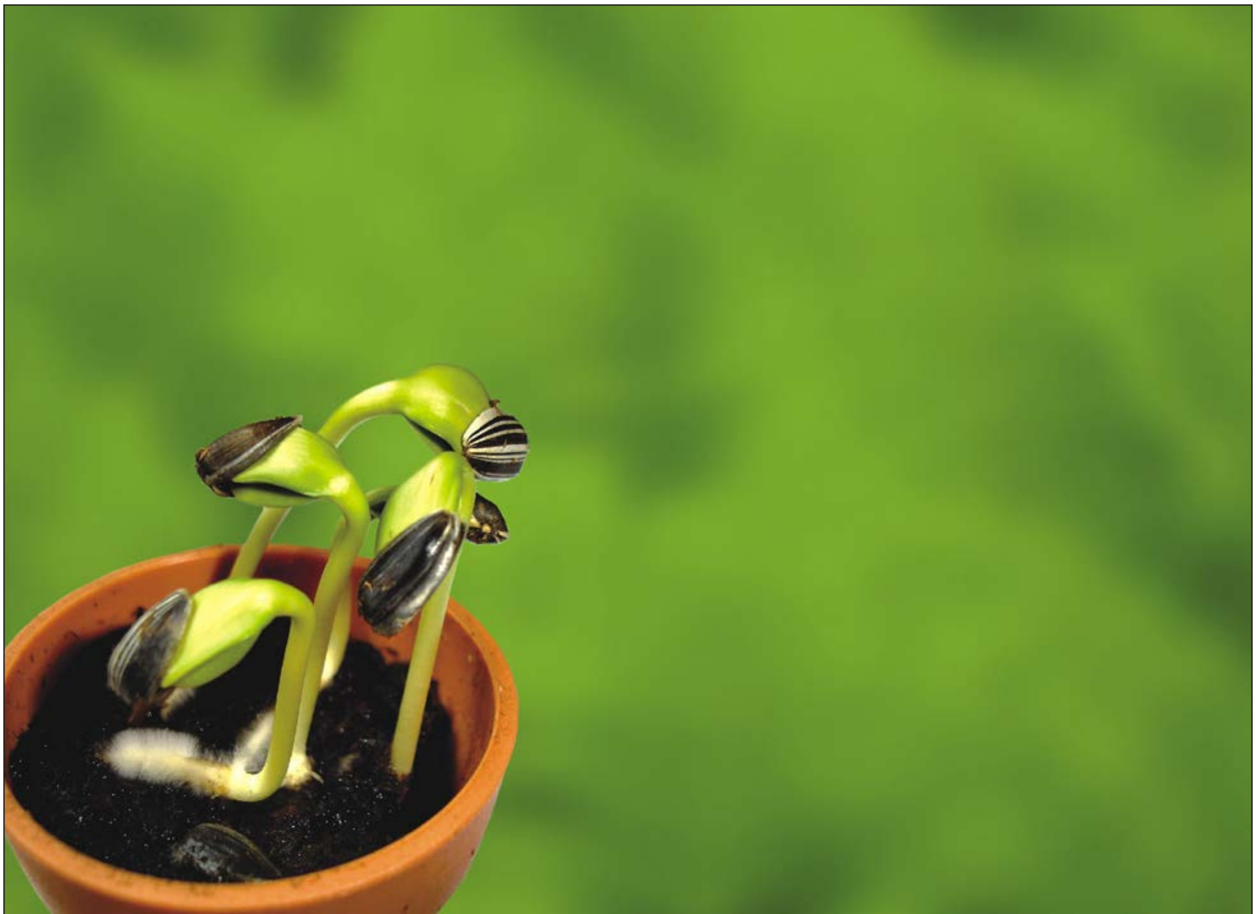

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Combining Ability Analysis for Yield and Yield Related Traits in Maize (*Zea mays* L.)

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Abstract: Present study was aimed to assess the general combining ability effects of parents and specific combining ability effects of hybrids for yield and yield related traits and explore their use in hybrid development. Combining ability analysis using line × tester design was conducted in maize (*Zea mays* L.) inbred lines by growing 45 F_1's generated by crossing fifteen lines with three well adapted testers. There was a great contribution of lines towards σ^2 gca for all the traits. Inbred lines viz., KDM 334, KDM 342 and KDM 347 were good combiners for yield and yield attributing characters. Tester C6 was high combiner for grain yield, number of kernel rows ear^{-1} and number of kernels row^{-1}. Among the hybrids, KDM 331 × super-1, KDM-333 × KDM-34, KDM 342 × C6, KDM331 × KDM-346 and KDM 336 × KDM-346 exhibited highest significant sca effects for yield and yield attributing traits.

