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Research Note

Combining ability analysis and estimation of heterosis for agronomic and oil parameters in sunflower

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Abstract
Combining ability of nine sunflower inbreds (four cytoplasmic male sterile lines and five restorers) was tested in line x tester mating design. The material including parents and cross combinations were evaluated for nine agro-biochemical parameters. The inbreds *viz*., 67A and 47R were identified as good general combiners for seed yield and oil yield, 88A, 89A, 47R and GMU 1080 were identified as good general combiners for oil content and 67A, 179R and GMU 1080 exhibited good general combining ability for early maturity. Similarly, highest significant positive specific combining ability effects for seed yield were observed for crosses 38A x 179R followed by 89A x 179R and 88A x 159R. On the basis of positive significant SCA effects for oil percent the crosses 67A x GMU 1080, 89A x 159R and 88A x 150R were found to be superior. All the traits exhibited non-additive gene action and the proportional contribution to variability was maximum by crosses except for seed yield where lines contributed more towards variability. The crosses 67A x 47R, 89A x 179R, 38A x 179R and 88A x 150R recorded maximum average heterosis for seed and oil yield and the cross combinations 67A x 47R, 88A x 150R and 67A x GMU 1080 revealed maximum heterosis against better parent also for the above traits.

Keywords: Sunflower, Combining ability, Heterosis, Line x Tester

Sunflower is a cross pollinated crop where exploitation of heterosis is important for developing hybrids with higher productivity potential. The major breeding objective for sunflower is to improve seed and oil yield, which are both complex in nature. It is thus pertinent to understand the genetic control of these traits and their component traits. Identification of elite inbreds is most important step for development of superior hybrids. This can be achieved by screening of inbreds for their *per se* performance as well as their ability to yield in a heterotic combination (Chandra *et al*., 2011 and Jockovic *et al*., 2018). Several studies have revealed that inbreds superior for their combining abilities is of much importance than superiority for their mean performance (Pathak *et al.,* 1985; Lakshman *et al.*, 2019 and Dhanalakshmi *et al.,* 2022).The magnitude of heterosis is result of genetic differences among the parents and can be utilized in identification of superior combinations. Different types of heterosis are estimated by researchers *viz*., average heterosis which is superiority of F_1 over mid parent value as well as hetoerobeltosis which is superiority of F_1 over better parent (Meena *et al.,* 2013; Aslam *et al.,* 2010; Chahal *et al.,* 2019 and Ahmed *et al.,* 2021). Furthermore, combining ability analysis is done to estimate the expected gains in productivity and its related traits, thus enabling selection based on genetic value of the parents. Combining ability analysis is also used to understand the genetic architecture of the parents as well as the gene action for various traits. Line x tester is an efficient method for evaluation of large number of inbreds and for identifying the parents and hybrids with good general combining ability (GCA) and specific combining ability (SCA) effects. Moreover it is a reliable technique for estimation of mode of gene action and relative contribution of parents as well as hybrids in total variability for a trait in question (Shamshad *et al.,* 2016; Chaudhary *et al.,* 2023). In sunflower availability of cytoplasmic male sterility (CMS) system allows utilization of line x tester mating design with ease and has been utilized extensively (Chahal *et al*., 2019 and Saeed *et al*., 2022).

