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Research Note

Combining ability and heterosis for grain yield and yield component traits in maize (*Zea mays* L.)

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Abstract
The present investigation was conducted on maize hybrids to determine the extent of heterosis and combining ability for 12 quantitative traits including yield and its contributing traits during *Kharif*, 2021. A set of 28 F_1s developed by 8 x 8 half diallel mating design and the resultant hybrids along with parents and standard checks were evaluated in Randomised Block Design (RBD) with three replications. For standard heterosis over hybrid Bio 9544 ranged from 11.10 to 44.86 % and four F_1 cross combinations (SNL 142828-4 x CML 451, CAL 1473-4 x CML 451, CAL 1424-1 x CML 470-1 and SNL 142828-4 x CML 470-1) exhibited standard heterosis of 10 % or more for grain yield/ ha. On the basis of general combining ability (*gca*) estimates, V351 was the best general combiner followed by CML 451 for grain yield/ ha. Considering the *per se* performance, standard heterosis and specific combining ability (*sca*) effects, the four hybrids i.e., SNL 142828-4 x CML 451, CAL 1473-4 x CML 451, CAL 1424-1 x CML 470-1 and SNL 142828-1 x CML 470 1 were identified as promising for exploiting heterosis for grain yield.

Keywords*:* Maize, gca, sca, heterosis, diallel

Maize (*Zea mays* L.) is a gift of nature to humankind due to its great versatility and flexibility in adapting to diverse agro-ecologies and multiple utilization as human food, livestock feed, biofuel and a component for a large number of industrial products. Additionally, maize is a model plant for biological research worldwide. For more than a century, maize has been the focus of genetic research that has significantly illuminated the fields of genetics, breeding, and evolution (Hake *et al.,* 2015). For example, hybrid vigour (Shull, 1908), quantitative genetics (Emerson and East, 1913), mobile genetic elements (McClintock, 1950), and the role of epigenetics (Kermicle, 1970) are some of the notable contributions. In contrast to some member species of the Poaceae family, maize, as a C4 plant, is physiologically more productive and possesses the highest genetic yield potential among cereal crops, for which it is popularly known as the "Queen of Cereals". Maize, being an allogamous crop due to its monoecious and protandrous nature, has a natural advantage in exploiting the phenomenon of heterosis. Successful exploitation of heterosis or hybrid vigour in maize compared to other crops has led to significant improvements in acreage and production over the years. However, despite significant advancements, the complex interplay of factors such as escalating input costs, climate change, emerging pests and diseases, and the imperative to enhance farmers' livelihoods necessitates a continuous pursuit of development of novel and superior hybrids. These efforts are crucial to bridge the gap between current production and burgeoning demand for ensuring food, feed, nutritional and bioenergy security with environmental sustainability.

Maize exhibits heterosis across all traits, though the magnitude of this hybrid superiority differs substantially based on parental lines and the traits examined. Diallel analysis is a tool to dissect the genetic basis of hybrid superiority, by partitioning the genetic influence into additive and non-additive components (Glover *et al.,* 2005). Combining ability analysis is a fundamental technique in maize breeding that helps breeders to understand the genetic factors influencing complex traits, select promising parent lines, and ultimately develop improved hybrid varieties. Combining ability analysis can be performed by different methods and among the different methods, diallel analysis elaborated by Griffings (1956) is a simple and effective means for assessing the general combining ability of parents as well as specific combining ability of crosses and also for understanding the nature and magnitude of gene action for yield and yield attributing traits to isolate the superior lines and cross combinations with high heterotic effects. In line with the importance of identifying superior parent lines and cross combinations for maize hybrid development, the present study was conducted to assess combining ability and heterosis in 28 single cross hybrids developed through a half-diallel approach, along with their parental lines. The hypothesis was that this study would lead to the identification of parental lines with good general combining ability and F_1 hybrids demonstrating significant heterosis for yield and associated traits warranting further commercial exploration.

The present study was carried out under All India Co-ordinated Research Project on Maize at O.U.A.T., Bhubaneswar to evaluate 28 single cross F_1 hybrids developed by 8 x 8 half diallel mating design, eight parental inbreds and four standard check hybrids (**Table 1**). The entries were sown following field plot technique during the *Kharif*, 2021 with a spacing of 60 cm x 20 cm in a randomized block design (RBD) with three replications. The plot size of each treatment was 4.8 m^2 (2 rows of 4 meter length). Observations were recorded on twelve quantitative traits *viz.* days to 50 % anthesis, days to 50 % silking, days to 75% dry husk, plant height (cm), ear height (cm), cob yield (kg/ plot), cob length (cm), cob diameter (cm), number of kernel rows per cob, number of kernels per row, shelling percentage, grain yield (kg/ ha).