Key words: Maize, combining ability

INTRODUCTION

Maize occupies an important place in the food grain production scenario of Jand K State. All though it occupies the highest area in the State, however, the productivity figures are very low primarily because of the cultivation of land races and the composite varieties. Efforts are, therefore, required to be made to develop hybrids with high yield potential in order to increase production of maize. It was precisely with this objective in view that the materials were introduced from the various sources, through Directorate of Maize Research, New Delhi, to strengthen the breeding programmes for the development of elite lines having better yielding abilities. Most efficient use of such materials would be possible only when adequate information on the amount and type of genetic variation and combining ability effects in the materials is available.

A wide array of biometrical tools are available to breeders for characterizing genetic control of economically important traits as a guide to decide upon an appropriate breeding methodology varying from recurrent selection schemes to hybrid breeding.

The present investigation were carried out to determine breeding value of genotypes and nature and magnitude of gene action governing various morphological, yield and yield related traits in maize. Line x tester mating design developed by Kempthorne (1957), which provides a reliable information on the general and specific combining ability effects of parents and their hybrid combinations was used to generate the information. 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).

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The objective of the present investigation were to generate information on nature and magnitude of gene action, combining ability effects, heritability and nature and extent of heterosis for different traits.

MATERIALS AND METHODS

Fifteen maize lines viz., KDM-328, KDM-329, KDM-330, KDM-331, KDM-332, KDM-333, KDM-334, KDM-335, KDM-336, KDM-337 KDM-340, KDM-342, KDM-345, KDM-347 and KDM-349 (used as males) and three testers viz., C6, super-1 and KDM-346 at Karewa Damuder Maize Research Station Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir were crossed in a line × tester mating design during kharif 2004 to generate a total of 45 hybrids. All the 45 hybrids along with 18 parents, were planted in a randomized block design with 3 replications in 3 row experimental plot of 5 m row length having 60×20 cm crop geometry at K.D. Research Station during kharif 2005. The data were recorded on yield and yield attributing traits viz., ear length, ear diameter, No. of kernel rows^{-1}, number of kernels row-1 and 1,000 grain weight. Combining ability analysis was done according to procedure of Kempthorne (1957).

RESULTS AND DISCUSSION

Recently in India, research strategies are being diverted to produce two parent single cross hybrids to achieve quantum jump in production and productivity of maize. In the present investigation the analysis of variance for combining ability revealed that mean squares due to lines, testers and line x testers were significant for all the characters except due to testers for 1,000 grain weight (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 those of Joshi *et al.* (2002) whereas, Sharma *et al.* (2004) reported preponderance additive gene effects.

The non significant variance for 1,000 grain weight in testers suggest that the testers chosen had lighter and comparable potential for grain weight. A higher proportion of σ^2 sca and σ^2 gca also indicated that additive x non additive and non additive interaction were significantly higher among hybrids. Contrarily, importance of additive gene effects was reported by (Alamnie *et al.*, 2006). Higher magnitude of dominance variance for number of kernel rows per ear, number of kernels per row and

Table 1: Analysis of variance of combining ability for different traits in line × tester cross of maize (*Zea mays* L.)

Source of variation	df	Ear length (cm)	Ear diameter (cm)	No. of kernel rows ear^{-1}	No. of kernels row^{-1}	1000 grain weight (g)	Grain yield plot^{-1} (kg)
Line	14	12.743*	9.984**	14.102**	62.985*	10504.817**	10.409**
Tester	2	44.839*	20.854**	21.632*	128.843*	1034.635	16.669**
Line × tester	28	4.957**	3.019**	4.979**	31.991	3492.374**	2.376**
Error	88	1.025	0.629	1.069	5.739	79.794	0.070
σ^2L		1.302*	1.038**	1.448**	6.360*	1158.335**	1.148**
σ^2T		0.973*	0.449*	0.457*	2.735*	228.085	0.368*
σ^2gca		1.02*	0.547*	0.622**	3.339*	383.127*	0.498*
σ^2sca		1.308**	0.796**	1.303**	8.751**	1137.526**	0.768**
σ^2sca/σ^2gca		1.571	1.375	0.954	0.763	0.673	1.297
σ^2 A		2.056	1.095	1.244	6.679	766.254	0.997
σ^2 D		1.308	0.796	1.303	8.751	1137.526	0.768
σ^2 A/D		1.571	1.375	0.954	0.763	0.673	1.297
Degree of dominance		0.797	0.852	1.023	1.144	1.218	0.872
Genetic advance		2.200	47.710	1.504	3.304	35.926	1.536