The material for the present investigation included four CMS lines *viz.,* 67A, 88A, 38A, 89A, used as female parents and five restorer lines *viz.,* 150R, 159R, 179R, 47R, GMU 1080, used as male parent for developing hybrids. The inbreds utilized as female and male parents were mated in line x tester mating design for synthesizing 20 cross combinations. The maintainer lines of female parents were sown along with restorer inbreds and hybrids in the evaluation trial. The crosses were synthesized during 2020 while evaluation trial for lines, testers and cross combinations was conducted during spring 2021 at sunflower experimental area, Punjab Agricultural University, Ludhiana. The evaluation trial was laid out as per randomized block design in three replications with plot size of 3.6 m^2 each; the spacing of 60 x 30 cm was maintained. Two seeds were sown per hill to ensure optimum plant stand and thinning was carried out at 30 DAS (as per recommended package of practices) to maintain single plant per hill. The observations were recorded from 5 randomly selected plants for days to 50 per cent flowering, days to maturity, plant height (cm) and head diameter (cm). The seed yield was recorded after threshing and drying the seeds from entire plot. For recording 100 seed weight (g) and volume weight (g/100ml) and estimation of oil content (%) random sample were drawn from the plot yield. Seed yield per hectare (kg/ha) and oil yield per hectare (kg/ha) were estimated from seed yield per plot (g) and oil content (%). The data was analyzed for estimation of analysis of variance and combining ability as per Kempthorne (1957). The estimation of magnitude of mid parent heterosis and better parent heterosis for these traits was done as per Wynne *et al*. (1970).

The analysis of variance revealed that significant differences existed among treatments for all the parameters. While comparing parents and crosses, significant differences were found among parents for all the parameters except for head diameter and volume weight (p=0.01). Similarly for parents *vs* crosses significant differences were found for oil content at p=0.05 and rest of the parameters exhibited significant differences at p=0.01 except for head diameter. Analysis for variance for line x tester design revealed significant differences among lines only for seed yield per ha (p=0.05) whereas, differences among testers were not significant. The line x tester interaction revealed significant differences for all the parameters at 1% level of significance **(Table 1).** The above results suggested that ample variation was present among parents however, differences between male and females were more than within lines and testers. Also, the significance with respect to effects of parents *vs* crosses indicated the presence of heterosis among cross combination. Several workers have reported significant differences among lines, testers as well as line x tester interactions for yield and contributing traits and these traits can be subjected to heterosis breeding (Lakshman *et al*., 2019 and Karande *et al*., 2020)

The combining ability studies showed high magnitude of SCA variance in comparison to variance due to GCA for all of the parameters studied indicating the predominance of non-additive gene action. The highest degree of dominance was observed for days to fifty percent flowering (17.4) while lowest for seed yield per hectare (2.4). The contribution of lines x tester was maximum towards total variability for all of the traits except for seed yield per hectare where lines contributed maximum towards variation **(Table 2).** When only lines and testers were compared for their contribution in variability, lines contributed more for traits such as days to maturity, plant height, seed yield per hectare, volume weight and oil yield

Table 1. Analysis of Variance (mean squares) for combining ability analysis

	Days to 50% flowering	Days to maturity	Plant height	Head diameter	Seed Yield (kg/ ha)	100 seed wt	Vol.wt	Oil Content	Oil Yield
Replications	14.7**	37.4**	117	3.9	687810**	13.9	0.0	1.8	91436
Treatments	19.8**	32.9**	1453**	9.5**	1872147**	20.7	5.6	25.3	287748
Parents	28.1**	44.3**	1269**	2.3	739086**	4.3*	1.9	16.3	106862
Parents vs. Crosses	72.7**	184.1**	3334**	9.9*	16761241**	292.2	5.5*	7.2	2377279
Crosses	13.6**	20.1**	1432**	12.5**	1565589**	13.3	7.2	30.1	253935
Lines	13.7	33.0	2401	9.8	4807705**	11.1	10.2	13.5	615116
Testers	12.8	17.9	1327	17.1	1073453	6.3	9.1	25.3	212628
Lines X Testers	13.8*	17.7*	1224**	11.6**	919105**	16.2	5.8	35.8	177409
Error	2.0	3.6	56.6	2.0	92851	2.1	0.7	1.3	14722

*, ** indicated significant at 5% and 1% level of significance.

