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RESEARCH PAPER

Combining ability analysis in newly developed S_6 inbred lines of maize (*Zea mays* L.)

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Abstract: The present study was conducted to assess the GCA of parents and SCA of hybrids for yield and yield related traits and to know the extent of heterosis. Ninety F_1s were generated by crossing thirty inbreds and three testers. These hybrids along with parents (lines and testers) and checks were evaluated in RBD with two replications during *kharif* 2014. The ratio of sca/gca variance revealed that there was preponderance of non-additive gene action in the expression of most the traits under study. Inbred lines *viz.,* N-4, N-5, N-6, N-7, N-14, N-22 and N-30 were good general combiners for grain yield. Tester T-5 and DMIL-101 are good general combiner for grain yield. Among the hybrids, Hybrid-12, Hybrid-14, Hybrid-21, Hybrid-23, Hybrid-26, Hybrid-38, Hybrid-46, Hybrid-52, Hybrid-65, Hybrid-71, Hybrid-73 and Hybrid-90 exhibited highest significant sca effects for grain yield. Hybrid-21, Hybrid-42, Hybrid-65, Hybrid-73 and Hybrid-90 exhibited high heterosis over checks for grain yield.

Keywords*;* Heterosis, Hybrids, Inbreds, Tester

Introduction

Maize (*Zea mays* L: 2n=20) is the most versatile crop with wider adaptability in varied agro-ecologies. Globally maize is one of the staple food crops and rank second to wheat in production and in India maize is rank third position after wheat and rice. Maize grain gaining popularity in our country due to huge demand, particularly for poultry and feed industry, besides it has diversified use as food and industrial raw materials. With the introduction of single cross hybrids and its high yielding potential lead to continuous increase in acreage and production of maize. Combining ability analysis is useful to assess the potential inbreds lines and also helps in identifying the nature of gene action involved in various quantitative characters. This information is helpful to plant breeders for formulating hybrid breeding programmers. A wide array of biometrical tools are available to breeders for characterizing genetic control of economically important traits to decide appropriate breeding methodology to involve in hybrid breeding. The present investigation was carried out to determine breeding value of genotypes, nature and magnitude of gene action and heterosis for various yield and other important traits in maize. Line×tester mating design developed by Kempthorne (1957), which provides reliable information on the general combining ability effects of parents and specific combining ability effects of their hybrid combinations. The design has been widely used in maize by several workers and continues to be applied in quantitative genetic studies in maize (Joshi *et al.,* 2002; Sharma *et al.,* 2004).

Material and methods

Thirty inbred lines and three testers were crossed in a line×tester mating design during *Summer* 2014. The resulting 90 F_1s their parents (30 lines and testers) and three checks Arjun, Bio-9681 and Super-900M were sown in a Randomized Complete Block Design with two replications at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *Kharif* 2014, which is located at a latitude of $15^0$26 N, longitude of $75^0$07E and altitude of 678m above Mean Sea Level (MSL). The spacing between rows was 60 cm and between plants 20 cm and one plant per hill was maintained. Observations were recorded on thirteen yield and yield attributing traits *viz.,* days to 50% tasselling, days to 50% silking, days to 50% brown husk, plant height, cob height, ear length, ear diameter, number of kernel rows per cob, number of kernels per row, cob weight, shelling percentage , hundred grain weight and grain yield per hectare. The data were subjected for analysis of variance for all the characters studied as per the method suggested by Panse and Sukhatme (1961). The variance of combining ability was estimated as per the procedure developed by Kempthorne (1957). The mean squares for GCA and SCA were tested against desired error variance. Heterosis was computed as per the method of Tuner (1953) and Hayes *et al.* (1955).

Results and discussion

The analysis of variance for combining ability revealed that mean squares due to line effect were significant for days to 50 per cent tasseling, days to 50 per cent silking, plant height, cob height, ear length, ear diameter and hundred seeds weight. Mean sum of squares due to tester effect significant for days to 50 per cent tasseling, days to 50 per cent silking, plant height, cob height, ear length, number of kernel rows per ear and number of kernels per row and mean sum of squares due to line × testers effect were significant for all the characters except cob height (Table 1). This indicated that both additive and non additive gene effects were important in the genetic expression of most of the traits studied. These results are in general agreement with Joshi *et al.* (2002) whereas, Sharma *et al.* (2004) reported preponderance of additive genetic effects. The mean sum of squares for crosses was highly significant, which indicated the diverse performance of different cross combinations for all traits. The parents versus hybrids mean sum of squares were highly significant for all traits, which revealed the presence of heterosis