*,**Significant at 5 and 1% levels, respectively

Table 2: Estimates of general combining effects of lines and testers for yield and yield attributing traits in maize

Parents	Ear length (cm)	Ear diameter (cm)	No. of kernel rows ear^{-1}	No. of kernels row^{-1}	1000 grain weight (g)	Grain yield plot^{-1} (kg)
KDM 328	0.674 (18.60)	-1.956 (6.73)**	-0.338 (13.64)	-0.604 (28.22)	-0.064 (253.90)	0.151 (5.58)
KDM 329	-0.081 (17.84)	-0.711 (7.97)*	-0.249 (13.73)	1.040 (29.86)	29.865(283.83)**	0.694 (6.12)**
KDM 330	1.207 (19.13)**	-0.222 (8.46)	-1.582 (12.40)**	1.973 (30.80)*	16.132 (270.09)**	-0.163 (5.26)
KDM 331	-2.770 (15.15)**	0.067 (8.75)	-0.782 (13.20)*	-6.338 (22.48)**	-21.439 (232.52)**	-1.440 (3.99)**
KDM 332	-0.793 (17.13)*	-0.133 (8.55)	0.151 (14.13)	-0.627 (28.20)	-30.742 (223.22)**	-0.832 (4.60)**
KDM 333	-0.637 (17.28)	0.122 (8.81)	0.018 (14.00)	-3.960 (24.86)**	14.893 (268.86)**	-0.362 (5.07)**
KDM 334	1.074 (19.00)**	3.256 (11.94)**	0.018 (14.00)	0.173 (29.00)	21.036 (275.00)**	0.501 (5.93)*
KDM 335	0.341 (18.26)	0.311 (9.00)	3.618 (17.60)**	1.373 (30.20)	-4.774 (249.19)	1.409 (6.84)**
KDM 336	0.941 (18.86)*	0.044 (8.73)	-0.782 (13.20)*	0.573 (29.40)	-46.019 (207.94)**	-0.824 (4.60)**
KDM 337	-0.237 (17.68)	0.267 (8.95)	-0.827 (13.15)*	0.773 (29.60)	-50.234 (203.73)*	-1.399 (4.03)*
KDM 340	0.074 (18.00)	0.044 (8.73)	0.284 (14.26)	0.173 (29.00)	28.662 (282.62)**	0.617 (6.04)**
KDM 342	1.741 (19.66)**	-0.089 (8.60)	1.618 (15.60)**	4.907 (33.73)**	8.983 (262.95)**	1.501 (6.93)**
KDM 345	0.941 (18.86)**	-0.289 (8.4)	-0.516 (13.46)	1.129 (29.95)	48.747 (302.71)**	0.446 (5.87)**
KDM 347	-1.193 (16.73)*	-0.378 (8.31)	0.418 (14.40)	1.707 (30.53)*	42.796 (296.76)**	1.434 (6.86)**
KDM 349	-1.281 (16.64)**	-0.333 (8.35)	-1.049 (12.93)**	-2.293 (26.53)*	-57.842 (196.12)*	-1.732 (3.70)**
SE±gi (Lines)	±0.337	±0.264	±0.344	±0.798	±2.979	±0.088
SE±gi-gj (Lines)	±0.477	±0.374	±0.487	±1.129	±4.221	±0.125
Testers						
C6	0.585 (18.51)**	0.182 (8.87)	0.427 (14.40)**	1.724 (30.55)**	-13.876 (240.09)**	0.098 (5.53)*
Super-1	0.567 (18.46)**	0.571 (9.26)**	-0.800 (13.18)**	-1.658 (27.16)**	-2.306(251.66)**	-0.652 (4.78)**
KDM 346	-1.153 (16.77)**	-0.753 (7.93)**	0.373 (14.35)*	-0.067 (28.76)	16.182 (270.14)**	0.554 (5.98)**
SE±gi (Testers)	±0.150	±0.118	±0.154	±0.357	±1.331	±0.039
SE±gi-gj (Testers)	±0.213	±0.167	±0.218	±0.505	±1.883	±0.056s