Table 2. Components of genetic variance and contribution of lines and testers in total variability

	Days to 50% flowering	Days to maturity	Plant height	Head diameter	Seed Yield (kg/ ha)	100 seed weight	Volume wt	Oil Content	Oil Yield
σ^2GCA	-0.01	0.07	6.05	0.02	18868	-0.08	0.04	-0.17	2233
σ^2SCA	3.82	6.29	519.39	3.58	686898	3.19	2.48	8.20	102309
σ^2A	0.03	0.29	24.20	0.10	75472	0.34	0.16	0.67	8934
σ^2D	7.86	9.40	778.86	6.46	550836	9.39	3.40	23.02	108457
degree of dominance	17.43	5.71	5.67	8.07	2.70	5.27	4.55	5.87	3.48
Proportional Contribution in Variability									
Lines	15.9	25.8	26.5	12.4	48.5	13.1	22.5	7.1	38.2
Testers	19.8	18.8	19.5	28.7	14.4	9.9	26.7	17.7	17.6
Lines x Testers	64.2	55.4	54.0	58.9	37.1	76.8	50.8	75.2	44.1

per hectare. The testers contributed more towards trait variability in terms of days to fifty percent flowering, head diameter, hundred seed weight and oil content. The GCA and SCA variances indicate the additive and non-additive gene effects, respectively. Higher degree of dominance for seed and oil yield and their component traits have been reported by Nirmala *et al*. (1999) and Dhanalakshmi *et al*. (2022), while some workers have also reported higher variance for GCA in comparison to SCA variance (Thitiporn *et al*., 2011 and Habib *et al*., 2021). The results suggest that hybridization among the inbreds used as lines and testers can result in heterotic combinations for the parameters studied.

The estimates of general combining ability of lines and testers (**Table 3)** indicated that 67A (-1.22) and 179R (-1.53) exhibited superior general combining ability for days to fifty percent flowering, while for days to maturity good GCA estimates were observed for 67A (-1.97), 179R (-1.13) and GMU 1080 (-1.47). High significant GCA effects for oil content were exhibited by 88A (0.74), 89 A (0.86), GMU 1080 (0.97) and 47R (1.90). For seed yield per ha and oil yield per ha, 67A (631.3, 221.96) and 47R (402.64, 180.45) exhibited superior GCA effects. The inbreds exhibiting superior GCA effects are considered to have better genetic value and thus can be expected to give rise to superior cross combinations with other inbreds. These inbreds selected for good general combining ability can also be used as parents for constitution of synthetic or composite varieties.

The specific combining ability estimates (**Table 4**) revealed that for days to fifty percent flowering and days to maturity the crosses 38A x 47R (-2.95, -3.0), 38A x 179R (-2.53, 2.33) and 67A x 159R (-1.78, -2.28) were superior, whereas the cross 88A x GMU 1080 (1.73) was superior only for days to fifty percent flowering. The cross combinations 38A x 179R and 88A x 150R exhibited significant positive SCA effects for plant height and hundred seed weight. For head diameter 38A x 47R exhibited superiority while

Table 3. General combining ability effects of parental lines for different traits

Genotype	Days to 50% flowering	Days to maturity	Plant height	Head diameter	Seed Yield (kg/ ha)	100 seed weight	Volume wt	Oil Content	Oil Yield
38A	0.12	0.17	5.06*	0.29	111.30	-0.15	-0.98*	-1.05*	32.47
67 A	-1.22*	-1.97*	4.89*	-0.40	631.30*	0.17	-0.45	-0.56	221.96*
88 A	-0.02	0.17	-18.78*	-0.87*	-742.04*	-1.01*	0.82*	0.74*	-269.23*
89 A	1.12	1.63*	8.84*	0.98*	-0.56	0.99*	0.62	0.86*	14.80
CD (0.05)	0.71	0.95	3.81	0.71	154.21	0.58	0.74	0.57	61.41
150R	0.47	0.45	-14.65*	-1.90	-239.49*	-1.38*	-0.43	-1.84*	-133.93*
159 R	1.05*	0.95	-6.36*	0.06	-345.28*	0.63*	-0.77	-0.52	-129.98*
179 R	-1.53*	-1.13*	3.16	0.82	126.71	0.82*	0.73	-0.51	42.07
47 R	0.55	1.20*	11.91*	-0.15	402.64*	0.14	0.82	1.90*	180.45*
GMU 1080	-0.53	-1.47*	5.95*	1.17	55.42	-0.21	-0.35	0.97*	41.40
CD (0.05)	0.79	1.07	4.25	0.79	172.41	0.54	0.82	0.64	68.65

* indicated significant at 5% level of significance.

