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RESEARCH PAPER

Combining ability and heterosis studies in single cross hybrids synthesized from CIMMYT based inbred lines of maize (*Zea mays* L.)

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Abstract: Combining ability and heterosis for grain yield and growth characters were studied in maize through line x tester mating design using twenty-six lines and two testers along with three checks. The variance due to SCA was higher than GCA indicating the predominance of non-additive type of gene action for most of the yield attributing traits except days to 50 per cent tasseling, days to 50 per cent silking, cob length and brown husk maturity. The lines *viz.,* CIMMYT10, CIMMYT16 and CIMMYT23 and the tester KDMI6 were found to be the best general combiners with better performance for most of the yield attributing traits. Among the hybrids, GH1628 and GH1630 were identified as superior as they recorded high magnitude of *per se* performance along with significant positive *sca* effects and standard heterosis for grain yield.The hybrids, GH1628 and GH1630 involving parents of positive and significant *gca* effects and high heterosis for grain yield could be exploited further after testing across locations and environments to ascertain their yield stability. From the study it was evident that the single cross hybrids synthesised by using exotic (CIMMYT) lines as females will improve cob and grain traits in domestic maize hybrids.

Key words: Combining ability, Gene action, Heterosis, Maize

Introduction

Maize is a highly cross pollinated crop and there is a wide scope for exploitation of hybrid vigour, hence it has been successfully exploited for the production of hybrids. Parental selection is very important in hybrid development. Among different statistical designs line × tester method is considered one of the efficient one for estimating the general and specific combining ability and hybrid vigour (Kempthorne, 1957). The value of any inbred line in hybrid breeding ultimately depends on its ability to combine very well with other lines to produce superior hybrids. Hence, combining ability analysis is an important tool to identify parents with better potential to transmit desirable characteristics to the progenies and to identify the best specific cross for yield.

The exploitation of heterosis in maize can be accomplished through the development and identification of high per se performance, vigorous parental lines and their subsequent evaluation for combining ability in cross combinations to identify the hybrids with high significant heterosis. The information about the heterosis and combining ability of the parents and crosses facilitate the breeders in the selection and development of single cross hybrids.

Material and methods

The present investigation was carried out at Main Agricultural Research Station (MARS), Dharwad. Base population was raised and crossing programme was conducted during *rabi* 2015-2016. The evaluation of parents and F_1s were carried out during *kharif* 2016.The experimental material for present study comprised of 26 newly received inbred lines from CIMMYT and two indigenous testers. The 52 single cross hybrids were developed by using L × T mating design, by crossing 26 inbred lines with two testers during *rabi* 2015-2016.

The 52 F_1hybrids thus generated from the above Line x Tester crossing programme were evaluated in RBD (Randomized Block Design) with two replications along with parental lines and three check hybrids (GH0727, BIO-9681 and 900 M Gold). Each entry was raised in two rows of four meter length following a spacing of 60 x 20cm. The observations were recorded on twelve quantitative characters *viz.,* plant height (cm), ear height (cm), days to 50 per cent tasseling, days to 50 per cent silking, cob length (cm), cob girth(cm), number of kernel rows per ear, number of kernels per row, 100-grain weight (g), Shelling percentage, brown husk maturity and grain yield (q/ha). Observations related to days to 50 per cent tasseling, days to 50 per cent silking, brown husk maturity and grain yield (q/ha) were recorded on plot basis while other characters were recorded on five randomly selected competitive plants leaving border plants of each row. Data of all the biometrical traits were subjected to the analysis of variance for Line x Tester mating design as suggested by Kempthorne (1957).

Results and discussion

Analysis of variance for combining ability in respect of 12 quantitative traits under study is presented in Table 1. The analysis of variance for combining ability revealed that lines had significant amount of variability for all the characters, while testers had significant variability for days to 50 per cent tasseling,days to 50 per cent silking, number of kernel rows per ear and number of kernels per row. However, crosses had significant amount of variability for all characters except cob length and cob girth. The parents *vs* crosses were significant for majority of the characters except number of kernels per row and brown husk maturity which suggested the presence of substantial amount of heterosis in crosses for majority of the characters. In case of Line x Tester effects significant amount

Table 1. ANOVA for Combining ability by line x tester analysis for 12 quantitative characters in maize