The significance of differences between treatments was assessed by conducting an analysis of variance (ANOVA) for Randomized Block Design (RBD) as per the procedure outlined by Panse and Sukhatme (1985), for all the metric traits studied. Combining ability analysis was performed following Method-II, Model-I of Griffing's (1956). Heterosis, measured as the superiority of the F_1 hybrids over the better parent (heterobeltiosis), and standard checks (standard heterosis), was calculated for various traits including grain yield following the method described by Mather and Jinks (1971). Significance of heterosis is tested with the help of standard error using 't' test.

ANOVA: Analysis of variance (**Table 2**) showed highly significant differences among genotypes for all 12 traits examined, indicating substantial genetic variability. Further analysis revealed significant differences among the eight parents for these traits, confirming considerable variability within the parental lines as well. Similarly, significant differences were observed among the 28 F_1 cross combinations for all traits, likely due to the contribution of genes from diverse parents, enhancing hybrid vigour in terms of grain yield and yield-contributing traits. Additionally, the variance between parents and hybrids was significant for all investigated traits, indicating a substantial level of relative heterosis among the cross combinations.

Table 1. List of parents and standard checks used in this study

S. No.	Name of the inbred lines	Source
1.	CAL 1424-1	
2.	SNL 142828-4	
3.	CAL 1473-4	
4.	CML 425-4	
5.	CML 290-1	Maintained by AICRP on Maize
6.	CML 470-1	
7.	V 351	
8.	CML 451	
S. No.	**Name of the standard checks**	**Source**
1.	Bio 9544	Shriram Bioseed Genetics Pvt. Ltd.
2.	DHM 121	PJTSAU, Telangana
3.	Hishell	Bayer Crop Science Pvt. Ltd.
4.	Kalinga Raj	O.U.A.T., Odisha

Table 2. Analysis of variance of parents and hybrids (F_1) for 12 characters in an 8 x 8 half diallel cross of maize

S. No.	Source of variation	d.f.	Days to 50% anthesis	Days to 50% silking	Days to 75% dry husk	Plant height	Ear height	Cob yield (kg/ plot)	Cob length	Cob diameter	Number of kernel rows per cob	Number of kernels per row	Shelling percentage	Grain yield (kg/ ha)
1	Replication	2	0.176	0.148	1.231	65.290	66.037	0.011	0.018	0.004	1.208**	0.456	1.062	7958.065
2	Genotypes	35	4.116**	4.358**	6.720**	1420.624**	498.141**	3.025**	9.380**	0.539**	5.492**	67.407**	7.892**	7970716.619**
3	Parents	7	8.851**	9.310**	7.810**	1620.682**	436.119**	0.263**	8.484**	0.333**	7.253**	14.970**	2.106**	651115.470**
4	Hybrids	27	2.717**	3.000**	6.322**	577.854**	380.552**	1.787**	13.811**	0.278**	3.238**	33.897**	5.338**	4585725.721**
5	Parents vs Hybrids	1	8.747**	6.352**	9.844**	22774.981**	4107.185**	55.803**	596.012**	9.030**	54.022**	1339.239**	117.334**	150602678.890**
6	Error	70	0.357	0.548	0.698	107.385	60.173	0.071	0.431	0.028	0.191	1.168	0.661	170759.541

* and ** Significant at 5% and 1% level of probability respectively

Table 3. Combining ability variances for 12 characters in 8 x 8 half diallel crosses of maize

S. No.	Characters	Days to 50% anthesis	Days to 50% silking	Days to 75% dry husk	Plant height	Ear height	Cob yield (kg/ plot)	Cob length	Cob diameter	Number of kernel rows per cob	Number of kernels per row	Shelling percentage	Grain yield (kg/ ha)
1	σ^2gca	0.192	0.158	0.249	37.03	26.646	0.016	0.129	0.004	0.197	0.478	0.062	36779.399
2	σ^2sca	1.087	1.193	1.887	454.608	115.872	1.191	11.74	0.204	1.715	26.406	2.858	3158033.618
3	σ^2e	0.119	0.183	0.233	35.795	20.058	0.024	0.144	0.009	0.064	0.389	0.22	56919.847
4	σ^2gca/σ^2sca	0.177	0.132	0.132	0.081	0.23	0.013	0.011	0.018	0.115	0.018	0.022	0.012
5	Predictability factor	0.261	0.209	0.209	0.14	0.315	0.026	0.021	0.034	0.187	0.035	0.042	0.023