Table 4. Specific combining ability effects of parental lines for different traits

	Days to 50% flowering	Days to maturity	Plant height	Head diameter	Seed Yield (kg/ ha)	100 seed weight	Volume wt	Oil Content	Oil Yield
38Ax150R	2.47**	3.42**	-17.35**	-1.21	370.42*	-0.10	-0.69	-2.50**	58.53
38Ax159R	0.55	0.58	-7.30	-0.46	-742.32**	-3.43**	0.26	-5.91**	-349.95**
38Ax179R	-2.53**	-2.33*	20.26**	-0.10	594.95**	3.40**	0.80	3.74**	286.33**
38Ax47R	-2.95**	-3.00**	19.43**	3.25**	285.69	0.65	1.58**	3.02**	183.67*
38AxGMU 1080	2.47**	1.33	-15.03**	-1.49	-508.75**	-0.52	-1.95**	1.65*	-178.58*
67Ax150R	-0.87	-0.12	9.07*	1.95*	-245.88	-0.63	-0.20	1.92*	-46.30
67Ax159R	-1.78*	-2.28*	2.03	-0.26	300.65	1.03	1.22*	1.97*	140.37
67Ax179R	0.13	-0.87	-38.33**	-2.36**	-811.16**	-3.13**	0.61	-4.78**	-398.55**
67Ax47R	2.05*	2.80*	12.93**	-0.47	470.32*	1.45	-1.89**	-2.10**	113.96
67AxGMU 1080	0.47	0.47	14.30**	1.14	286.07	1.28	0.26	2.99**	190.53**
88Ax150R	-1.07	-1.58	19.82**	0.95	213.57	2.43**	1.92**	2.27**	128.65
88Ax159R	0.68	-0.08	-8.05	-0.63	507.32**	1.77*	-1.11*	1.25	200.53**
88Ax179R	-0.07	0.00	7.01	1.11	-345.23	0.27	-0.73	-0.88	-139.38
88Ax47R	2.18**	2.00	-23.41**	-2.92**	-461.90*	-3.15**	-0.70	-0.38	-183.23*
88AxGMU 1080	-1.73*	-0.33	4.63	1.51	86.25	-1.32	0.62	-2.25**	-6.57
89Ax150R	-0.53	-1.72	-11.55*	-1.69*	-338.10	-1.70*	-1.02*	-1.68*	-140.89*
89Ax159R	0.55	1.78	13.33**	1.35	-65.65	0.63	-0.37	2.69**	9.05
89Ax179R	2.47*	3.20**	11.06*	1.34	561.44**	-0.53	-0.67	1.92*	251.60**
89Ax47R	-1.28	-1.80	-8.94*	0.15	-294.12	1.05	1.00*	-0.54	-114.39
89AxGMU 1080	-1.20	-1.47	-3.90	-1.16	136.44	0.55	1.06*	-2.39**	-5.38
CD (0.05)	1.64	2.19	8.73	1.62	353.73	1.69	0.96	1.30	140.85
CD (0.01)	2.18	2.92	11.65	2.17	471.87	2.26	1.28	1.74	187.90

*, ** indicated significant at 5% and 1% level of significance.

