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ASSESSMENT OF COMBINING ABILITY AND HETEROSIS FOR YIELD AND YIELD RELATED TRAITS IN MAIZE (*ZEA MAYS* L.)

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Abstract

The present investigation was conducted at Department of Genetics and Plant Breeding, School of Agriculture, Lovely Professional University, Jalandhar, Punjab during 2015-2016. The experimental material consisted of 7 inbreed lines with 3 tester in maize and 21 F_1s, along with one check (P-1543). All these are were grown in a Randomized Block Design (RBD) with three replications. The hybrids were evaluated to know the extent of heterosis and combining ability for grain yield per plant, yield contributing characters in maize. Considerable variability existed among the genotypes for all the characters studied as observed from the significant mean squares due to genotypes. Combining ability analysis showed the predominant role of non-additive gene action for all characters studied. The line I-07-19-6 was found to be good general combiner and tester CML-269 was found average combiners for grain yield per plant. Crosses I-07-19-6 x CM-140, I-07-19-5 x CML-269 and I-07-26-7 × CML-269 revealed high specific combining ability effects for grain yield per plant. The hybrids I-07-19-6 × CM-140, I-07-19-2 × HKI-193-1 and I-07-19-5 × CML-269 were identified as superior hybrids as it recorded high percentage of relative heterosis, heterobeltiosis and standard heterosis for grain yield per plant along with other characters. These hybrids were identified as potential hybrids for widespread cultivation and commercial exploitation.

Key words: Combining ability, Heterosis, Maize.

Introduction

Maize is the third most important cereal grain in world and it's mainly utilized for direct human consumption and livestock feed. One of the most important objectives of maize breeding is the production of high yielding hybrids. Good results have been achieved in increasing maize yield through the successful exploitation of heterosis. Maize is a highly cross pollinated crop and the scope for the exploitation of hybrid vigor will depend on the magnitude of heterosis and direction, biological feasibility and the type of gene action involved. Maize is one of the world's leading crops cultivated over an area of about 161.0 million ha with a production of about 822.0 million tons and average productivity is 5100 kg/ha^{-1} (Food Corporation of India, 2015). Maize is not only used as food, feed and fodder but also used for some five hundred different industrial purposes for manufacturing. Maize has been widely cultivated as a rainfed crop in India. Recent studies have shown that maize can be successfully grown during *rabi* in many parts of the country due to evolution of new improved cultivars and assured irrigation facility as well. The yield level of maize during *rabi* season is considerably higher than that of *kharif* due to its higher water and fertilizer use efficiencies. More over recent emphasis on development of hybrids meant for both the seasons, has paid rich dividends in terms of higher maize production and productivity in the country.

Material and methods

The experimental materials consisted of seven lines I-07-21-3, I-07-26-7, I-07-27-9, I-07-19-2, I-07-19-4, I-07-19-5, I-07-19-6 and three testers HKI-193-1, CML-269, CM-140 of maize with diverse genetic base. Their 21 cross combinations were recovered through Line × Tester mating design. The 21 F_1s, 10 parents and one standard checks (P-1543) were grown in a randomized block design with three replications with spacing of 60 × 20 cm at Department of Genetics and Plant Breeding, Lovely Professional University, Jalandhar, Punjab during 2016.

Five randomly selected plants in each replication for each cross were used for recording observations *viz.,*

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days to 50% tasselling, days to 50% silking, plant height, length of ear, number of seed rows per ear, No of rows per ear, 1000 grain weight, width of ear, grain yield per plant and days to maturity. The analysis of variance for the experimental design was analyzed by the method given by Panse and Sukhatme (1967). The magnitude of standard heterosis was calculated as by increase of mean F_1 performance over that of mean performance of the standard variety. Relative heterosis was estimated for hybrids as per Turner (1953), heterobeltiosis as per Fonseca and Patterson (1968) and combining ability variance analysis was based on the method developed by Kempthorne (1957).