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Combining ability: he analysis of variance for combining ability (**Table 3**) showed that the variances due to *gca* and *sca* were significant for all the characters studied, suggesting the importance of both additive and non-additive gene action in the expression of the traits. However, the higher estimates of *sca* variance as compared to *gca* variance, ratio of *gca* variance to *sca* variance and predictability factor indicated the preponderance of non-additive gene action in expression of all the traits.

gca effects: A perusal of *gca* effects (**Table 4**) indicated that parent V351 was the best general combiner for grain yield/ha, exhibiting maximum significantly positive *gca* effect (269.74). It also recorded high *gca* effects for cob yield/ plot and medium *gca* effects for cob length, cob diameter, and days to 50% silking. CML 451, the second-best general combiner for grain yield/ha (250.61) with high *gca* effects for yield component traits such as cob length, cob yield/ plot, number of kernel rows per cob, plant height, and ear height. Thus, the positive and significant higher *gca* effects for one or more yield components contributed to the high *gca* effects in V351 and CML 451 for grain yield/ha.

The parent CAL 1424-1 displayed the highest *gca* effects in the desirable direction for flowering and maturity traits, suggesting that CAL 1424-1 could be a good general combiner for these traits in cross combinations to produce short duration hybrids. Conversely, SNL 142828-4, CML 425-4, and CML 470-1 were identified as poor general combiners for grain yield, along with one or more yield component traits like cob yield, number of kernel rows/ cob, and number of kernels per row. The results of this study regarding the relationship between *gca* effects on grain yield and component traits align well with the previous findings of Ahmad and Ansari (2017), Rani *et al*. (2018), Patel *et al*. (2019), and Patel (2022) in maize.

sca effects: The estimates of *sca* (**Table 5**) effects revealed that a number of hybrids possessed significant *sca* effects for all the twelve characters. Out of 28 hybrids, 18 hybrids exhibited significant and positive *sca* effects for grain yield/ha. The maximum positive *sca* effects for grain yield/ ha were exhibited by SNL 142828-4 x CML 470-1 followed by CAL 1424-1 x CML 470-1, CML 425-4 x CML 470-1, and SNL 142828-4 x CML 451, though SNL 142828-4, CML 425-4, and CML 470-1 were poor general combiners for grain yield along with one or more yield component traits like cob yield, number of kernel rows per cob and number of kernels per row. The aforementioned crosses had parental combinations of low x low, medium x low, and low x high *gca* effects of parents indicating the effects of dominance x dominance and dominance x additive interactions in the manifestation of high *sca* (**Table 6**). The finding also revealed that high *gca* of both the parents is not always sufficient criterion for predicting superior cross combinations. Positive and significant *sca* effects for grain yield, along with notable *sca* effects for certain yield components in maize, have been documented in previous studies by Ahmad and Ansari (2017), Patel *et al*. (2019), Scaria *et al*. (2020), and Patel (2022).

Heterosis: The heterosis estimates for yield and its related traits were calculated and compared against the better parent and best check hybrid (Bio 9544) (**Table 6**). Significant and positive heterobeltiosis was observed in 25 F_1 hybrids for grain yield (kg/ ha). Among 28 F_1 hybrids, 11 F_1 hybrids displayed significant and positive heterobeltiosis for five component traits like cob length, cob diameter, shelling percentage, number of kernels per row, and cob yield per plot, while 24 F_1 hybrids exhibited significant and positive heterobeltiosis for cob length, 20 F_1 hybrids each for cob diameter and shelling percentage, 25 F_1 hybrids each for cob yield and number of kernels per row, and 14 hybrids for number of kernel rows/ cob. Significant negative heterobeltiosis was evident in seven F_1 hybrids for days to 50% anthesis, five F_1 hybrids for days to 50% silking, and nine F_1 hybrids for days to 75% dry husk.