Table 1. Analysis of variance for combining ability of inbreds and hybrids of maize

Source of variance Characters	Replications	Crosses	Line effect	Tester effect	Line x Tester effect	Error
Df	1	89	29	2	58	89
Days to 50 per cent tasseling	9.800*	7.407**	14.846**	41.717**	2.504*	1.688
Days to 50 per cent silking	6.806*	7.965**	16.445**	35.822**	2.765*	1.615
Days to 75 per cent dry husk	20.000**	16.412**	18.712	10.772	15.456**	2.303
Plant height (cm)	72.708	329.035**	429.450*	1305.875**	245.144*	160.879
Cob height (cm)	338.390	171.514**	228.343*	835.288**	120.210	98.884
Ear length (cm)	14.855**	4.601**	5.705*	36.669**	2.943*	1.974
Ear diameter (cm)	0.216	0.208**	0.335**	0.191	0.145**	0.065
No. of Kernel rows per ear	0.125	2.438**	2.990	8.938*	1.938**	1.118
No. of Kernels per row	42.002	35.299**	38.826	181.602**	28.490**	11.865
Cob weight (g)	0.112	2271.841**	2857.878	2106.146	1984.536**	91.281
Shelling percentage	6.120	46.074**	27.374	112.699	53.126**	17.028
100 seed weight (g)	4.150	24.308**	40.105**	14.120	16.760**	3.520
Grain yield (q/ha)	91.735	333.308**	433.515	255.039	285.904**	42.677

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

due to the significant difference in the mean performance of hybrids and parents.

The data showed that, higher degree of SCA variance as compared to GCA variance for all traits except days to 50 per cent tassling, days to 50 per cent silking and cob height (Table 2). The higher SCA variance revealed the predominance of non additive genetic variance. Contrarily, importance of additive gene effects was reported by Alamnie *et al.* (2006). From the results it was evident that per cent contribution of line x tester interaction appeared high to the bulk of the variation observed in hybrids. Similar findings were reported for ear length and ear diameter by Kanta *et al.* (2005).

Persual of GCA effects (Table 3) revealed that no line was observed to be good combiner for all the traits. However N-1 was good general combiner for ear length and ear diameter, N-3, N-6 and N-28 were good combiner for early maturity, N-7 and N-22 were good combiner for ear diameter and number of kernel rows per ear and N-30 was observed to be good general combiners for ear diameter and hundred seeds weight. Inbred lines *viz.,* N-4, N-5, N-6, N-7, N-14, N-22 and N-30 were good general combiners for grain yield. Tester T-5 and DMIL-101 are good general combiner for grain yield and T-3 good general combiner for early maturity and shelling percentage.

A critical evaluation of the results with respect to specific combining ability effects showed that none of the cross combinations exhibited desirable significant sca effects for all the characters. Results indicated that crosses having significantly higher sca effects generally involved high and low overall general combiners.

For grain yield Hybrid-90 was the best specific combiner followed by Hybrid-73 and Hybrid-38 (Table-4). Other good specific combining crosses *viz.,* Hybrid-12, Hybrid-14, Hybrid-21, Hybrid-23, Hybrid-26, Hybrid-46, Hybrid-52, Hybrid-65 and Hybrid-71 were having high x low or low x high general combining ability status of parents, suggesting that involvement of one good general combiner appears to be essential to get the better specific combination. The results are in general agreement with the findings of Surya and Ganguli (2004), Kambe Gowda *et al.* (2013) and Sara *et al.* (2014) also reported high positive specific combining ability effects along with high per se performance for grain yield. The superiority of crosses involving high x low combiners as parents could be

Table 2. Estimates of variance components in respect to thirteen quantitative characters