Results and discussion

The results of analysis of variance are presented in table 1. Considerable variability existed among the genotypes for all the characters studied as observed from the significant mean squares due to genotypes. The mean squares due to parents were found to be significant for all the characters excepted grain yield per plant. Significant mean squares for the hybrids were recorded for all the characters. The mean squares due to parents vs. hybrids was found to be significant for day to 50% silking, no of rows per ear, no. of seed per row, 1000 grain yield, width of ear and grain yield per plant which indicated that the parents chosen were diverse and with a different genetic background. The above results were also reported by Bajaj *et al.* (2007), Hemavathy and Balaji (2008), Abdel-Moneam *et al.* (2009), Yusuf *et al.* (2009) and Sundararajan and Shenthil (2011).

The results on relative heterosis, heterobeltiosis and standard heterosis for various characters revealed that the estimates and magnitude of various heterotic effects varied with cross combinations and characters. The hybrid I-07-19-6 × CM-140 recorded significant relative heterosis and heterobeltiosis for days to 50% silking, no. of rows per ear, 1000 grain weight, days to 50% tasseling in desirable direction.

Table 1: Analysis of variance for different characters of maize.

Source of variation	d.f.	Days to 50% Tasselling	Days to 50% Silking	Plant height (cm)	Length of ear (cm)	No. of rows per ear	No. of seeds per row	1000 seed weight (g)	Width of ear (cm)	Grain yield/ plant (g)	Days to maturity
Replications	2	0.5036	0.160	580.38	0.1563	0.7088	0.1346	1.095	0.0947	14.01	10.400
Genotypes	30	33.34**	28.23**	2624.05**	4.764**	4.039**	5.889**	2010.00**	1.350**	279.64	30.498**
Parents (P)	9	21.43**	44.87**	3467.53**	2.672**	6.350**	1.994	1416.46**	1.080**	222.33	45.657**
Lines	6	17.08**	49.11**	3453.03**	2.704**	6.816**	2.268	1798.31**	0.286	195.411	65.874**
Testers	2	10.72**	52.88**	2090.30*	0.8577	7.897**	0.5200	352.19**	0.0533	320.88	7.737
L Vs T	1	68.93**	3.446*	6309.01**	6.113**	0.458	3.300	1253.91**	7.880**	186.74	0.192
P Vs H	1	0.0230	40.90**	330.19	0.04801	13.68**	10.609*	1430.49**	2.939**	413.62	9.335
Hybrids (H)	20	40.37**	20.11**	2359.17**	5.942**	2.516**	7.406**	2306.07**	1.392**	298.73*	24.735**
Error	60	0.281	0.4377	298.96	0.3032	0.3666	1.219	12.706	0.2062	114.70	5.380

*, ** indicate level of significance at 5% and 1%, respectively.

Table 2: Manifestation of relative heterosis, heterobeltiosis and standard heterosis for other characters in three crosses showing higher grain yield per plant in Maize.

Hybrids	Heterosis over	Days to 50% Tasselling	Days to 50% Silking	Plant height (cm)	Length of ear (cm)	No. of rows per ear	No. of seeds per row	1000 seed weight (g)	Width of ear (cm)	Grain yield/ plant (g)	Days to maturity
I-07-10-1	RH	-14.56**	-5.46**	-14.94*	0.17	-8.71**	-2.30	13.57**	5.65*	16.10**	-0.69
×	HB	-14.62**	-11.67**	-15.16	-1.82	-15.38**	-3.42	9.80**	0.44	16.02*	-1.82
HKI-163	SH	-13.64**	1.19	-17.43	-4.54	-1.79	-14.69	4.46**	3.27	16.19	0.12
I-07-8-6	RH	2.92**	4.93**	-13.95*	-12.52**	-16.20**	5.68**	-6.98**	-0.58	15.70*	-2.89
×	HB	2.42**	4.32**	-16.28*	-19.06**	-20.16**	5.31	-16.10**	-3.33	13.72	-4.43**
CLQ-30	SH	4.70**	6.68**	10.33	-16.10**	-13.69**	8.25**	-13.47**	-2.36	1.66	-3.88**
I-07-7-4	RH	14.18**	-9.63**	11.08	-3.72	15.21**	2.41	0.03	2.94	12.73	-2.77
X	HB	5.28**	-10.54**	9.74	-3.62	12.61**	-0.47	-0.39	0.71	8.11	-3.11
CLQ-30	SH	13.75**	1.31**	35.34**	-2.81	11.61**	-14.69**	-4.40**	2.68	13.13	-2.49

*, ** indicate Significant at 5% and 1% levels, respectively RH= Relative heterosis, HB= Heterobeltosis, SH= Heterosis over P-1543

Table 3: Analysis of combining ability and variance components of different characters in maize.