Source of variation Characters	Replication	Parents	Females (Lines)	Males (Testers)	Females vs Males	Parents vs Crosses	Crosses	Line effect	Tester effect	Line × tester effect	Error
Degrees of freedom	1	27	25	1	1	1	51	25	1	25	79
Plant height (cm)	87.02	186.01*	187.67*	2.25	328.46	1768.2**	175.00*	166.66	336.24	176.9	107.6
Ear height (cm)	204.75	268.41**	286.81**	6.25	70.78	1885.1**	130.49*	93.60	264.96	162.0*	75.16
Days to 50% tasselling	5.625	12.20**	12.03**	16.00**	12.65**	116.7**	9.43**	12.29**	84.96**	3.56**	1.14
Days to 50% silking	10.00	12.14**	11.78**	20.25**	13.19**	134.6**	8.71**	12.89**	67.84**	2.16**	1.07
Cob length (cm)	1.58	3.88**	3.78**	4.20	6.10	12.04**	1.97	1.561	21.82**	1.58	1.62
Cob girth (cm)	0.29	0.10**	0.20*	0.034	0.01**	1.69**	0.041	0.359*	0.19	0.145	0.043
Number of kernel rows per ear	2.02	1.36**	1.23**	4.00*	1.94	3.24*	1.13**	1.739**	2.10*	0.493	0.605
Number of kernels per row	7.48	13.00**	10.65**	53.29**	31.40*	16.91	12.49**	10.76	52.79	12.60**	5.103
Shelling percentage	0.32	2.28**	2.45**	0.057	0.203	12.14**	2.36**	2.676	7.75	1.83	1.03
100 grain weight (g)	27.04	27.13**	27.09**	6.25	25.06**	179.58**	9.37*	11.76	1.038	7.35	6.02
Brown husk maturity	4.83	17.58**	18.83**	4.00	0.087	9.15	7.65**	9.183*	48.47**	4.491*	2.94
Grain yield (q/ha)	0.092	85.18**	88.27**	45.69	47.43	2331.0**	168.6**	200.9	438.00	125.62**	18.92

* Significant at 5% level ** Significant at 1% level

of variability was observed for ear height, days to 50% tasseling, days to 50% silking, number of kernels per row, brown husk maturity and grain yield (q/ha).

The proportional contribution of lines, testers and their interaction to total hybrid variances for the characters are presented in Table 2. In this study, it is clear that contribution of females towards total hybrid variance was higher than males for all characters. On the other hand, the contribution of females x males interaction for the total hybrid variance was higher than the females for plant height, ear height, cob length and number of kernels per row. This indicates that specific cross combinations interact significantly to improve the per se values for important traits of yield.

The predominant component of genetic variation determines the choice of an efficient breeding method for incorporation of concerned genes into new materials.However, the ratio of variance to the total variance suggested the preponderance of non-additive gene action for majority of the

Table 2. Proportional contributions of lines, testers and their interaction to total hybrid variance and estimation of genetic components of variance for different characters

Characters	Characters contribution (%)			6^2_{gca}	6^2_{sca}	$6^2_{gca}/ 6^2_{sca}$
	Lines	Testers	Line × Tester			
Plant height (cm)	46.6822	3.7673	49.5505	5.137	34.646	0.148
Ear height (cm)	35.1615	3.9814	60.8571	3.718	43.420*	0.085
Days to 50% tasselling	63.8543	17.6494	18.4963	1.695**	1.208**	1.402
Days to 50% silking	72.5463	15.2674	12.1863	1.403**	0.545*	1.380
Cob length (cm)	38.8322	21.7035	39.4643	0.359**	-0.018	-19.86
Cob girth (cm)	52.4240	2.0644	45.5116	0.25**	0.63	0.396
Number of kernel rows per ear	75.0710	3.6360	21.2929	0.047**	-0.055	-0.842
Number of kernels per row	42.2456	8.2871	49.4673	0.952*	3.751**	0.253
Shelling percentage	55.4752	6.4299	38.0949	0.149**	0.402*	0.371
100 grain weight (g)	53.7603	1.3054	44.9343	0.013	0.666	0.020
Brown husk maturity	58.8176	12.4178	28.7646	0.924**	0.772	1.196
Grain yield (q/ha)	58.4013	5.0914	36.5073	10.734*	53.352**	0.201

traits *viz.,* plant height, ear height, cob girth, number of kernels per row, shelling percentage, 100-grain weight and grain yield (q/ha).