Characters	σ^2GCA	σ^2SCA	σ^2GCA/σ^2SCA	σ^2A	σ^2D	σ^2A/σ^2D
Days to 50 per cent tasseling	0.7811**	0.4759*	1.6413	3.1245	1.9036	1.6414
Days to 50 per cent silking	0.7081**	0.5376*	1.3171	2.8326	2.1503	1.3173
Days to 75 per cent dry husk	-0.0216	6.3927**	-0.0033	-0.0866	25.5708	-0.0034
Plant height (cm)	18.8642**	47.5104*	0.3970	75.4568	190.0415	0.3971
Cob height (cm)	12.4729**	8.5620	1.4567	49.8916	34.2479	1.4568
Ear length (cm)	0.5528**	0.5768*	0.9583	2.2113	2.3070	0.9585
Ear diameter (cm)	0.0036**	0.0394**	0.0913	0.0143	0.1577	0.0907
No. of Kernel rows per ear	0.1220**	0.3613*	0.3376	0.4880	1.4454	0.3376
No. of Kernels per row	2.4765**	8.4933**	0.2915	9.9059	33.9731	0.2916
Cob weight (g)	15.0751*	953.3401**	0.0158	60.3002	3813.3600	0.0158
Shelling percentage	0.5124	16.5990**	0.0308	2.0498	66.3962	0.0309
100 seed weight (g)	0.3137**	6.6644**	0.0470	1.2548	26.6576	0.0471
Grain yield (q/ha)	1.7689*	120.6620**	0.0146	7.0755	482.6479	0.0147

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

Table 3. Estimates of general combining ability effects of parents for thirteen quantitative traits of maize

Parents	Days to 50 per cent tasseling	Days to 50 per cent silking	Days to 75 per cent dry husk	Plant height (cm)	Cob height (cm)	Ear length (cm)	Ear diameter (cm)	No. of Kernel rows per ear	No. of Kernels per row	Cob weight (g)	Shelling percentage	100 seed weight (g)	Grain yield (q/ha)
N-1	0.067	0.706	0.678	-9.507**	-6.496**	1.221*	0.138**	0.276	-0.808**	8.337	3.146	-3.423**	-6.431**
N-2	1.233*	1.372*	-0.322**	6.560	-1.029**	-0.629**	0.053*	0.543	0.692	9.961	0.791	1.307	4.126
N-3	-0.933**	-0.961**	-0.489**	-7.273**	-6.129**	1.121	-0.242**	-0.540**	2.526	5.118	0.650	-1.719**	0.551
N-4	-0.100**	0.039	3.344**	3.060	0.238	2.246**	0.03	0.076	2.392	39.888	-1.329**	2.206	9.508
N-5	1.067*	1.206*	-2.822**	-5.407**	1.138	0.279	0.205**	1.010*	-0.741**	3.135	-0.220**	2.154	6.418
N-6	-0.767**	-0.961**	-0.989**	-6.340**	-9.162**	1.405*	-0.265**	-1.424**	2.192	13.645	-0.157**	0.704	9.718
N-7	0.233	0.039	0.511	17.993	7.904	0.630	0.245**	1.310*	3.709	22.732	0.485	3.994**	12.633
N-8	-0.767**	-0.294**	0.511	3.093	-4.729**	-0.912**	-0.175**	0.143	-1.458**	-32.892**	2.485	-3.883**	-15.456**
N-9	-1.433**	-1.294**	0.844	2.060	2.538	-0.395**	0.188**	0.476	1.911	1.412	-3.777**	-0.784**	-2.959**
N-10	-1.267**	-1.128**	-0.489**	-1.740**	4.704	0.213	-0.725**	-0.457**	1.792	-42.465**	1.321	-5.169**	-9.622**