Source of variation	d.f.	Days to 50% Tasselling	Days to 50% Silking	Plant height (cm)	Length of ear (cm)	No. of rows per ear	No. of seeds per row	1000 seed weight (g)	Width of ear (cm)	Grain yield/ plant (g)	Days to maturity
Replications	2	0.297	0.299	160.83	0.392	0.431	1.604	2.813	0.0125	56.352	13.688
Hybrids (H)	20	40.373**	20.11**	2359.17**	5.942**	2.516**	7.406**	2306.07**	1.392**	298.73	24.735**
Lines (L)	6	55.88	21.30	2934.34	10.011	1.866	10.981	483.69	0.867	375.83	40.068
Testers (T)	2	10.18	13.53	55.05	2.120	1.135	3.509	3833.39	0.338	378.51	7.0177
L X T	12	37.64**	20.61**	2455.61**	4.544**	3.072**	6.268**	2962.70**	1.830	246.88	20.021*
Error	40	0.328	0.493	324.74	0.319	0.2761	1.203	7.224	0.2018	126.34	6.607
σ^2gca		-0.308	-0.213	-64.06	0.1014	-0.1047	0.065	-53.61	-0.0819	8.686	0.234
σ^2sca		12.45**	6.725**	718.88**	1.413**	0.9019	1.683**	983.33**	0.5414**	44.059	4.880**
σ^2gca/σ^2sca		-0.0246	-0.0316	-0.0891	0.0716	-0.1160	0.0386	-0.0545	-0.1513	0.197	0.0479
σ^2A		-1.230	-0.852	-256.24	0.405	-0.418	0.260	-214.44	-0.327	34.745	0.939
σ^2D		49.82	26.90	2875.53	5.655	3.607	6.731	3933.33	2.165	176.23	19.52
σ^2A/σ^2D		-0.024	-0.0317	-0.0891	0.0717	-0.1161	0.038	-0.0545	-0.151	0.1972	0.0481

*, ** indicate level of significance at 5% and 1%, respectively.

Table 4: Estimation of general combining ability effects of parents for various characters in maize.

Parents	Days to 50% tasseling	Days to 50% silking	Plant height (cm)	Ear Length (cm)	No. of rows per ear	No. of seeds per row	1000 seed weight (g)	Width of ear (cm)	Grain yield per plant (g)	Days to maturity
I-07-21-3	2.171**	0.003	-14.148	-0.981**	0.032	-0.683	7.419**	-0.073	0.889	0.978
I-07-26-7	2.127**	0.048	18.70*	0.339	0.410	-0.105	9.063**	-0.277	-4.967	-0.022
I-07-27-9	0.794**	-0.997**	11.188	0.201	0.676*	-0.371	2.330	0.351	-2.767	3.133**
I-07-19-2	-0.651**	1.425**	5.767	-1.510**	-0.746**	0.317	1.463	-0.446*	0.691	-3.089**
I-07-19-4	-0.651**	2.559**	9.381	0.419	-0.035	-0.683	-10.87**	-0.011	-8.689	0.489
I-07-19-5	1.216**	-1.441**	3.032	-0.215	-0.124	-0.816	-1.937	0.414*	3.466	-2.333
I-07-19-6	-5.006**	-1.597**	-33.922**	1.748**	-0.213	2.340**	-7.470**	0.043	11.377*	0.844
CM-140	-0.140	0.292	-0.489	-0.165	0.073	-0.321	9.892**	0.118	-2.626	0.054
CML-269	0.756**	-0.908**	-1.318	0.366*	0.187	0.460	5.502**	0.016	4.898	0.549
HKI-193-1	-0.616	0.616**	1.807	-0.201	-0.260	-0.140	-15.39**	-0.134	-2.272	-0.603
Range	-5.006	-1.597	-33.922	-1.510	-0.746	-0.683	-15.39	-0.446	-8.689	-3.089
	2.171	2.559	18.70	1.748	0.676	2.340	9.892	0.351	11.377	3.133

*, ** indicate level of significance at 5% and 1%, respectively.

