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Heterosis studies for yield and physiological traits in sunflower (*Helianthus annuus* L.)

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Abstract
In the present investigation, information on the magnitude of heterosis was obtained for seed yield per plant and its related components following line x tester mating design involving four lines and seven testers of sunflower (*Helianthus annuus* L.). The eleven parents and their 28 F_1s with two standard checks were tested for five characters in a randomized block design with three replications at Bharuch (Gujarat). The standard heterosis ranged from -7.82% (SVCMS-1 x SVSR-4) to 44.87% (SVCMS-4 x SVSR-4) over LSFH-171 for seed yield per plant. The highest standard heterosis was observed for head diameter in cross SVCMS-4 X SVSR-4 (30.60). The maximum value of seed volume weight in cross SVCMS-2 x SVSR-5 (16.32%). While considering physiological traits like chlorophyll content better parent heterosis ranged from 18.03% (SVCMS-1 x SVSR-4) to 85.19% (SVCMS-2 x SVSR-5) and standard heterosis ranged from -10.61% (SVCMS-1 x SVSR-2) to 30.65% (SVCMS-4 x SVSR-4). For leaf area standard heterosis ranged from -18.15% (SVCMS-1 x SVSR-1) to 12.94% (SVCMS-1 x SVSR-5). The high heterotic response in these hybrids for seed yield per plant resulted mainly due to substantial heterosis for head diameter, leaf area, chlorophyll content and seed volume weight.

Keywords: Heterosis, physiological, sunflower, *Helianthus annuus* L.

Introduction
Sunflower is highly cross pollinated crop and the main objective of sunflower breeding is to develop high yielding hybrid cultivars with stable and high yield through exploitation of heterosis. Sunflower (*Helianthus annuus* L.) is the fourth important oilseed crop in the world next to soybean, groundnut and rapeseed. It belongs to the genus *Helianthus*, family Asteraceae, tribe Heliantheae, sub-tribe Helianthae which includes 20 genera with 400 sub-species, originated in USA (Heiser, 1978). It has 2n=34 and cross pollinated in nature. Sunflower, being a highly cross-pollinated crop is ideally suited for exploitation of heterosis. Commercial exploitation of heterosis has been possible using cytoplasmic male sterility-restorer system. However, commercial cultivation in India started with open pollinated varieties like EC 68414 (Peredovik), EC 68415 (Armaviriski, 3497) and Morden (Cermianka-66). Heterosis breeding has evolved successfully in sunflower breeding ever since the discovery of first cytoplasmic male sterility (CMS) source by Leclercq (1969) [13] from the interspecific cross *H. petiolaris* Nutt, x *H. annuus* and fertility restoration by Kinman (1970) [11] that gave the required momentum for commercial hybrid seed production in sunflower using CMS source.

To develop sunflower hybrids with improved yield potential, the choice of parents through careful and critical evaluation is of very importance in order to improve productivity and total production. The seed yield and yield attributing characters show polygenic inheritance and thus susceptible to environmental fluctuations. Therefore, selection of parents for hybridization is a complex problem. Hybrids using lines developed based on heterosis are preferred by farmers due to their high yielding performance, quality and uniformity. The choice of the parents is governed by per se performance of the parents and heterosis study is important. Thus, this investigation was undertaken to determine magnitude of heterosis for yield and other quantitative traits and *per se* performance using L x T mating design. The line x tester analysis (Kempthorne, 1957) [10] is one of the simplest and efficient method of evaluating large number of in breds for combining ability and *per se* performance.

Materials and Methods

In the present study 28 hybrids obtained by adopting line x tester mating design consisted 4 lines (SVCMS-1, SVCMS-2, SVCMS-3 and SVCMS-4) and 7 testers (SVSR-1, SVSR-2, SVSR-3, SVSR-4, SVSR-5, SVSR-6 and SVSR-7) along with two checks *viz*., Phule Raviraj and LSFH-171 were evaluated in randomized block design with three replication and tested at Bharuch (Gujarat) during *rabi* 2019-20. The performance of different hybrids, parents and checks in respect to five characters was studied for estimating the heterosis. Each hybrid was represented by single Rows of 3.0 m length with 60 x 30 cm spacing between and within rows, respectively. Observations were recorded in each entries on randomly selected five plants for five characters *viz*., head diameter (cm), seed yield per plant (g), seed volume weight (g/100 ml), chlorophyll content (SPAD value) and leaf area (cm^2). The analysis was carried out in computer using software INDOSTAT as per standard method of line x tester in order to estimate GCA, SCA effect along with heterosis study for each genotype.