*,**Significant at 5 and 1% levels, respectively, The values in brackets represent mean *per se* performance

thousand grain weight revealed importance of non-additive gene action in the inheritance of these traits, whereas, for other traits inheritance was under the control of additive gene action indicated by preponderance of additive genetic variance. Similar findings were reported for ear length and ear diameter by Kanta *et al.* (2005), whereas, results contradict in the findings of Surya and Ganguli (2004) thousand grain weight revealed importance of non-additive gene action in the inheritance of these traits, whereas, for other traits inheritance was under the control of additive gene action indicated by preponderance of additive genetic variance. Similar findings were reported for ear length and ear diameter by Kanta *et al.* (2005), whereas, results contradict in the findings of Surya and Ganguli (2004) Similar findings were reported for (Joshi *et al.*, 2002). Perusal of gca effects (Table 2) revealed that no line was observed to be good combiner for all the traits. However, KDM 334 and KDM 342 was observed to be good combiner for most of the traits excepting number of kernel rows ear-1, No. of kernels rows-1 (KDM 334) and ear diameter (KDM 342). Among testers, KDM 346 and super 1 were observed to be good combiner for all the traits excepting number of kernels row-1 (KDM 346) and 1,000 grain weight (super-1).

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, average and low general combiners. For grain yield KDM-349 × KDM-346 was the best specific combiner (Table 3). Other top ranking specific cross combinations viz., KDM-345 × KDM-346 and KDM 342 × C6 had both the parents as high general combiners whereas, KDM 328 × super-1 was a result of average × low general combiners. Most of the top ranking specific combiners revealed average specific combining ability for yield attributing traits excepting KDM-333 × KDM-346, KDM-329 × C6 and KDM-328 × super-1 which showed high specific combining ability for thousand grain weight. Studies indicated that most of the superior crosses were between high × low, high × high

Table 3: Estimates of specific combining ability effects for yield and yield attributing traits in maize