The next hybrid I-07-19-2 × HKI-193-1 exhibited significant relative heterosis and heterobeltiosis for days to 50% tasseling, days to 50% silking, plant height, no of rows per ear, 1000 grain weight, grain yield per plant and significant standard heterosis over standard check P-1543 for days to 50% tasseling, days to 50% silking, number of seed rows per ear, length of ear, no. of seeds per row, 1000 grain weight, days to maturity in desirable direction.

The third hybrid I-07-19-5 × CML-269 showed significant relative heterosis and heterobeltiosis for days to 50% tasseling, days to 50% silking, number of seed rows per ear, grain yield per plant and significant heterosis over standard check P-1543 for in days to 50% tasseling, plant height, no of rows per ear, 1000 grain weight, desirable direction (table 2). A perusal of heterosis indicated that hybrids I-07-19-6 × CM-140 I-07-19-2 × HKI-193-1 and I-07-19-5 × CML-269 were identified as potential hybrids for widespread cultivation and commercial exploitation. The results confirm the findings of Verma *et al.* (2006), Bajaj *et al.* (2007), Hemavathy and Balaji (2008), Abdel-Moneam *et al.* (2009), Singh and Gupta (2009) and Sundararajan and Shenthil (2011).

Analysis of variance for combining ability revealed that mean square due to line × tester comparisons was found to be significant for all the traits under study excepted width of ear, grain yield per plant. The variance due to specific combining ability (σ^2sca) was significant for all the characters excepted no of rows per ear, grain yield per plant and higher than variance due to general combining ability (σ^2gca) indicating the influence of non

Table 5: Estimates of specific combining ability effects associated of hybrids for various characters in maize

Hybrids	Days to 50 % tasselling	Days to 50 % silking	Plant height (cm)	Length of ear (cm)	No. of rows per ear	No. of seeds per row	1000 seed weight(g)	Width of ear (cm)	Grain yield per plant (g)	Days to maturity
I-07-21-3× CM-140	0.362	-0.203	12.807	-0.848	-0.051	0.054	-49.981**	-0.058	-4.441	-1.054
I-07-21-3 ×CML-269	-1.400**	0.530	-33.840*	-0.620	-0.565	-0.327	36.543**	-0.109	0.335	0.051
I-07-21-3×HKI-193-1	1.038*	-0.327	21.034	1.468**	0.616	0.273	13.438**	0.167	4.106	1.003
I-07-26-7×CM-140	-1.194**	-0.648	1.648	0.318	-0.029	0.943	1.841	0.013	-3.619	2.413
I-07-26-7×CML-269	-2.089**	0.219	0.201	-1.200**	-0.143	-0.571	-28.568**	0.036	12.424	-5.016**
I-07-26-7×HKI-193-1	3.283**	0.429	-1.848	0.881*	0.171	-0.371	26.727**	-0.048	-8.805	2.603
I-07-27-9×CM-140	1.206**	3.463**	29.311*	1.216**	1.438**	1.276	0.108	1.404**	3.615	-0.410
I-07-27-9×CML-269	0.844*	1.263*	0.261	0.078	-0.810	-0.238	-32.102**	0.127	-5.709	1.895
I-07-27-9×HKI-193-1	-2.051**	-4.727**	-29.572*	-1.294**	-0.629	-1.038	31.994**	-1.530**	2.095	-1.486
I-07-19-2×CM-140	-3.083**	-0.892	21.169	0.721	0.860	0.187	2.708	-0.798*	1.723	-1.187
I-07-19-2×CML-269	-0.911*	-0.159	12.702	-0.304	0.079	-1.394	6.698*	0.444	-7.367	0.251
I-07-19-2×HKI-193-1	3.994**	1.051*	-33.871*	-0.417	-0.940	1.206	-9.406**	0.354	5.643	0.937
I-07-19-4×CM-140	3.851**	-1.492**	3.151	0.278	-0.384	0.787	-9.559**	-0.687	-3.397	1.168
I-07-19-4×CML-269	-2.378**	-2.959**	6.787	-0.140	0.168	0.206	17.565**	-0.298	-2.520	2.806
I-07-19-4×HKI-193-1	-1.473**	4.451**	-9.938	-0.139	0.216	-0.994	-8.006**	0.985**	5.917	-3.975*
I-07-19-5×CM-140	0.584	-1.559**	-28.640*	0.105	-1.762**	-0.479	42.041**	-0.312	-8.419	-1.876
I-07-19-5×CML-269	5.622**	2.441**	14.840	-0.073	1.724**	-0.327	-7.368**	0.084	10.891	0.629
I-07-19-5×HKI-193-1	-6.206**	-0.883	13.800	-0.032	0.038	0.806	-34.673**	0.227	-2.472	1.248
I-07-19-6×CM-140	-1.727**	1.330*	-39.446**	-1.790**	-0.073	-2.768**	12.841**	0.439	14.537	0.946
I-07-19-6×CML-269	0.311	-1.337*	-0.949	2.258**	-0.454	2.651**	7.232*	-0.284	-8.054	-0.616
I-07-19-6×HKI-193-1	1.416**	0.006	40.395**	-0.468	0.527	0.117	-20.073**	-0.155	-6.483	-0.330
Range	-6.206 to 5.622	- 4.727 to 4.451	-39.446 to 40.395	-1.294 to 2.258	-1.762 to 1.724	-2.768 to 2.651	-49.981 to 36.543	-1.530 to 1.404	-8.805 to 14.537	-5.016 to 2.806