The general combining ability effects of parents for all the traits studied are presented in Table 3. For improving the early maturity maize genotypes lower values of days to 50 per cent tasselling, days to 50 per cent silking and brown husk maturity are favourable, therefore ten lines with significant negative gca effects were considered as good combiners for improving these maturity trait. The parent CIMMYT16 showed significant positive gca effects for cob girth and grain yield whereas negative gca effects for days to 50 per cent tassseling and days to 50 per cent silking, while parent KDMI6 showed significant positive gca effects for number of kernel rows per ear and grain yield. Therefore, these two parents, CIMMYT16 and KDMI6 combine well for the inheritance of above mentioned traits. The present study revealed CIMMYT16 as a good combiner for most of the traits. These results were in agreement with the earlier findings of Wali *et al.* (2010), Palkar *et al.* (2013), Rajitha *et al.* (2014), Mahdi *et al.* (2011) and Muttappa Hosamani *et al.* (2014). This combining ability is not fixed property of the line but it depends upon the tester population used (Rissi and Hallauer, 1991).

The results of sca effects of crosses for the different traits are presented in Table 4. The positive sca effects suggested that those respective specific combinations would be useful to breeders as would lead to improvement of those traits in maize breeding program. Hybrids having significant positive sca are

Table 3. General combining ability (gca) effects of parents in respect of 12 characters

