.040	130.303	13.242	9.637
EV-1097Qx Pop/209	128.916	53.226	47.021	25.118	166.414	58.108	18.913	9.637
EV-1097QxB-316	103.497	17.339	32.519	8.182	103.509	21.395	11.452	3.436
EV-1097QxEV-340	35.099	-17.742	11.645	-8.373	39.387	-22.745	7.203	-6.499
EV-1097QxE-322	-12.018	-21.774	-5.823	-10.275	705.536	465.049	43.973	35.784
EV-1097QxF-96	-48.837	-54.019	-29.992	-31.968	194.134	66.883	29.265	15.390
EV-1097QxEV-347	-48.276	-69.758	-15.381	-32.919	657.295	437.374	39.832	32.348
B-327xPop/209	-63.636	-71.429	-9.228	-11.417	-32.685	-60.689	-21.760	-59.915
B-327xB-316	0.000	-10.417	0.000	-0.951	-28.083	-58.191	-18.611	-57.449
B-327xEV-340	19.608	12.963	2.197	1.332	-52.993	-69.694	-38.948	-68.805
B-327xE-322	-53.527	-70.984	-14.172	-26.069	-86.732	-92.849	-53.289	-91.665
B-327xF-96	-4.735	-45.016	-1.868	-26.640	-69.438	-81.158	-48.804	-80.123
B-327xEV-347	248.889	227.083	24.609	20.741	-70.785	-84.298	-43.369	-83.223
Raka-poshixPop/209	264.602	145.238	32.849	23.215	16.977	8.238	3.537	1.606
Raka-poshixB-316	523.881	450.000	38.561	32.539	40.966	28.544	8.411	5.566
Raka-poshixEV-340	369.880	261.111	33.728	26.830	9.557	-7.843	2.653	-2.241
Raka-poshixE-322	125.225	29.534	30.542	10.846	42.857	-0.383	6.729	-0.075
Raka-poshixF-96	32.941	-27.331	12.305	-16.174	-30.756	-36.039	-7.548	-8.292
Raka-poshixEV-347	553.521	452.381	43.176	36.154	404.444	247.893	62.800	48.335
Sh-139xPop/209	111.715	63.226	29.333	18.648	-1.568	-43.005	-1.100	-45.123
Sh-139xB-316	176.684	72.258	37.463	21.312	-20.531	-54.183	-14.341	-56.852
Sh-139xEV-340	138.278	60.645	31.750	17.887	-95.915	-97.401	-73.928	-102.198
Sh-139xE-322	-43.103	-48.705	-16.479	-17.887	-61.327	-79.245	-39.875	-83.148
Sh-139xF-96	-50.215	-62.701	-25.708	-37.106	-76.818	-85.867	-56.740	-90.096
Sh-139xEV-347	-65.482	-78.065	-14.172	-23.025	-80.047	-89.320	-51.909	-93.719

Table 7: Heterosis and heterobeltiosis for water use efficiency

Parents/Crosses	Hetr	Hetrb	t_Hetr	t_Hetrb	Parents/Crosses	Hetr	Hetrb	t_Hetr	t_Hetrb
B-11xPop/209	21.070	-29.010	4.500	-9.150	B-327xPop/209	-61.920	-79.109	-21.975	-44.320
B-11xB-316	55.360	24.075	16.102	7.594	B-327xB-316	-55.650	-70.370	-24.055	-39.424
B-11xEV-340	-59.780	-62.056	-20.543	-19.574	B-327xEV-340	-68.060	-76.056	-33.007	-42.609
B-11xE-322	-8.140	-20.912	-2.553	-6.596	B-327xE-322	-95.930	-97.135	-43.639	-54.418
B-11xF-96	-18.380	-48.254	-4.244	-15.220	B-327xF-96	-65.200	-79.976	-24.271	-44.805
B-11xEV-347	170.910	46.504	33.662	14.668	B-327xEV-347	-65.860	-82.146	-22.281	-46.021
B-336xPop/209	-16.930	-46.370	-2.360	-8.674	Raka-poshixPop/209	53.330	7.982	5.781	1.064
B-336xB-316	40.750	40.255	8.834	7.584	Raka-poshixB-316	-17.590	-29.643	-3.268	-5.585
B-336xEV-340	24.210	3.634	6.525	1.017	Raka-poshixEV-340	-37.500	-53.860	-8.943	-15.068
B-336xE-322	-27.630	-34.085	-6.616	-7.761	Raka-poshixE-322	-0.800	-21.361	-0.166	-4.864
B-336xF-96	309.580	197.321	48.543	36.912	Raka-poshixF-96	254.250	189.424	31.975	25.252
B-336xEV-347	1572.040	850.998	193.137	159.194	Raka-poshixEV-347	290.800	133.109	26.701	17.744
EV-1097QxPop/209	727.100	423.553	108.810	86.719	Sh-139xPop/209	-39.610	-67.769	-19.717	-54.737
EV-1097QxB-316	304.560	288.418	69.130	59.051	Sh-139xB-316	37.670	-15.109	21.664	-12.203
EV-1097QxEV-340	49.040	29.062	13.719	8.130	Sh-139xEV-340	-15.360	-43.019	-9.641	-34.746
EV-1097QxE-322	-0.180	-5.211	-0.044	-1.187	Sh-139xE-322	-60.170	-74.470	-35.969	-60.149
EV-1097QxF-96	18.950	-15.970	3.165	-3.270	Sh-139xF-96	-82.940	-90.579	-42.725	-73.160
EV-1097QxEV-347	-38.770	-65.540	-5.159	-13.419	Sh-139xEV-347	-96.270	-98.078	-46.325	-79.217

Conclusions

It was concluded that B-336 × B-316, EV-1097Q × EV-340, EV-1097Q × E-322, B-336 × Pop/209, B-336 × F-96, B-327 × F-96, B-327 × EV-340, B-327 × Pop/209, B-327 × E-322 showed higher heterosis and heterobeltiosis for all traits. Higher values of heritability, genetic advance, heterosis and heterobeltiosis indicated that selection of higher grain yielding maize genotypes of batter photosynthetic rate may be made on the basis of physiological traits of maize.

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