*, ** indicate level of significance at 5% and 1%, respectively

additive gene action for expression of this trait as suggested by less than unity ratio of σ2σσγχα/σ2σχα. Τηε ratio of additive to dominance (σ^2A/σ^2D) was lower than unity for all character and it indicates the higher magnitude of sca variances than gca variances *i.e.* higher dominant variances than additive variances suggesting the scope of improvement of these characters through heterosis breeding (table 3). Similar non-additive gene action was also reported by Lukose and Godawat (2007), Hemavathy and Balaji (2008) and Abdel-Moneam *et al.* (2009), Sundarajanan and Shenthil Kumar (2011).

Selection of parents with good general combining ability is a prime requisite for any successful breeding programme especially for heterosis breeding. Based on the GCA effects the line I-07-19-5 was good general combiner for days to 50% silking, Width of ear, days to maturity while line I-07-19-6 was good general grain yield per plant along with combiner for grain yield per plant along with days to 50% tasselling, days to 50% silking, plant height, length of ear, no of seed per row. In case of testers CML-269 was average general combiner for grain yield per plant, Days to 50% tasseling, length of ear (table 4).

Among hybrids I-07-19-5 × HKI-193-1 showed highest negative and significant SCA effects for days to 50 % tasselling, I-07-27-5 × HKI-193-1 for days to 50% silking, I-07-19-6 × CM-140 for plant height and I-07-26-7 × CML-269 for days to maturity. Hybrid I-07-19-6 × CML-269 showed highest positive and significant SCA effects number of seeds per row, I-07-19-6 × CML-269 for length of ear, I-07-19-5 × CML-269 for number of seed rows per ear, I-07-19-5 × CM-140 for 1000 grain weight, I-07-27-9 × CM-140 for width of ear. Three hybrids I-07-19-6 × CM-140 I-07-19-2 × HKI-193-1 and I-07-19-5 × CML-269 showed highest significant SCA effects for grain yield per plant. These hybrids were also having good SCA effects for different yield components *viz.*, days to 50% tasselling, days to 50% silking, plant height, length of ear, number of seed rows per ear, No of seeds per row, 1000 grain weight, Width of ear .These hybrids could be utilized in heterosis breeding to exploit hybrid vigour for grain yield per plant (table 5). The results are in accordance with the findings of Verma *et al.* (2006), Lukose and Godawat (2007), Hemavathy and Balaji (2008), and Abdel-Moneam *et al.* (2009), Jagdish *et al*, (2015), Lekha Ram (2015).

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