N-11	-0.600**	-0.794**	1.344	5.060	6.438	-0.045**	0.130**	-0.140**	-3.024**	2.613	1.478	1.267	1.696
N-12	-1.100**	-0.961**	-1.656**	-9.907**	1.738	-1.287**	-0.077**	-0.490**	-2.308**	-13.782**	-0.030**	-5.026**	-7.714**
N-13	0.233	0.706	0.678	6.360	7.871	0.846	0.600**	0.143	0.109	-0.352**	-2.709**	2.211	2.703
N-14	-3.100**	-3.461**	1.511	10.193	10.304	-0.362**	0.150**	-0.940**	-2.391**	12.842	3.276	0.999	21.313
N-15	-0.267**	-0.961**	-5.322**	7.293	9.804	0.013	-0.180**	-0.224**	-3.241**	-32.397**	3.315	-3.083**	-13.477**
N-16	3.733**	3.706**	2.678*	1.927	-0.562**	-0.537**	-0.053**	0.443	1.386	31.177	0.961	3.979**	3.536
N-17	-2.433**	-2.961**	0.511	-5.907**	-0.896**	-0.587**	-0.015**	-0.424**	-1.024**	-6.384**	1.578	-0.109**	-1.012**
N-18	-1.100**	-0.961**	-0.822**	0.293	5.671	1.105	-0.210**	-0.590**	2.559	-39.502**	-1.297**	-0.903**	-14.036**
N-19	-0.433**	-0.461**	3.178**	8.260	5.771	-1.546**	0.052*	-1.124**	-0.641**	-13.045**	1.331	1.511	-6.186**
N-20	-0.933**	-1.294**	0.178	-8.040**	-3.662**	-1.421**	0.027	0.710	-5.424**	-41.867**	-1.334**	-1.699**	-9.277**
N-21	0.900	0.872	-0.322**	11.860	-0.629**	1.180*	-0.013**	0.610	3.892	19.588	-1.774**	-2.736**	-2.021**
N-22	0.567	0.872	-0.989**	-6.84**	-0.162**	-0.387**	0.077*	1.535**	4.209	21.968	0.391	4.724**	8.746
N-23	1.733*	2.039**	0.344	6.960	0.871	-1.079**	-0.087**	-0.624**	-0.541**	2.645	0.003	0.384	4.823
N-24	2.067**	2.539**	-0.156**	10.760	1.638	-0.337**	-0.298**	-0.399**	-0.108**	17.608	-3.599**	-0.534**	-8.477**
N-25	0.733	0.539	-0.489**	-0.907**	1.271	0.986	-0.165**	0.193	0.392	11.120	0.595	-0.256**	5.169
N-26	2.233**	2.039**	0.011	-18.007**	-16.596**	-0.779**	0.142**	-0.190**	-1.991**	-9.685**	-3.394**	0.321	1.279
N-27	3.233**	2.872**	0.178	0.293	1.338	-1.562**	0.24**	0.543	-5.308**	-14.004**	-3.134**	-0.126**	-5.006**
N-28	-2.267**	-2.294**	-3.322**	-16.807**	-10.596**	-0.129**	0.258**	-0.390**	-2.124**	-11.299**	2.371	0.607	0.479
N-29	-0.600**	-0.628**	1.178	-1.340**	-2.962**	0.371	-0.092**	-0.757**	2.242	6.428	1.801	-0.636***	3.883
N-30	0.067	-0.128**	0.511	-4.007**	-5.629**	0.379	0.058*	0.701	1.126	27.457	-3.225**	3.717*	5.098
S.Em±	0.508	0.530	0.667	5.002	4.145	0.546	0.105	0.450	1.384	3.602	1.822	0.756	2.725
C.D. at 5%													
female	1.010	1.054	1.325	9.938	8.236	1.085	0.209	0.894	2.751	7.157	3.621	1.502	5.416
C.D. at 1%													
female	1.338	1.396	1.756	13.166	10.910	1.437	0.277	1.184	3.644	9.481	4.797	1.990	7.174