38A x 47R and 88A x 150R were found to have best SCA effects for volume weight. Desirable and significant SCA effects were revealed by nine cross combinations *viz*., 38A x 179R (3.74), 38A x 47R (3.02), 67A x GMU1080 (2.99), 89A x 159R (2.69), 88A x 150R (2.27), 67A x 159 R (1.97), 67A x 150 R (1.92), 89A x 179 R (1.92), 38A x GMU 1080 (1.65) for oil percent. The cross combinations expressing significant positive specific combining ability for seed yield were 38A x 179R (594.95), 89A x 179R (561.44), 88A x 159R (507.32), 67A x 47R (470.32), 38A x 150R (370.42) similarly for oil yield per hectare 38A x 179R (286.33), 89A x 179R (251.60), 88A x 159R (200.53), 67A x GMU 1080 (190.53), 38A x 47R (183.67). Most of the cross combinations revealed significant SCA effects for seed yield and oil content, this could be due to the fact that most of the inbreds are selected for these traits and the parents are likely to be different for these traits. The significant GCA and SCA estimates in this study suggest that both additive and non-additive gene effects had prominent role in expression of these traits. The parents 67A and 47R revealed superior GCA effects for seed and oil yield. The female parent 67A was a good general combiner for days to fifty percent flowering, days to maturity, plant height, seed yield and oil yield while 89A was good combiner for plant height, head diameter, 100 seed weight and oil content. Among testers, 47R was the best general combiner for plant height, seed yield, oil content and oil yield. Highest significant positive SCA effects were observed for cross 38A x 179R (594.95) exhibited best combining ability for seed yield followed by 89A x 179R (561.44) and 88A x 159R (507.32). On the basis of positive significant SCA effects for oil percent crosses 67A x GMU 1080 (2.99), 89A x 159R (2.69) and 88A x 150R (2.27) were identified. Similarly the GCA and SCA effects have been utilized for selection of superior parents and hybrids by Chandra *et al*. (2011), Shamshad *et al*. (2016) and Patil *et al*. (2017).

Ample variation existed among all the parameters for both better parent heterosis and mid parent heterosis except for days to fifty percent flowering and days to maturity. Earliness is a desired character in sunflower for its suitability for spring cultivation thus the crosses exhibiting heterosis in negative directions were selected. For days to fifty percent flowering the magnitude for heterosis against better parent ranged from -9.3 to 9.8, the top three hybrids with superior better parent heterosis were 38A x 47R (-9.3), 38A x 179R (-8.1) and 88A x GMU 1080

Table 5. Magnitude of average heterosis over mid parent (MP) and heterobeltosis over better parent (BP) of different cross combinations