Crosses	Ear length (cm)	Ear diameter (cm)	No. of kernel rows ear^{-1}	No. of kernels row^{-1}	1000 grain weight (g)	Grain yield plot^{-1} (kg)
KDM 328 x C_6	-1.185 (18.00)	0.751(7.66)	-0.338 (13.73)	2.453 (32.40)	-27.127 (212.90)**	-0.202 (5.48)
KDM 328 x Sup-1	1.433 (20.60)*	-0.704 (6.60)	1.156 (14.00)	-2.364 (24.20)	50.269 (301.86)**	0.938 (5.87)**
KDM 328 x KDM 346	-0.247 (17.20)	-0.047 (5.93)	-0.818 (13.20)	-0.089 (28.06)	-23.142 (246.94)**	-0.737 (5.40)**
KDM 329 x C_6	1.304 (19.73)*	-0.627 (7.53)	-1.760 (12.40)**	1.609 (33.20)	5.071 (275.02)	-0.412 (5.81)*
KDM 329 x Sup-1	-0.412 (18.00)	0.584 (9.13)	0.667 (13.60)	-0.809 (27.40)	-14.496 (267.03)*	-0.128 (5.34)
KDM 329 x KDM 346	-0.892 (15.80)	0.042 (7.26)	1.0393 (15.20)	-0.800 (29.00)	9.426 (309.44)	0.540 (7.22)*
KDM 330 x C_6	-0.319 (19.40)	-0.649 (8.00)	0.773 (13.60)	0.476 (33.00)	0.507 (256.73)	-0.037 (5.33)
KDM 330 x Sup-1	0.299 (20.00)	0.562 (9.60)	0.800 (12.40)	-0.942 (28.20)	-10.893 (256.90)	0.393 (5.01)*
KDM 330 x KDM 346	0.019 (18.00)	0.087 (7.80)	-1.573 (11.20)*	0.467 (31.20)	10.386 (296.66)	-0.356 (5.46)*
KDM 331 x C_6	0.859 (16.60)	-0.738 (8.20)	0.773 (14.40)	0.013 (24.20)	2.432 (221.08)	0.453 (4.54)*
KDM 331 x Sup-1	-0.056 (15.66)	2.540 (11.86)**	0.800 (13.20)	0.902(21.70)	17.278 (247.50)**	0.600 (3.94)**
KDM 331 x KDM 346	-0.803 (13.20)	-1.802 (6.20)**	-1.573 (12.00)*	-0.889 (21.53)	-19.710 (229.00)**	-1.052 (3.49)**
KDM 332 x C_6	0.481 (18.20)	-0.338 (8.40)	-0.960 (13.60)	1.676 (31.60)	-10.649 (198.70)	-0.198 (4.50)
KDM 332 x Sup-1	0.299 (18.00)	-0.660 (8.46)	-0.133 (13.20)	4.658 (31.20)**	-19.943 (200.97)**	0.552 (4.50)**
KDM 332 x KDM 346	-0.781 (15.20)	0.998 (8.80)	1.093 (15.60)	-6.333 (21.80)**	30.593 (270.00)**	-0.354 (4.80)*
KDM 333 x C_6	-0.074 (17.80)	0.007 (9.00)	0.373 (14.80)	0.609 (27.20)	-34.984 (220.00)**	-0.502 (4.66)**
KDM 333 x Sup-1	-0.390 (17.46)	-0.782 (8.60)	-2.000 (11.20)**	0.791 (24.00)	3.446 (270.00)	-0.675 (3.74)**
KDM 333 x KDM 346	0.464 (16.60)	0.776 (8.83)	1.627 (16.00)*	-1.400 (23.40)	31.538 (316.58)**	1.176 (6.80)**
KDM 334 x C_6	-1.185 (18.40)	1.073 (13.20)*	0.373 (14.80)	1.676 (32.40)	-32.697 (228.43)**	-0.132 (5.90)
KDM 334 x Sup-1	-0.567 (19.00)	0.518 (13.03)	0.400 (13.60)	0.658 (28.00)	7.303 (280.00)	0.718 (6.00)**
KDM 334 x KDM 346	1.753 (19.60)**	-1.591 (9.60)**	-0.773 (13.00)	-2.333 (26.60)	25.395 (316.58)**	-0.587 (5.90)**
KDM 335 x C_6	-1.052 (17.80)	-0.182 (9.00)	-0.427 (17.60)	-0.924 (31.00)	20.303 (255.62)**	0.261 (7.20)