The cross SNL 142828-4 x CML 290-1 displayed the maximum significant negative heterobeltiosis for days to 50% anthesis (-4.52%) and days to 50% silking (-4.29%), while SNL 142828-4 x V 351 recorded the maximum significant negative heterobeltiosis for days to 75% dry husk (-3.27%). For grain yield (kg/ha) (93.33%), number of kernel rows/ cob (32.92%), and cob diameter (39.16%), CAL 1473-4 x CML 290-1 exhibited the maximum significant positive heterobeltiosis. CML 425-4 x CML 290-1 (94.00%), CML 425-4 x CML 470-1 (92.68%), V 351 x CML 451 (55.07%), and CAL 1424-1 x V 351 (5.91%) displayed significant positive heterosis for cob length, cob yield, number of kernels per row and shelling percentage, respectively. Similar desirable heterobeltiosis for various traits in maize has been reported in the studies by Patil *et al*. (2017), Brahmbhatt *et al*. (2018), Reddy *et al*. (2018), Tafa *et al*. (2020), and Agarwal *et al*. (2021).

Among the 28 crosses evaluated, four hybrids namely, SNL 142828-4 x CML 451 (11.10%), CAL 1473-4 x CML 451 (10.86%), CAL 1424-1 x CML 470-1 (10.42%), and SNL 142828-4 x CML 470-1(10.21%) exhibited significant and positive standard heterosis over the best check, Bio 9544 for grain yield. The crosses also demonstrated significant and positive standard heterosis over the best check for various yield components such as in four hybrids for cob length, three hybrids each for cob yield and number of kernel rows per cob, two hybrids each for cob diameter and number of kernels per row, and eleven hybrids for shelling percentage. No hybrids exhibited significant heterosis in the desired direction for days to 50% silking or days to 75% dry husk.

Table 4. ***gca*** **effects of eight parents for 12 characters in 8 x 8 half-diallel crosses of maize**

S. No.	Characters / Parents	Days to 50% anthesis	Days to 50% silking	Days to 75% dry husk	Plant height	Ear height	Cob yield (kg/ plot)	Cob length	Cob Diameter	Number of kernels rows per cob	Number of kernels per row	Shelling percentage	Grain yield
1	CAL 1424-1	-0.83**(H)	-0.73**(H)	-0.88**(H)	0.09(M)	0.86(M)	-0.05 (M)	0.14(M)	0.11**(H)	0.44**(H)	1.16**(H)	0.06(M)	-36.89 (M)
2	SNL 142828-4	0.17(M)	0.20(M)	-0.48**(H)	6.52**(L)	2.16(M)	-0.11* (L)	-0.07 (M)	0.07*(H)	0.29**(H)	0.61**(H)	0.09(M)	-167.39*(L)
3	CAL 1473-4	0.23*(L)	0.37**(L)	-0.14 (M)	1.18(M)	-1.86 (M)	0.12**(H)	0.01(M)	-0.11**(L)	-0.08 (M)	0.46*(H)	-0.35* (L)	160.48*(H)
4	CML 425-4	-0.40**(H)	-0.37**(H)	-0.01 (M)	3.62*(L)	1.71(M)	-0.15**(L)	-0.25* (L)	0.00(M)	-0.31**(L)	0.18(M)	-0.01 (M)	-233.79* (L)
5	CML 290-1	0.13(M)	0.17(M)	-0.08 (M)	-1.90 (M)	4.16**(L)	-0.02 (M)	-0.72**(L)	0.02(M)	-0.56**(L)	-0.70**(L)	0.5**(H)	-15.36 (M)
6	CML 470-1	0.33**(L)	0.33*(L)	0.66**(L)	-7.03**(H)	-0.08 (M)	-0.13**(L)	0.56**(H)	-0.05 (M)	-0.01 (M)	-0.53**(L)	-0.22 (M)	-227.39**(L)
7	V 351	-0.20 (M)	-0.33* (H)	0.33*(L)	8.01**(L)	5.11**(L)	0.16**(H)	0.03(M)	-0.02 (M)	-0.47**(L)	-0.90**(L)	0.23(M)	269.74**(H)
8	CML 451	0.57**(L)	0.37**(L)	0.59**(L)	-10.50**(H)	-12.06**(H)	0.18**(H)	0.29*(H)	-0.02 (M)	0.72**(H)	-0.29 (M)	-0.31* (L)	250.61**(H)
	SE g(i)	0.10	0.13	0.14	1.77	1.32	0.05	0.11	0.03	0.07	0.18	0.14	70.57
	Predictability Factor	0.261	0.209	0.209	0.140	0.315	0.026	0.021	0.034	0.187	0.035	0.042	0.023