Parents	Days to 50 per cent tasseling	Days to 50 per cent silking	Days to 75 per cent dry husk	Plant height (cm)	Cob height (cm)	Ear length (cm)	Ear diameter (cm)	No. of Kernel rows per ear	No. of Kernels per row	Cob weight (g)	Shelling percentage	100 seed weight (g)	Grain yield (q/ha)
Tester-3	-0.850**	-0.711**	-0.489**	-5.320**	-3.832**	-0.867**	0.015**	-0.162**	-1.994**	-6.840**	1.515*	0.069	-2.378**
Tester-5	0.033	-0.111**	0.228*	3.393	3.621	0.650**	-0.062**	-0.279**	1.211*	3.528	-0.363**	0.447**	1.293
DMIL-101	0.817**	0.822**	0.261*	1.927	0.211	0.217**	0.048	0.441**	0.783*	3.313	-1.153**	-0.516**	1.085
S.Em±	0.161	0.168	0.211	1.582	1.311	0.173	0.033	0.142	0.438	1.139	0.576	0.239	0.862
C.D. at 5% female	0.320	0.333	0.419	3.143	2.605	0.343	0.066	0.283	0.870	2.263	1.145	0.475	1.713
C.D. at 1% female	0.423	0.442	0.555	4.164	3.450	0.455	0.088	0.375	1.153	2.998	1.517	0.630	2.269

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

Table 4. Estimation of specific combining ability effects for thirteen characters of single cross hybrids