KDM 335 x Sup-1	-0.434 (18.40)	-0.171 (9.40)	1.200 (18.00)	-1.542 (27.00)	35.883 (282.77)	0.911 (7.10)**
KDM 335 x KDM 346	1.486 (18.60)*	0.353 (8.60)	-0.773 (17.20)	2.467 (32.60)	-56.185 (209.19)**	-1.171 (6.22)**
KDM 336 x C_6	-0.052 (19.40)	-0.116 (8.80)	-0.427 (13.20)	0.676 (31.80)	27.772 (221.84)**	0.817 (5.52)**
KDM 336 x Sup-1	-1.234 (18.20)	-0.304 (9.00)	1.200 (13.60)	-1.742 (26.00)	-26.582 (179.06)**	-0.656 (3.30)**
KDM 336 x KDM 346	1.286 (19.00)*	0.420 (8.40)	-0.773 (12.80)	1.067 (30.40)	1.190 (222.96)	-0.161 (5.00)
KDM 337 x C_6	-0.674 (17.60)	0.129 (9.26)	0.418 (14.00)	-4.724 (26.60)	13.743 (203.60)*	0.068 (4.20)
KDM 337 x Sup-1	0.210 (18.46)	-1.127 (8.40)*	-1.022 (11.33)	7.058 (35.00)**	-9.937 (191.49)	0.618 (4.00)**
KDM 337 x KDM 346	0.464 (17.00)	0.998 (9.20)*	0.604 (14.13)	-2.333 (27.20)	-3.805 (216.11)	-0.687 (3.90)**
KDM 340 x C_6	-0.385 (18.20)	-0.316 (8.60)	0.107 (14.80)	0.276 (31.00)	-9.026 (259.72)	0.653(6.80)**
KDM 340 x Sup-1	0.433 (19.00)	-0.104 (9.20)	-0.267 (13.20)	-3.342 (24.00)*	37.570 (307.89)**	-3.00 (5.09)
KDM 340 x KDM 346	-0.047 (16.80)	0.420 (8.40)	0.160 (14.80)	3.067 (32.00)	-28.544 (270.26)**	-0.352 (6.25)*
KDM 342 x C_6	-0.652 (19.60)	-0.782 (8.00)	-1.627 (14.40)*	2.942 (38.40)*	58.023 (307.09)**	0.968 (8.00)**
KDM 342 x Sup-1	-1.434 (18.80)*	-0.371 (8.80)	1.200 (16.00)	-6.276 (25.80)**	-34.731 (225.91)**	-1.282 (5.00)**
KDM 342 x KDM 346	2.086 (20.60)**	1.153 (9.00)*	0.427 (16.40)	3.333 (37.00)*	-23.292 (255.84)**	0.313 (7.80)
KDM 345 x C_6	0.748 (20.20)	0.418 (9.00)	0.107 (14.00)	-2.213 (29.46)	29.735 (318.57)**	-0.976 (5.00)**
KDM 345 x Sup-1	1.566 (21.00)*	0.229 (9.20)	-0.667 (12.00)	1.102 (29.40)	-39.279 (261.13)**	-0.326 (4.90)*
KDM 345 x KDM 346	-2.314 (15.40)**	-0.647 (7.00)	0.560 (14.40)	1.111 (31.00)	9.544 (328.44)	1.302 (7.73)**
KDM 347 x C_6	1.681 (19.00)*	1.107 (9.60)*	1.973 (16.80)**	-1.258 (31.00)	-57.267 (225.62)**	-0.165 (6.80)
KDM 347 x Sup-1	0.699 (18.00)	0.118 (9.00)	-1.600 (12.00)*	-0.876 (28.00)	18.873 (313.33)**	-0.315 (5.90)
KDM 347 x KDM 346	-2.381 (13.20)**	-1.224 (6.33)*	-0.373 (14.40)	2.133 (32.60)	38.395 (351.34)**	0.480 (7.90)**
KDM 349 x C_6	0.504 (17.73)	0.262 (8.80)	0.640 (14.00)	3.258 (25.00)*	14.167 (196.41)*	-0.598 (3.20)**
KDM 349 x Sup-1	-0.412 (16.80)	-0.327 (8.60)	-1.733 (10.40)	2.724 (27.60)	-14.760 (179.06)	-1.048 (2.00)**
KDM 349 x KDM 346	-0.092 (15.40)	0.064 (7.66)	1.093 (14.40)	0.533 (27.00)	0.593 (212.90)	1.646 (5.90)**
SE±Sij	±0.584	±0.458	±0.596	±1.383	±5.15	±0.153
SE±Sij-skl	±0.826	±0.647	±0.844	±1.955	+7.293	+0.216