	Days to50% flowering		Days to maturity		Plant height		Head diameter		Seed Yield (kg/ ha)		100 seed weight		Volume wt		Oil Content		Oil Yield	
Code	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
38Ax150R	9.8**	3.9**	7.9**	2.6**	-2.8	1.1	-17.8**	-14.5**	16.2	76.7**	7.3**	9.2**	-47.1**	-43.6	-11.9**	-8.5**	1.9	58.1**
38Ax159R	1.0	-1.2	0.3	-2.2**	4.6	8.5	1.2	1.7	-44.8**	-25.6*	-9.3**	-6.1**	-17.5**	-8.5	-22.8**	-20.4**	-54.9**	-40.4**
38Ax179R	-8.1**	-10.0**	-5.4**	-7.5**	42.7**	43.4**	10.3**	14.5**	45.8**	125.3**	20.0**	22.2**	15.0**	26.8**	9.4**	12.9**	58.7**	149.1**
38Ax47R	-9.3**	-11.2**	-7.8**	-8.4**	50.9**	53.9**	27.8**	34.6**	44.2**	86.0**	12.7**	12.7**	16.8**	19.2**	7.7**	10.8**	63.7**	107.2**
38AxGMU 1080	1.0	-1.0	-4.3**	-5.3**	-21.4**	-6.1	-7.2*	-2.5	-13.0	-0.9	4.5**	5.4**	-52.3**	-50.4**	1.1	4.3*	-6.7	3.6
67Ax150R	2.2*	1.1	1.8*	0.9	20.7**	24.9**	7.9*	8.3*	57.0**	117.4**	7.3**	9.2**	-26.3**	-25.2**	-9.0**	-0.3	44.0**	110.7**
67Ax159R	-0.5	-2.6**	-1.8	-3.3**	11.8*	16.6**	-2.4	1.6	88.1**	123.7**	3.4*	7.0**	-0.3	15.7**	-5.5*	-3.2	77.8**	115.7**
67Ax179R	-1.6	-3.9**	-2.5**	-4.3**	-6.6	-5.7	-4.7	-4.5	43.0**	102.0**	3.6*	5.6**	29.9**	36.6**	-22.5**	-15.7**	12.6	67.4**
67Ax47R	4.8**	-2.0*	3.9**	-1.0	46.8**	48.9**	2.6	4.3	153.0**	184.9**	16.4**	16.4**	-33.5**	-31.5**	-9.7**	-7.2**	128.2**	163.3**
67AxGMU 1080	0.5	-1.8*	-1.4	-4.4**	-4.8	14.3**	5.6	14.8**	102.7**	108.8**	10.7**	11.7**	-12.8*	-5.0	0.8	3.3	114.7**	115.9**
88Ax150R	3.8**	-1.8*	2.5**	-2.9**	-2.2	6.8	-9.9**	-6.6*	108.0**	123.5**	17.0**	20.2**	-13.5*	-9.9	7.8**	11.4**	139.8**	149.9**
88Ax159R	1.0	-1.2	-0.3	-3.2**	-17.2**	-16.0**	-8.5**	-7.8*	55.0**	98.6**	8.5**	11.3**	-47.8**	-40.7**	0.8	4.6*	56.0**	105.5**
88Ax179R	-4.6**	-6.5**	-3.1**	-5.5**	1.6	6.3	11.4**	15.2**	90.0**	97.7**	14.3**	17.5**	-21.2**	-15.1**	2.7	5.3*	106.4**	109.3**
88Ax47R	-1.9	-4.1**	-3.6**	-3.9**	-15.0**	-8.9	-25.6**	-21.8**	16.1	55.5**	5.4**	6.3**	-33.3**	-33.0**	3.5	7.1**	20.3	64.9**
88AxGMU 1080	-5.6**	-7.5**	-6.0**	-7.2**	-23.8**	-12.8**	5.0	10.6**	-1.9	44.3**	7.2**	7.2**	-25.6**	-20.9**	-4.5*	-0.9	-6.2	40.8**
89Ax150R	6.5**	1.3	3.9**	-0.2	-14.1**	-2.0	-15.7**	-12.6**	5.9	46.6**	5.4**	8.3**	-41.0**	-33.6**	-1.6	0.9	3.9	46.2**
89Ax159R	2.6*	0.8	3.1**	1.5	8.8	15.8**	19.4**	20.3**	17.6	39.9**	5.1**	7.8**	-10.7*	-6.1	4.9*	9.6**	35.3**	55.0**
89Ax179R	1.0	-0.5	1.7*	0.5	13.8**	24.8**	26.8**	31.2**	95.2**	175.9**	11.6**	14.7**	-2.8	12.8*	12.6**	14.7**	119.9**	214.6**
89Ax47R	-4.4**	-6.9**	-3.3**	-4.9**	6.1	18.9**	10.8**	16.3**	54.3**	73.8**	16.1**	17.1**	12.1*	21.1**	3.3	7.7**	73.4**	88.2**
89AxGMU 1080	-3.0**	-4.5**	-5.6**	-5.6**	-12.9**	-4.6	-0.4	5.0	50.7**	55.3**	11.6**	11.6**	7.8	10.1	-4.5*	-0.2	43.9**	54.7**
CI at 5%	2.1	1.7	1.8	1.4	9.6	8.8	6.2	6.5	20.8	22.9	2.9	2.8	10.4	11.3	4.2	4.1	23.0	25.4
CI at 1%	2.7	2.2	2.4	1.8	12.6	11.6	8.1	8.5	27.4	30.1	3.8	3.7	13.7	14.8	5.6	5.4	30.2	33.4

*, ** indicated significant at 5% and 1% level of significance.
BP- Better Parent; MP- Mid Parent