Crosses	Days to 50 per cent tasseling	Days to 50 per cent silking	Days to 75 per cent dry husk	Plant height (cm)	Cob height (cm)	Ear length (cm)	Ear diameter (cm)	No. of Kernel rows per ear	No. of Kernels per row	Cob weight (g)	Shelling percentage	100 seed weight (g)	Grain yield (q/ha)
Hybrid-1	1.02	1.21	-1.34	-18.75*	-9.57	-1.00	-0.14	-0.24	-0.19	-19.54**	-1.47	0.14	-1.34
Hybrid-2	-1.37	-1.39	-0.06	22.14*	6.58	1.68	0.11	-0.22	0.26	2.14	2.31	1.91	-3.86
Hybrid-3	0.35	0.18	1.41	-3.39	2.99	-0.68	0.04	0.46	-0.07	17.39**	-0.84	-2.05	5.20
Hybrid-4	0.85	0.54	1.66	7.79	-8.63	2.33*	-0.06	0.20	3.81	50.60**	-3.57	4.79**	7.48
Hybrid-5	0.97	0.94	-1.56	3.67	9.31	-0.69	-0.26	-0.29	-2.64	-49.92**	2.51	-1.57	1.52
Hybrid-6	-1.82*	-1.49	-0.09	-11.46	-0.68	-1.63	0.33	0.09	-1.17	-0.68	1.05	-3.22*	-9.00
Hybrid-7	0.52	0.88	-1.18	14.02	8.17	0.05	0.42	0.08	-2.22	-31.85**	0.14	0.49	-4.46
Hybrid-8	-0.37	-0.72	2.61*	-19.29*	-5.99	0.46	-0.51**	0.55	1.12	43.85**	-0.65	1.47	8.22
Hybrid-9	-0.15	-0.16	-1.43	5.27	-2.18	-0.51	0.09	-0.62	1.10	-11.99	0.51	-1.96	-3.76
Hybrid-10	-0.32	-1.12	0.99	1.19	2.50	-0.32	-0.14	-0.34	3.31	14.96*	0.41	-0.78	8.56
Hybrid-11	-0.20	-0.72	-1.23	6.77	4.35	0.21	0.06	-0.62	-3.69	-13.86*	-5.92	-4.07**	-20.84**
Hybrid-12	0.52	1.84*	0.24	-7.96	-6.84	0.12	0.08	0.96	0.38	-1.09	5.51	4.85**	12.28*
Hybrid-13	-1.48	-1.29	-2.84*	8.55	13.10	0.74	-0.17	-0.87	0.84	-9.47	0.27	-1.74	-5.96
Hybrid-14	2.13*	2.11*	4.44**	-7.26	-8.05	-0.05	-0.12	2.45**	2.89	29.22**	4.09	3.56**	15.27**
Hybrid-15	-0.65	-0.82	-1.59	-1.29	-5.04	-0.69	0.29	-1.57*	-3.73	-19.75**	-4.35	-1.82	-9.31
Hybrid-16	0.85	0.88	1.32	-20.91*	-13.60	-1.96*	-0.30	0.56	-2.69	-46.99**	0.13	-1.92	-3.32
Hybrid-17	-0.03	0.78	-0.89	1.37	4.25	1.68	0.10	0.08	1.71	17.90**	-1.08	-0.62	-0.74
Hybrid-18	-0.82	-1.66	-0.43	19.54*	9.36	0.28	0.20	-0.64	0.98	29.08**	0.95	2.54	4.06
Hybrid-19	-0.65	-1.12	-5.18**	-0.35	-4.57	-0.08	0.14	-0.67	-1.71	1.00	0.75	-0.25	0.12
Hybrid-20	-1.53	-1.72	1.11	1.44	-0.52	0.30	0.03	-0.36	1.29	-27.59**	-4.46	-3.53**	-16.47**
Hybrid-21	2.18*	2.84**	4.07**	-1.09	5.09	-0.22	-0.17	1.03	0.42	26.60**	3.71	3.78**	16.35**
Hybrid-22	-0.15	-0.29	-0.18	-6.25	-9.43	-0.67	0.00	-0.21	-4.99*	-2.89	2.41	-0.46	-8.25
Hybrid-23	0.97	1.11	-0.89	7.54	6.51	0.17	0.00	-0.39	1.91	-3.42	-3.13	-2.16	10.06*
Hybrid-24	-0.82	-0.82	1.07	-1.29	2.92	0.50	0.00	0.59	3.08	6.31	0.72	2.62*	-1.82

Contd...