Parents	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
CIMMYT-1	3.548	-0.500	1.077*	1.42**	0.886	-0.380 *	0.673	0.468	0.137	-2.096	1.394	11.72**
CIMMYT-2	-4.952	-2.000	0.327	0.423	0.161	-0.355 *	-0.327	-0.582	-0.205	0.404	1.144	12.90**
CIMMYT-3	10.430*	1.390	1.577**	2.17**	-0.852	0.452 *	0.073	2.318*	0.730	-0.596	0.894	10.87**
CIMMYT-4	-1.202	-4.000	2.077**	1.42**	0.361	-0.142	0.673	0.068	0.042	1.354	-0.106	13.84**
CIMMYT-5	-12.452 *	-8.000	2.57**	2.42**	-0.014	0.481**	0.273	0.018	-1.038*	0.904	0.394	2.264
CIMMYT-6	2.798	-6.000	1.827**	2.47**	0.636	-0.362*	0.273	1.518	1.175*	-0.096	2.39**	-1.283
CIMMYT-7	-10.480*	-0.750	0.827	0.923	0.436	-0.285	-0.527	0.068	-1.303*	3.90**	0.644	6.139**
CIMMYT-8	-8.160	-1.500	0.577	0.173	-0.539	-0.462**	-0.927*	-1.532	-0.278	-2.096	0.144	-8.178**
CIMMYT-9	1.298	9.380*	-1.423*	-2.32**	-0.664	-0.485*	-0.927*	-1.257	0.367	-1.846	-1.456	-13.15**
CIMMYT-10	-0.702	1.000	-2.173**	-2.57**	0.036	-0.267	-0.327	-0.132	-0.468	0.404	-1.856*	-4.898 *
CIMMYT-11	-2.202	-5.500	0.577	0.423	0.636	-0.280	0.573	0.168	-0.435	-0.596	0.394	-0.718
CIMMYT-12	-1.202	5.000	-4.173**	-3.82**	-0.839	-0.410*	-1.027*	0.118	0.792	-1.346	-3.85**	-13.26**
CIMMYT-13	-1.702	-1.000	-2.673**	-2.57**	-1.074*	-0.227	-0.327	-4.00**	-0.528	-0.596	-3.60**	-10.32**
CIMMYT-14	6.298	8.850*	1.077*	1.42**	0.511	-0.300	0.073	0.868	0.560	1.454	1.144	-0.083
CIMMYT-15	-4.952	5.250	1.827**	1.92**	1.286*	-0.197	0.473	2.318*	1.63**	1.354	0.894	-0.331
CIMMYT-16	-1.702	-4.250	-2.923**	-3.47**	0.336	-0.210	1.47**	-0.632	-0.553	-1.596	-1.606	9.679**
CIMMYT-17	3.548	2.000	-1.973**	-1.87**	-0.164	-0.500**	-0.427	-0.032	0.942	-1.596	-0.806	-0.713
CIMMYT-18	6.548	-6.750	-1.327*	-0.877	-0.839	-0.575**	-0.727	0.218	-0.235	-3.34**	0.894	-1.218
CIMMYT-19	4.048	2.750	1.077*	1.173 *	0.336	-0.185	0.673	0.818	-0.598	-0.346	0.144	5.382*
CIMMYT-20	3.298	-8.750*	0.077	0.173	0.661	-0.150	-0.427	-1.832	-1.60**	3.40**	-1.356	-3.111
CIMMYT-21	16.298**	-2.750	0.827	1.42**	-0.239	0.312**	0.573	-3.63**	-0.928	2.154	0.644	5.662*
CIMMYT-22	-1.652	-4.250	-1.921**	-0.933	1.48**	-0.242	0.373	2.168	0.635	-0.096	-1.506	5.717*
CIMMYT-23	-2.452	-6.750	0.077	-0.423	1.011	-0.110	0.973*	0.618	-0.218	1.954	1.144	-0.918
CIMMYT-24	-6.702	3.000	1.577**	1.173*	0.986	-0.132	-0.627	2.568*	1.39**	2.514*	2.39**	-0.633
CIMMYT-25	0.798	7.250	-1.873**	-1.97**	-0.964	-0.340 *	-1.027*	-1.107	1.090*	1.154	-1.408	-2.893
CIMMYT-26	5.548	8.000	-1.423 *	-1.077*	-0.739	0.290	-0.720	-2.382*	0.187	-0.846	-1.606	-7.58**
Males (Testers)												
CI-5	-1.798	-1.596	-0.904**	-0.80**	-0.187	-0.28**	-0.142	-0.713*	0.273	-0.019	-0.68**	-2.052**
KDMI-6	1.798	1. 596	0.904**	0.80**	0.187	0.28**	0.142	0.713*	-0.273	0.019	0.68**	2.052 **
C.D. at 5% female	10.412	8.7025	1.0736	1.0412	1.069	0.309	0.7809	2.2677	1.0201	2.4640	1.7228	4.3664
C.D. at 1% female	13.878	11.5987	1.4309	1.3877	1.424	0.412	1.0408	3.0224	1.3596	3.2840	2.2961	5.8195
S.Em±	5.186	4.3348	0.5348	0.5186	0.532	0.154	0.3890	1.1296	0.5081	1.2273	0.8581	2.1749
C.D. at 5% male	2.888	2.4136	0.2978	0.2888	0.296	0.085	0.2166	0.6289	0.2829	0.6834	0.4778	1.2110
C.D. at 1% male	3.849	3.2169	0.3969	0.3849	0.395	0.114	0.2887	0.8383	0.3771	0.9108	0.6368	1.6140
S.Em±	1.438	1.2023	0.1483	0.1438	0.147	0.042	0.1079	0.3133	0.1409	0.3404	0.2380	0.6032

*Significant at 5% level
**Significant at 1% level

X1 - Plant height (cm)	X4 – Days to 50% silking	X7 – Number of kernel rows per ear	X10 – 100-grain weight (g)
X2 - Ear height (cm)	X5 - Cob length (cm)	X8 – Number of kernels per row	X11– Brown husk maturity
X3 – Days to 50% tasselling	X6 – Cob girth (cm)	X9 – Shelling percentage	X12 – Grain yield (q/ha)

Table 4. Specific combining ability (*sca*) effects of single cross hybrids in respect of 12 characters

Hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
GH1601	-2.702	-1.404	0.904	0.808	0.162	0.287	0.242	1.913	-0.121	0.019	0.433	-2.808
GH1602	5.298	11.096	0.654	0.808	0.587	0.482*	0.242	0.162	-1.003	0.108	0.183	-16.245**
GH1603	5.798	1.846	0.404	0.058	0.402	-0.385	0.442	0.662	0.557	0.017	0.453	1.98
GH1604	10.048	5.096	2.404 **	1.308	0.137	0.225	-0.158	0.813	-1.511*	-2.231	0.482	-4.275
GH1605	9.298	7.096	1.404	0.808	0.662	0.252	-0.358	3.213*	-0.546	-0.481	0.463	-5.273
GH1606	1.048	6.096	0.154	0.558	-0.388	0.27	0.042	0.463	0.682	0.019	1.433	7.115*
GH1607	5.048	11.846	-0.346	0.308	-1.678*	0.292	-0.058	-2.488	-1.462*	0.519	-0.317	-0.818
GH1608	5.548	1.096	-1.596 *	-0.942	0.087	0.451*	-0.158	0.012	-0.461	1.519	0.683	5.64
GH1609	-7.452	-2.904	0.404	1.058	0.162	0.232	0.042	2.238	0.344	-1.731	0.683	-0.86
GH1610	-1.452	3.096	-0.846	-0.692	-0.338	0.235	-0.158	-1.188	0.254	0.519	-0.817	-1.96
GH1611	2.048	3.096	-0.596	-0.692	0.362	0.337	0.342	3.313*	0.192	1.019	-0.067	5.145
GH1612	-5.452	0.596	-1.346	-0.942	-0.213	0.267	-0.458	0.463	0.149	-1.231	-1.817	-2.028
GH1613	-2.452	-7.404	0.154	-0.192	0.312	0.315	0.442	1.938	0.224	-0.481	1.933	2.685
GH1614	-15.952*	-12.654 *	-0.596	-0.192	0.487	0.327	0.042	2.013	-0.908	1.269	1.183	-4.735
GH1615	-7.702	-7.654	0.654	0.308	-0.338	0.2	0.242	0.762	0.559	1.269	-0.567	-5.398
GH1616	6.048	4.846	0.904	0.808	0.162	0.162	0.042	-0.188	0.879	0.019	-0.067	1.147
GH1617	-1.702	-2.404	-0.346	-0.192	-0.288	0.257	-1.158*	-0.688	0.194	3.619*	0.433	2.67
GH1618	-2.702	0.346	-1.846 *	-1.692 *	-0.263	0.192	-0.558	0.263	0.692	0.269	-1.067	-0.85
GH1619	-0.702	-2.154	-0.096	0.058	-0.688	0.312	0.042	-2.338	-0.236	3.669*	1.183	0.87
GH1620	-14.952*	-12.654 *	-0.096	-0.442	-0.463	0.297	1.145*	-1.288	0.207	0.519	-0.817	5.777
GH1621	-9.452	-4.154	0.154	0.308	-0.813	0.413	0.142	-1.688	-0.776	-3.581*	-1.457	0.22
GH1622	2.298	-3.654	0.654	0.308	-0.788	0.26	0.542	-1.888	0.492	-0.981	-1.067	-7.675*
GH1623	2.798	6.846	-1.096	-1.192	-1.813 *	0.297	-0.058	-2.038	1.459*	-3.531*	-1.317	8.295**
GH1624	6.548	0.596	-0.596	0.058	-1.088	0.295	-0.158	-2.588	-0.328	-0.231	-0.067	10.37**
GH1625	9.548	0.846	0.154	-0.192	0.362	0.267	-0.458	1.838	0.047	0.769	0.933	-1.385
GH1626	-3.702	-7.404	0.404	-0.192	-1.113	0.032	-0.358	-3.438*	0.344	0.269	0.433	2.395
GH1627	2.702	1.404	-0.904	-0.808	-0.162	-0.287	-0.242	-1.913	0.121	-0.019	-0.433	2.808
GH1628	-5.298	-11.096	-0.654	-0.808	-0.587	-0.482	-0.242	-0.162	1.003	-0.108	-0.183	16.245**