*p < 0.05; **p < 0.01; L-Low gca parent, M-Medium gca parent, H-High gca parent

Table 5. ***sca*** **effects of F_1 hybrids in 8 x 8 half diallel crosses of maize**

S. No.	Characters	Range of *sca*	Number of hybrids with significant *sca*
1.	Days to 50 % anthesis	-1.89 to 2.37	14
2.	Days to 50 % silking	-2.00 to 2.34	10
3.	Days to 75% dry husk	-2.39 to 2.48	15
4.	Plant height	-12.15 to 32.58	14
5.	Ear height	-13.25 to 26.45	12
6.	Cob yield (kg/ plot)	-1.49 to 1.47	22
7.	Cob length	-3.65 to 4.96	25
8.	Cob diameter	-0.37 to 0.73	19
9.	Number of kernel rows per cob	-1.48 to 2.52	20
10.	Number of kernels per row	-6.27 to 6.82	24
11.	Shelling percentage	-1.72 to 2.86	15
12.	Grain yield (kg/ ha)	-2467.39 to 2263.27	23

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Table 6. Heterosis and *sca* effects in top five performing hybrids for yield traits in 8 x 8 Half-diallel crosses of maize

Characters	Top ranking hybrids on the basis of *sca* effects	*sca* effects	*gca* status of Parents	Heterobeltiosis (%)	Standard heterosis (%)	*Per se* Performance
Grain yield (kg/ ha)	SNL 142828-4 x CML 470-1	2263.27**	Low x Low	67.36**	10.21*	8138.67
	CAL 1424-1 x CML 470-1	2149.11**	Med x Low	88.32**	10.42*	8647.00
	CML 425-4 x CML 470-1	1874.67**	Med x Low	92.12**	4.40	8175.67
	SNL 142828-4 x CML 451	1854.94**	Low x high	68.72**	11.10*	8700.63
	CAL 1473-4 x CML 290-1	1567.04**	High x Med	93.33**	8.21	8474.33
Cob length	CAL 1424-1 x CML 470-1	4.96**	High x High	85.46**	20.66**	20.83
	CML 425-4 x CML 290-1	4.65**	Low x Low	94.00**	9.17**	18.85
	SNL 142828-4 x CML 290-1	3.08**	Low x Low	47.19**	1.16	17.47
	CAL 1424-1 x CAL 1473-4	3.07**	High x Med	65.27**	6.56*	18.40
	CML 425-4 x CML 470-1	2.92**	Low x High	63.80**	6.56*	18.40
Cob diameter	SNL 142828-4 x CML 290-1	0.73**	High x High	31.67**	9.51**	4.77
	CAL 1424-1 x CAL 1473-4	0.73**	High x Low	23.60**	7.32*	4.67
	CAL 1424-1 x CML 470-1	0.55**	High x Low	20.51**	4.63	4.55
	CML 290-1 x CML 470-1	0.53**	High x Low	33.87**	2.20	4.45
	SNL 142828-4 x V 351	0.45**	High x Low	23.17**	2.44	4.46
Cob yield (kg/plot)	SNL 142828-4 x CML 470-1	1.47**	Low x Low	70.10**	10.74*	5.50
	CML 425-4 x CML 470-1	1.28**	Low x Low	92.68**	6.04	5.27
	CAL 1424-1 x CML 470-1	1.25**	Med x Low	77.78**	7.38	5.33
	SNL 142828-4 x CML 451	1.07**	Low x High	67.01**	8.72*	5.40
	SNL 142828-4 x CML 290-1	1.00**	Low x Med	58.76**	3.36	5.13
Number of kernel rows per cob	CML 290-1 x CML 470-1	2.52**	Low x Med	29.21**	8.24**	15.33
	CAL 1473-4 x CML 425-4	1.87**	Med x Low	22.53**	4.94	14.87
	SNL 142828-4 x CML 451	1.68**	High x High	16.43**	13.41**	16.07
	CAL 1473-4 x CML 290-1	1.52**	Med x Low	32.92**	0.71	14.27
	CML 290-1 x V 351	1.38**	Low x Low	13.19**	-3.06	13.73
Number of kernelsper row	CAL 1424-1 x CML 470-1	6.82**	High x Low	43.38**	8.66**	36.80
	SNL 142828-4 x CML 290-1	6.43**	High x Low	42.04**	5.41*	35.70
	V 351 x CML 451	6.00**	Low x Med	55.07**	0.89	34.17
	CML 425-4 x CML 290-1	5.19**	Med x Low	38.16**	0.49	34.03
	SNL 142828-4 x CML 470-1	4.83**	High x Low	36.34**	1.18	34.27