Crosses	Days to 50 per cent tasseling	Days to 50 per cent silking	Days to 75 per cent dry husk	Plant height (cm)	Cob height (cm)	Ear length (cm)	Ear diameter (cm)	No. of Kernel rows per ear	No. of Kernels per row	Cob weight (g)	Shelling percentage	100 seed weight (g)	Grain yield (q/ha)
Hybrid-25	0.02	0.21	-3.01*	-1.21	2.60	-0.56	0.19	0.26	-1.81	-22.37**	4.01	-1.79	0.09
Hybrid-26	-0.37	-0.39	0.27	3.27	-4.05	1.45	0.16	-0.12	3.79	53.12**	6.70	4.30**	12.15*
Hybrid-27	0.35	0.18	2.74*	-2.06	1.46	-0.89	-0.34	-0.14	-1.98	-30.75**	-10.70**	-2.51	-12.23*
Hybrid-28	-0.15	0.54	3.82**	-5.91	-1.87	2.01*	0.11	1.20	0.91	16.70**	2.02	1.50	-0.96
Hybrid-29	-0.03	0.44	-2.39*	-3.23	-4.22	-0.16	0.24	-0.39	-1.44	1.19	-6.99*	0.26	6.62
Hybrid-30	0.18	-0.99	-1.43	9.14	6.09	-1.85	-0.35	-0.81	0.53	-17.89**	4.97	-1.76	-5.67
Hybrid-31	0.18	0.21	1.49	-3.31	-2.50	0.39	-0.37*	-0.12	4.28	-4.08	-0.58	-5.09**	-0.40
Hybrid-32	-0.20	-0.39	-4.23**	4.77	4.35	0.33	-0.16	0.35	-0.78	-0.96	-7.28*	3.69**	-2.09
Hybrid-33	0.02	0.18	2.74*	-1.46	-1.84	-0.72	0.53**	-0.22	-3.50	5.04	7.87*	1.40	2.49
Hybrid-34	0.68	0.38	-2.01	3.25	10.80	0.48	-0.22	0.43	0.71	-26.29**	-3.34	-0.81	-14.01**
Hybrid-35	-0.70	-0.22	-1.73	-14.06	-12.45	-0.16	0.36	-0.86	-0.94	0.57	1.85	0.84	6.38
Hybrid-36	0.02	-0.16	3.74**	10.81	1.66	-0.33	-0.13	0.43	0.23	25.73**	1.49	-0.03	7.63
Hybrid-37	-1.15	-0.29	-0.34	-10.21	-5.73	-1.57	0.13	-0.41	-5.26*	5.68	-3.47	0.65	-9.01
Hybrid-38	1.47	1.11	1.94	-5.03	-3.99	0.36	0.01	0.21	1.79	4.99	-2.88	-0.31	20.55**
Hybrid-39	-0.32	-0.82	-1.59	15.24	9.72	1.22	-0.15	0.19	3.47	-10.67	6.35*	-0.34	-11.54*
Hybrid-40	0.18	0.88	2.82*	5.55	9.03	1.71	0.06	0.18	-0.06	-24.24**	3.94	-0.37	3.52
Hybrid-41	0.30	0.28	2.11	2.44	-0.42	-0.11	-0.18	0.75	3.89	34.05**	-2.66	4.31**	-10.46*
Hybrid-42	-0.48	-1.16	-4.93**	-7.99	-8.61	-1.60	0.12	-0.92	-3.83	-9.81	-1.27	-3.94**	6.94
Hybrid-43	-0.65	0.38	0.16	-3.35	-1.57	-0.77	0.34	0.96	-3.76	-15.32*	5.17	0.25	6.13
Hybrid-44	-0.03	-0.72	-1.56	21.04*	11.68	-0.83	-0.51**	-1.12	-1.01	-15.96*	-1.99	-0.78	4.64
Hybrid-45	0.68	0.34	1.41	-17.69*	-10.11	1.60	0.17	0.16	4.77*	31.28**	-3.19	0.53	-10.77*
Hybrid-46	1.85*	1.21	2.16	10.32	12.00	0.83	0.10	0.50	9.04**	35.46**	-4.85	1.36	10.78*
Hybrid-47	-0.03	-0.39	-1.56	-21.39	-19.85**	-1.73	-0.25	-0.09	-9.59**	-54.47**	3.04	-3.82**	-20.08**
Hybrid-48	-1.82*	-0.82	-0.59	11.07	7.86	0.90	0.15	-0.41	0.55	19.01**	1.81	2.46	9.30
Hybrid-49	0.02	-0.12	-3.68**	-3.55	4.43	0.03	-0.09	-0.24	1.73	-42.51**	-1.01	0.46	3.76
Hybrid-50	0.13	-0.22	1.11	-1.86	-4.02	0.39	-0.26	-1.02	0.12	-3.60	2.72	-1.13	-1.99
Hybrid-51	-0.15	0.34	2.57*	5.41	-0.41	-0.43	0.35	1.26	-1.85	46.11**	-1.71	0.67	-1.78
Hybrid-52	0.68	0.38	2.16	-3.15	-5.43	-0.16	-0.17	-0.07	0.54	28.00**	-1.44	2.53	13.04**
Hybrid-53	-0.20	-0.22	0.44	1.34	-0.49	0.28	0.30	0.45	-3.36	0.76	3.00	1.31	-9.17
Hybrid-54	-0.48	-0.16	-2.59*	1.81	5.92	-0.12	-0.13	-0.37	2.82	-28.75**	-1.55	-3.84**	-3.87
Hybrid-55	1.02	1.38	-0.84	9.59	4.47	-0.66	-0.16	1.36	-0.76	21.32**	6.32*	-3.30*	2.79
Hybrid-56	-0.37	-0.22	1.94	0.17	3.21	-0.63	0.11	-0.82	-1.51	-24.35**	-4.08	0.28	-7.65
Hybrid-57	-0.65	-1.16	-1.09	-9.76	-7.68	1.28	0.05	-0.54	2.27	3.02	-2.24	3.02*	4.86
Hybrid-58	-1.98*	-1.29	-1.84	4.29	2.80	-0.28	0.08	-0.77	-1.77	-5.00	1.97	-0.39	4.21
Hybrid-59	1.63	1.61	1.44	-11.43	-2.65	-0.03	0.11	1.05	0.82	22.54**	0.62	-0.76	0.13
Hybrid-60	0.35	-0.32	0.41	7.14	-0.14	0.31	-0.19	-0.27	0.95	-17.54**	-2.59	1.15	-4.35
Hybrid-61	0.18	0.04	0.16	-0.01	-1.53	0.97	0.39*	0.03	0.26	42.32**	4.11	1.10	1.23
Hybrid-62	-1.70	-1.56	3.44**	5.37	5.61	-0.38	-0.27	-0.46	0.91	-32.14**	-1.04	1.25	-10.04*
Hybrid-63	1.52	1.51	-3.59**	-5.36	-4.08	-0.59	-0.11	0.43	-1.17	-10.17	-3.07	-2.35	8.81
Hybrid-64	0.52	0.04	-1.68	6.39	2.30	0.08	-0.08	-1.00	-2.71	-50.18**	-4.00	-1.86	-24.11**
Hybrid-65	0.13	-0.06	3.11**	-2.53	-2.25	-0.71	0.08	1.32	2.64	29.36**	3.51	-0.48	17.11**