GH1629	-5.798	-1.846	-0.404	-0.058	-0.402	0.385	-0.442	-0.662	-0.557	-0.017	-0.453	-1.98
GH1630	-10.048	-5.096	-2.40**	-1.308	-0.137	-0.225	0.158	-0.813	1.511*	2.231	-0.482	4.275
GH1631	-9.298	-7.096	-1.404	-0.808	-0.662	-0.252	0.358	-3.213*	0.546	0.481	-0.463	5.273
GH1632	-1.048	-6.096	-0.154	-0.558	0.388	-0.27	-0.042	-0.463	-0.682	-0.019	-1.433	-7.115*
GH1633	-5.048	-11.846	0.346	-0.308	1.678*	-0.292	0.058	2.488	1.462*	-0.519	0.317	0.818
GH1634	-5.548	-1.096	1.596 *	0.942	-0.087	-0.45*	0.158	-0.012	0.461	-1.519	-0.683	-5.64
GH1635	7.452	2.904	-0.404	-1.058	-0.162	-0.232	-0.042	-2.238	-0.344	1.731	-0.683	0.86
GH1636	1.452	-3.096	0.846	0.692	0.338	-0.235	0.158	1.188	-0.254	-0.519	0.817	1.96
GH1637	-2.048	-3.096	0.596	0.692	-0.362	-0.337	-0.342	-3.313*	-0.192	-1.019	0.067	-5.145
GH1638	5.452	-0.596	1.346	0.942	0.213	-0.267	0.458	-0.463	-0.149	1.231	1.817	2.028
GH1639	2.452	7.404	-0.154	0.192	-0.312	-0.315	-0.442	-1.938	-0.224	0.481	-1.933	-2.685
GH1640	15.95*	12.654*	0.596	0.192	-0.487	-0.327	-0.042	-2.013	0.908	-1.269	-1.183	4.735
GH1641	7.702	7.654	-0.654	-0.308	0.338	-0.2	-0.242	-0.762	-0.559	-1.269	0.567	5.398
GH1642	-6.048	-4.846	-0.904	-0.808	-0.162	-0.162	-0.042	0.188	-0.879	-0.019	0.067	-1.147
GH1643	1.702	2.404	0.346	0.192	0.288	-0.257	1.158*	0.688	-0.194	-3.619*	-0.433	-2.67
GH1644	2.702	-0.346	1.846 *	1.692 *	0.263	-0.192	0.558	-0.263	-0.692	-0.269	1.067	0.85
GH1645	0.702	2.154	0.096	-0.058	0.688	-0.312	-0.042	2.338	0.236	-3.669*	-1.183	-0.87
GH1646	14.95*	12.654*	0.096	0.442	0.463	-0.297	-1.145*	1.288	-0.207	-0.519	0.817	-5.777
GH1647	9.452	4.154	-0.154	-0.308	0.813	-0.413	-0.142	1.688	0.776	3.581*	1.457	-0.22
GH1648	-2.298	3.654	-0.654	-0.308	0.788	-0.26	-0.542	1.888	-0.492	0.981	1.067	7.675*
GH1649	-3.798	-6.846	1.096	1.192	1.813 *	-0.297	0.058	2.038	-1.459*	3.531*	1.317	-8.295**
GH1650	-6.548	-0.596	0.596	-0.058	1.088	-0.295	0.158	2.588	0.328	0.231	0.067	-10.37**
GH1651	-9.548	-0.846	-0.154	0.192	-0.362	-0.267	0.458	-1.838	-0.047	-0.769	-0.933	1.385
GH1652	3.702	7.404	-0.404	0.192	1.113	-0.032	0.358	3.438*	-0.344	-0.269	-0.433	-2.395
C.D. at 5% female	14.7259	12.3072	1.5184	1.4725	1.511	0.438	1.1044	3.2070	1.4426	3.4846	2.4364	6.1750
C.D. at 1% female	19.6268	16.4031	2.0237	1.9626	2.014	0.583	1.4720	4.2743	1.9227	4.6442	3.2472	8.2300
S.Em±	7.3351	6.1303	0.7563	0.7335	0.753	0.218	0.5501	1.5974	0.7186	1.7357	1.2136	3.0758