$^*p < 0.05$; $^{**}p < 0.01$

Table 7. Frequency of parental combinations for *gca* in 28 F_1 hybrids of maize for grain yield and other related characters

Characters	Number of hybrids with significant heterobeltiosis						Number of hybrids with significant SCA effects					
	Low x Low	Low x Med	Low x High	Med x Med	Med x High	High x High	Low x Low	Low x Med	Low x High	Med x Med	Med x High	High x High
GY	2	5	8	1	6	3	2	3	5	-	6	2
CL	1	7	4	4	8	-	1	4	4	4	7	0
CD	-	5	1	7	7	-	-	2	1	5	6	-
CY	2	5	8	1	6	3	2	3	5	-	5	2
NKRPC	3	5	9	1	5	2	1	5	8	-	5	1
NKPR	2	4	3	1	2	2	2	4	2	-	4	2
Total	10	31	33	15	34	10	8	16	25	9	33	7

Low=Low *gca* Parent, High= High *gca* Parent, Med= Medium *gca* Parent; GY-Grain yield (kg/ha), CL- Cob length, CD- Cob diameter, CY- Cob yield (kg/plot), NKRPC-Number of kernel rows per cob, NKPR- Number of kernels per row.

The cross SNL 142828-4 x CML 451 (13.41%) displayed the maximum standard heterosis for number of kernel rows per cob, while CAL 1473-4 x CML 451 (12.08%) showed the highest standard heterosis for cob yield per plot. CAL 1424-1 x CML 470-1 exhibited maximum standard heterosis for cob length (20.66%), number of kernels per row (8.66%), and shelling percentage (3.51%). Two hybrids namely, CML 425-4 x CML 470-1 (-1.99%) and SNL 142828-4 x CML 290-1 (-1.99%) displayed significant and negative standard heterosis for days to 50% anthesis. The findings of this investigation on standard heterosis for various traits, including grain yield, are consistent with earlier reports by Sumalini (2012), Mir *et al*. (2015), Patil *et al*. (2017), Ahmad and Ansari (2017), Brahmbhatt *et al*. (2018), Reddy *et al*. (2018), Scaria *et al*. (2020), and Agarwal *et al*. (2021) in maize.

Relationship of gca effects of parents with sca effects of crosses and heterosis: The *gca* effects of parents (high/ medium/ low) in cross combinations with significant heterobeltiosis, and *sca* effects for six characters including grain yield (kg/ha) are presented in **Table 7**. It was observed that crosses involving high x low (or low x high), high x medium (or medium x high), and low x medium (or medium x low) *gca* parents often produced hybrids with greater heterotic effects and higher *sca* effects for grain yield and yield-contributing traits than high x high or low x low *gca* parents. Earlier several scientists have also reported that diversity in parental *gca* effects was required for obtaining high heterotic effects (Maurya and Singh, 1978 in rice; Arunachalam and Reddy, 1981 in pearl millet; Khan *et al.,* 2014, Ahmad and Ansari, 2018, Sabitha *et al.,* 2021 in maize, Kumar *et al.,* 2023 in okra) as observed in the present study could be possibly due to compatible and complementary action of the divergent genes present in the parents involving high x low, high x medium, or low x medium *gca* effects. Heterotic hybrids found in respect of high x high *gca* parental combinations in certain cases due to accumulation of the additive genes in hybrids from both the parents. Surprisingly, the hybrid that manifested the maximum and significant *sca* effect for grain yield SNL 142828-4 x CML 470-1 was produced from a combination of two low *gca* parents, possibly due to the contribution of non-additive gene effects to the enhanced expression of the trait.

The findings of the present study revealed that four hybrids, i.e., SNL 142828-4 x CML 451, CAL 1473-4 x CML 451, CAL 1424-1 x CML 470-1 and SNL 142828-4 x CML 470-1, which exhibited superior *per se* performance for grain yield (kg/ ha) and also for one or few yield attributing traits along with *sca* effects and standard heterosis may be further evaluated for validation and commercial exploitation through heterosis breeding.

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