Contd...

Crosses	Days to 50 per cent tasseling	Days to 50 per cent silking	Days to 75 per cent dry husk	Plant height (cm)	Cob height (cm)	Ear length (cm)	Ear diameter (cm)	No. of Kernel rows per ear	No. of Kernels per row	Cob weight (g)	Shelling percentage	100 seed weight (g)	Grain yield (q/ha)
Hybrid-66	-0.65	0.01	-1.43	-3.86	-0.04	0.63	-0.01	-0.32	0.07	20.82**	0.48	2.34	7.00
Hybrid-67	0.35	0.38	1.99	-9.51	0.47	1.03	0.23	-0.14	1.19	10.52	-1.30	-2.17	-0.30
Hybrid-68	-0.03	0.28	-0.73	5.47	-0.99	-1.24	-0.04	0.18	-0.76	-14.58*	-1.60	0.05	-2.51
Hybrid-69	-0.32	-0.66	-1.26	4.04	0.52	0.22	-0.19	-0.04	-0.43	4.06	2.91	2.12	2.80
Hybrid-70	0.52	-0.12	0.49	10.49	-4.30	-0.72	-0.42*	0.04	-2.99	11.93	6.32*	2.76*	4.46
HYBRID-71	-0.37	0.28	-1.73	3.67	9.15	0.54	0.26	-0.45	2.26	4.31	6.93*	0.38	16.21**
HYBRID-72	-0.15	-0.16	1.24	-14.16	-4.84	0.18	0.16	0.41	0.73	-16.24*	-13.25**	-3.14*	-20.67**
HYBRID-73	-1.15	-1.12	3.82**	6.35	-5.43	2.16*	0.29	1.50	10.51**	51.17**	-0.26	3.93**	20.92**
HYBRID-74	-0.53	0.28	-0.89	-5.86	0.31	-0.63	0.06	0.16	-1.94	-7.86	-1.86	-2.62*	-10.77*
HYBRID-75	1.68	0.84	-2.93	-0.49	5.12	-1.52	-0.35	-1.66*	-8.57**	-43.32**	2.11	-1.31	-10.15*
HYBRID-76	0.85	0.88	-0.68	7.65	1.43	0.50	-0.01	0.33	0.54	-1.69	-0.12	2.04	6.99
HYBRID-77	-0.03	-0.22	-4.39**	-4.46	-1.42	-0.17	0.11	-0.76	1.49	18.61**	0.22	-1.73	-4.69
HYBRID-78	-0.82	-0.66	5.07**	-3.19	-0.01	-0.33	-0.10	0.43	-2.03	-16.92**	-0.10	-0.31	-2.30
HYBRID-79	0.35	0.04	2.16	-3.75	1.80	-0.17	0.08	-0.61	-0.64	35.97**	-1.08	2.35	0.47
HYBRID-80	0.47	0.44	-0.56	0.14	-0.35	-0.63	0.21	0.61	-0.14	-13.60*	-2.12	-1.42	1.59
HYBRID-81	-0.82	-0.49	-1.59	3.61	-1.44	0.80	-0.29	-0.01	0.78	-22.37**	3.20	-0.93	-2.06
HYBRID-82	0.35	-0.29	1.66	7.45	6.33	-0.55	-0.01	-1.27	0.43	10.35	-1.34	0.80	-3.77
HYBRID-83	-0.53	-0.39	0.94	-10.06	-5.82	-0.94	0.23	1.45	-1.48	-10.73	5.39	0.58	0.79
HYBRID-84	0.18	0.68	-2.59*	2.61	-0.51	1.49	-0.22	-0.17	1.05	0.38	-4.05	-1.38	2.98
HYBRID-85	-1.32	-0.96	-0.34	-15.81	-9.10	-1.92*	-0.20	0.80	-0.79	-8.87	3.34	-0.30	-2.69
HYBRID-86	0.30	-0.06	1.44	14.17	10.15	1.06	-0.02	-0.39	2.71	34.10**	0.60	2.41	7.91
HYBRID-87	1.02	1.01	-1.09	1.64	-1.04	0.87	0.22	-0.41	-1.92	-25.23**	-3.94	-2.11	-5.22
HYBRID-88	-1.98*	-2.46**	-1.68	3.15	1.07	-1.93	-0.01	-1.46	-5.77*	-24.69**	-13.45**	-3.94**	-15.99**
HYBRID-89	0.13	-0.06	-1.89	1.64	2.11	0.20	0.06	-1.25	-0.28	-23.68**	4.26	-1.59	-7.79
HYBRID-90	1.85*	2.51**	3.57**	-4.79	-3.18	1.73	-0.04	2.71**	6.05*	48.37**	9.19**	5.53**	23.78**
S.Em±	0.881	0.919	1.156	8.664	7.179	0.946	0.183	0.780	2.398	6.239	3.157	1.310	4.721
C.D. at 5% female	1.751	1.826	2.296	17.215	14.265	1.880	0.363	1.549	4.765	12.397	6.272	2.603	9.381
C.D. at 1% female	2.814	2.419	3.042	22.805	18.897	2.490	0.480	2.052	6.313	16.423	8.309	3.448	12.427

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

explained on the basis of interaction between positive alleles from good combiners and negative alleles for the poor combiners as parents. The high yield of such crosses would be non-fixable and thus could be exploited for heterosis breeding. The superior cross combinations involving high × low general combiners could result from over dominance and epistasis. Highest percentage of heterosis for grain yield per hectare over standard checks was exhibited by the crosses *viz.,* Hybrid-12, Hybrid-14, Hybrid-21, Hybrid-38, Hybrid-42, Hybrid-65, Hybrid-73 and Hybrid-90.

Parents *viz.,* N-1, N-3, N-6, N-7, N-22, N-28 and N-30 were identified as overall high general combiners and these could be utilized for development of synthetic varieties or an elite breeding population by allowing random mating among them to achieve new genetic recombination and then subjecting the resultant population to recurrent selection.

Conclusion

Twelve hybrids appeared to be out performed the commercial checks for grain yield and yield related traits should be tested further and released to farmers. The seven inbred lines showed significant positive GCA for grain yield and yield related traits can be used as best breeding materials for further crop improvement.

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