* Significant at 5% level

** Significant at 1% level

X1 - Plant height (cm)	X4 - Days to 50% silking	X7 - Number of kernel rows per ear	X10 - 100-grain weight (g)
X2 - Ear height (cm)	X5 - Cob length (cm)	X8 - Number of kernels per row	X11- Brown husk maturity
X3 - Days to 50% tasselling	X6 - Cob girth (cm)	X9 - Shelling percentage	X12 - Grain yield (q/ha)
			X13 - Grain yield (q/ha)

?

Table 5. Promising hybrids identified for grain yield and their *sca* effects in maize

Hybrids	Mean grain yield (q/ha)	Heterosis					*sca* effects	*gca* status of the parents
		MP	BP	BIO-9681	900 M Gold	GH0727		
GH1628	93.48	59.57**	42.85**	8.47	47.62**	85.54**	16.245**	High × High
GH1630	87.15	66.08**	65.46**	0.05	36.17**	71.14**	4.275	Low × High
GH1627	83.57	50.81**	42.73**	-4.06	30.57**	64.10**	2.808	High × High
GH1648	81.62	57.86**	56.13**	-6.3	27.53**	60.28**	7.675*	High × High
GH1629	77.33	43.16**	38.71**	-11.23	20.82**	51.85**	-1.980	High × High
GH1603	77.18	34.48**	30.73**	-11.39	20.59**	51.57**	1.980	High × Low
GH1631	76.57	30.49**	17.66**	-12.10*	19.63**	50.36**	5.273	Low × High
GH1624	74.67	37.44**	26.47**	-14.28**	16.66*	46.63**	10.375**	Low × Low
GH1604	74.50	33.38**	26.19**	-14.48**	16.40*	46.29**	-4.275	High × Low
GH1641	74.10	28.89**	18.18*	-14.94**	15.77**	45.51**	5.398	Low × High
Checks								
GH-0727	50.93							
BIO-9681	87.11							
900 M Gold	64.01							

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

due to favourable combinations of dominance effects when those parents are crossed. Negative sca combinations would also be useful for improvement of maturity traits suitably, because negative values are indicative of reduction in days to maturity compared to the parents. Positive sca effects are indicative of increase of a given trait compared to the parents (Jatasra, 1980). Hybrid GH1630 gave highest negative value for days to 50 per cent tasseling and days to 50 per cent silking and is a good source for earliness in hybridization program for development of early maturing genotypes. Hybrid GH1628 (16.24) gave the highest positive value signifying that this cross had increased grain yield than the expected mean performance of its parents and showed genetic diversity and hence heterosis. These two parents could be used in a hybrid production programme for better yield. Several workers support the present investigation like Wali *et al.* (2010), Premlatha and Kalamani (2010), Mahdi *et al.* (2011), Palkar *et al.* (2013), Rajitha *et al.* (2014) and Muttappa Hosamani *et al.* (2014).

Presence of significant differences among parents and crosses revealed the choice of exploitation of heterosis for all the characters studied. Expression of hybrid vigour even to a small magnitude for individual component is a desirable factor. The top ten hybrids based on grain yield (q/ha) were identified and their heterosis, gca status of parents and their sca effects have been presented in Table 5. Among these, ten hybrids, GH1628 hybrid recorded the highest grain yield 93.48 q/ha followed by the hybrid GH1630 with 87.15 q/ha whereas the hybrid GH1641 was the minimum with 74.10 q/ha grain yield. (Fig. 1) Similarly, the hybrid GH1628 recorded highest standard heterosis of 8.47% over the best standard check BIO-9681 followed by the hybrid GH1630 with 0.05%. The hybrids, GH1628 (16.24), GH1648 (7.67) and GH1624 (10.37) had significantly higher sca effects and their parents had High x High, High × High and Low × Low gca nature respectively. These two facts indicated that this particular cross had good combining parents which resulted in maximum amount of heterosis.

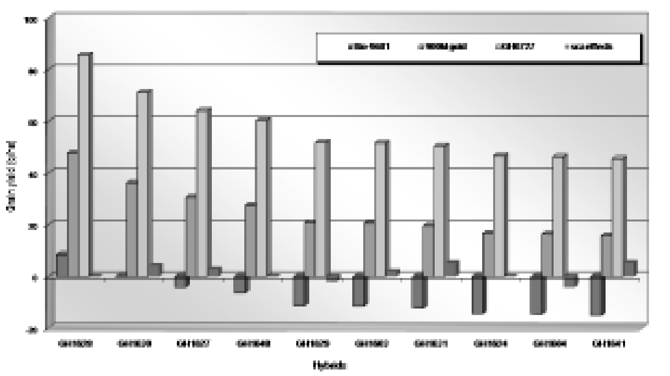

Fig. 1. Standard heterosis and sca effects for top 10 hybrids for grain yield (q/ha)

Many authors like Kanagarasu *et al.* (2010), Farhan Ali *et al.* (2012) and Naveen Kumar *et al.* (2014) revealed that, though the single cross hybrids have *sca* effect which is non-significant , but had high mean grain yield with relatively good amount of standard heterosis which may be considered for further testing. This also indicates that heterosis is cross specific being low for some and high for some other crosses. Therefore, in this direction the cross combination; GH-1628 can be used as a potential single cross hybrid combination for evaluation and further tested for its potentiality.

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