(-5.6) as given in **Table 5**. Similarly, the same hybrids exhibited superior mid parent heterosis for days to fifty percent flowering (-11.2, -10.0 and -7.5, respectively). The magnitude of mid parent heterosis for days to maturity ranged from -8.4 to 2.6 while heterosis against better parent ranged from -7.8 to 7.9. The superior hybrids with desirable better parent heterosis for days to maturity were 38A x 47R (-7.8), 88A x GMU 1080 (-6.0) and 89A x GMU 1080 (-5.6) whereas the top three hybrids with desirable mid parent heterosis were 38A x 47R (-8.4), 38A x 179R (-7.5) and 88A x GMU 1080 (-7.2). The hybrids expressing high heterosis for plant height were 38A x 47R, 67A x 47R and 38A x 179R with magnitude of better parent heterosis of 50.9, 46.8 and 42.7 respectively while the mid parent heterosis of these top ranking hybrids were 53.9, 48.9 and 43.4. Head diameter exhibited range in magnitude of better parent heterosis from -25.6 to 27.8 and for magnitude of mid parent heterosis from -21.8 to 34.6. The hybrids with maximum magnitude of mid parent and better parent heterosis for head diameter were 38A x 47R, 89A x 179R and 89A x 159R. For seed parameter such as volume weight the most of the hybrids reported better parent heterosis towards positive direction except for 38A x 159R with the values ranging between -9.3 to 20 and similarly for average heterosis the values ranged between -6.1 to 22.2. The hybrids which were ranked highest for average and better parent heterosis with respect to volume weight were 38A x 179R and 88A x 150R. The range of magnitude of better parent heterosis for hundred seed weight was between -52.3 to 29.9, while for mid parent heterosis ranged between-50.4 to 36.6. The top five hybrids showing maximum better parent and average heterosis for hundred seed weight were 67A x 179R, 38A x 47R and 38A x 179R. Average heterosis for seed yield per hectare was expressed in the positive direction by most of the cross combinations except for 38A x 159R and 38A x GMU 1080, similarly only three crosses exhibited magnitude of better heterosis in negative direction *viz.,* 38A x 159R, 38A x GMU 1080and 88A x GMU 1080. The top ranking hybrids with respect to better parent heterosis are 67A x 47R (153.0), 88A x 150R (108.0) and 67A x GMU 1080 (102.7), while for mid parent heterosis 67A x 47R (184.9), 89A x 179R (175.9) and 38A x 179R (125.3) were most desirable. The top ranking hybrids with best better parent heterosis for oil content were 88A x 150R (139.8), 67A x 47R (128.2) and 89A x 179R (119.9), while the hybrids having maximum mid parent heterosis for oil yield per hectare were 89A x 179R (214.6), 67A x 47R (163.3) and 88A x 150R (149.9).

Usefulness of crosses in heterosis breeding depends on their mean performance, combining ability and magnitude of heterosis (Kulkarni and Supriya 2017). Ample variation was present among average heterosis as well as heterobeltosis for all the traits. Most of the cross combinations revealed negative mean heterosis for days to fifty percent flowering and maturity however only half of these crosses also revealed negative heterosis against early parent. The magnitude of heterosis for seed and oil yield were high against mid parent value and slightly low when compared with better parent. Similar results have been reported by Kaya (2005), Meena *et al*. (2013),Aslam *et al*. (2010) and Ahmed *et al*.(2021).

Conclusively, the study allowed in identification of superior cross combinations based on combining ability and magnitude of heterosis. Among lines, 67A was identified to be good general combiner for earliness, seed and oil yield per hectare while, 88A and 89A were identified as good combiners for oil conent. Among testers, 47R was identified as superior combiner for for oil content, seed yield and oil yield per hectare, while, GMU 1080 was found superior for earliness and oil content. The combining ability analysis can also be utilized for identification heterotic groups for fast development of superior hybrids (Ismail *et al.,* 2023).

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