*,**Significant at 5% and 1% respectively, The values in brackets represent mean *per se* performances

and high × average combining 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 Dass *et al*. (1997). Top specific highest yielder KDM 342 × C6 also revealed significant positive sca effects but ranked 5th and was the outcome of high × high combining parents (Table 4). Chaudhary *et al*. (2000) and Surya and Ganguli (2004) also reported high positive specific combining ability effects along with high *per se* performance for grain yield. Crosses with good specific combining ability and *per se* performance can be selected to recover transgresive segregants. The superiority of crosses involving high × low or average × low combiner as parents could be explained on the basis of interaction between positive alleles from good/average 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 combination involving low x low general combiners could result from over dominance and epistasis.

Four parents viz., KDM-334, KDM-342, KDM-346 and super-1 were identified as best general combiners for several characters and these could be utilized for development of either the synthetic varieties or an elite breeding population by allowing thorough mixing among them to achieve new

Table 4: Top ranking cross combinations on the basis of *per se* performance, sca effects and heterosis for yield and yield related traits in maize

			Heterotic hybrids over		
Characters	*Per se* performance	Specific cross combinations	Mid parent	Better parent	Standard parent
Ear length (cm)	$L_{13}\times T_2$, $L_1\times T_2$, $L_{12}\times T_3$,$L_{13}\times T_1$, $L_3\times T_2$	$L_{12}\times T_3$, $L_7\times T_3$, $L_{14}\times T_1$, $L_{13}\times T_2$, $L_8\times T_3$	$L_2\times T_1$, $L_1\times T_2$, $L_3\times T_2$, $L_3\times T_1$, $L_{13}\times T_2$	$L_1\times T_2$, $L_{13}\times T_2$, $L_2\times T_1$,$L_3\times T_2$, $L_3\times T_1$	$L_{13}\times T_2$, $L_{12}\times T_3$, $L_1\times T_2$,$L_{13}\times T_1$, $L_3\times T_2$
Ear diameter (cm)	$L_7\times T_1$, $L_7\times T_2$, $L_4\times T_2$,$L_3\times T_2$, $L_7\times T_3$	$L_4\times T_2$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_7\times T_1$, $L_5\times T_3$	$L_7\times T_1$, $L_7\times T_2$, $L_4\times T_2$,$L_3\times T_2$, $L_6\times T_1$	$L_7\times T_1$, $L_7\times T_2$, $L_4\times T_2$,$L_{14}\times T_1$, $L_3\times T_2$	$L_7\times T_1$, $L_7\times T_2$, $L_4\times T_2$,$L_{12}\times T_2$, $L_{14}\times T_1$
No, of kernel rows ear^{-1}	$L_8\times T_2$, $L_8\times T_1$, $L_8\times T_3$,$L_{14}\times T_1$, $L_{12}\times T_3$	$L_{14}\times T_1$, $L_6\times T_3$	$L_{14}\times T_1$, $L_8\times T_2$, $L_8\times T_1$,$L_7\times T_1$, $L_3\times T_1$	$L_{14}\times T_1$, $L_8\times T_2$, $L_8\times T_1$,$L_7\times T_1$, $L_8\times T_3$	$L_8\times T_2$, $L_8\times T_1$, $L_8\times T_3$,$L_{14}\times T_1$, $L_{12}\times T_3$
No, of kernels row^{-1}	$L_{12}\times T_1$, $L_{12}\times T_3$, $L_10\times T_2$, $L_2\times T_1$, $L_3\times T_1$	$L_10\times T_2$, $L_5\times T_2$, $L_{12}\times T_3$, $L_{11}\times T_3$, $L_{12}\times T_1$	$L_2\times T_1$, $L_3\times T_1$, $L_7\times T_1$,$L_{12}\times T_1$, $L_5\times T_1$	$L_{12}\times T_1$, $L_{12}\times T_3$	$L_{12}\times T_1$, $L_{12}\times T_3$, $L_10\times T_2$,
1000 grain weight (g)	$L_{14}\times T_3$, $L_{13}\times T_3$, $L_{13}\times T_1$, $L_{11}\times T_2$, $L_6\times T_3$,	$L_{12}\times T_1$, $L_1\times T_2$ $L_{14}\times T_3$,$L_8\times T_2$, $L_{11}\times T_2$	$L_6\times T_3$, $L_5\times T_3$, $L_{14}\times T_3$, $L_7\times T_3$, $L_6\times T_2$	$L_{14}\times T_3$, $L_6\times T_3$, $L_7\times T_3$,$L_1\times T_2$, $L_3\times T_3$	$L_{14}\times T_3$, $L_{13}\times T_3$, $L_{13}\times T_1$,$L_{11}\times T_2$, $L_6\times T_3$
Grain yield plot^{-1} (kg)	$L_{12}\times T_1$, $L_{14}\times T_3$, $L_{12}\times T_3$, $L_{13}\times T_3$, $L_2\times T_3$	$L_{15}\times T_3$, $L_{13}\times T_3$, $L_6\times T_3$,$L_{12}\times T_1$, $L_1\times T_2$	$L_{12}\times T_1$, $L_{14}\times T_3$, $L_6\times T_3$,$L_{12}\times T_3$, $L_7\times T_2$	$L_{12}\times T_1$, $L_8\times T_2$, $L_{14}\times T_3$,$L_{12}\times T_3$,$L_8\times T_1$	$L_{12}\times T_1$, $L_{14}\times T_3$, $L_{12}\times T_3$,$L_{13}\times T_3$,$L_8\times T_1$

L_1-KDM 328, L_2-KDM 329,L_3-KDM330, L_4-KDM331, L_5-KDM 332, L_6-KDM 333, L_7-KDM 334, L_8-KDM 335, L_9-KDM 336, L_{10}-KDM 337, L_{11}-KDM 340, L_{12}-KDM 342, L_{13}-KDM 345, L_{14}-KDM 347, L_{15}-349

genetic recombinations and then subjecting the resultant population to recurrent selection. These populations could serve as the source of new desirable inbred lines. Multiple crossing involving KDM-331 × Super-1, KDM-333 × KDM-346, KDM-342 × C6, KDM-331 × KDM-346 and KDM-336 × KDM-346 followed by selective intermating is suggested for recovery of gene constellation more useful in present set of conditions.

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