Results and Discussion

Analysis of variance result given in table 1. Significant differences for all the traits existed for treatments. Significant differences for all the traits existed for parents except seed yield per plant and leaf area. The variance due to parents was further partitioned into variance due to females, males and females *vs*. males. The results revealed that mean squares due to female have significantly differed for head diameter. Similarly, mean squares due to male non-significant differences for seed yield per plant and leaf area. The mean square due to female *vs*. male in comparison was found significant for head diameter.

The variance due to hybrids was significantly differed for all the traits. The mean squares due to parents *vs*. hybrids were significantly differed for all the traits. \

Table 1: Analysis of variance for five characters of sunflower

Source	D.F.	Head diameter (cm)	Seed yield per plant (g)	Seed vol wt (g/100 ml)	Chlorophyll content (SPAD value)	Leaf area (cm^2)
Replicates	2	0.023	5.865	12.160	0.346	183.805
Treatments	38	22.006**	207.567**	95.165**	166.259**	52806.851**
Parents	10	3.944**	30.618	15.225**	15.005**	3430.247
Parents (Line)	3	4.563**	22.215	4.682	4.391	4651.216
Parents (Testers)	6	3.954**	31.926	22.908**	19.317**	2697.762
Parents (L vs T)	1	2.0254*	47.982	0.754	20.976	4162.245
Parents vs Crosses	1	448.884**	5148.796**	2752.515**	3982.801**	1769891**
Crosses	27	12.885**	90.093**	26.352**	80.926**	7498.75**
Error	76	0.46	16.25	4.80	5.70	2377
* and ** Significant at 5% and 1% level of probability, respectively						

Heterosis

Heterosis is the measure of deviation of progeny means from parental means. For exploitation of hybrid vigour, high degree of heterosis for yield and its components is a prerequisite in crop improvement programme. In the present investigation two types of heterosis *viz*; heterobeltiosis or better parent heterosis and standard or economic heterosis have been studied. Major objectives of the present study were to identify promising hybrids which may give high degree of useful (economic) heterosis. The results were given in Table 2.

The magnitude of heterosis for head diameter over better parent ranged from 9.06% (SVCMS-1 x SVSR-4) to 53.88% (SVCMS-2 x SVSR-5) and for economic heterosis -9.15% (SVCMS-4 x SVSR-2) to 30.60% (SVCMS-4 x SVSR-4). Among the 28 hybrids, 11 hybrids showed significant positive standard heterosis over best check LSFH-171. The magnitude of heterobeltiosis for seed yield per plant ranged from 16.50% (SVCMS-1 x SVSR-4) to 87.17% (SVCMS-1 x SVSR-7 and SVCMS-2 x SVSR-5), while the standard heterosis ranged from -7.82% (SVCMS-1 x SVSR-4) to 44.87% (SVCMS-4 x SVSR-4) over LSFH-171. Total 8 crosses found significant positive heterosis for seed yield per plant. The presence of significant positive heterosis in determining for above traits has been reported by Thombare *et al.* (2007) [19], Sawargaonkar and Ghodke (2008) [16], Dudhe *et al.* (2009) [5], Sujata and Reddy (2009), Datta *et al.* (2011) [3], Rathi *et al.* (2016) [15] and Dhootmal (2017) [4], Hilli *et al.* (2020) [8] and Lakshman *et al*. (2020) [12].

The spectrum of variation for better parent heterosis for seed volume weight ranged from 16.65% (SVCMS-4 x SVSR-2) to 52.46% (SVCMS-4 x SVSR-4) and for economic heterosis -9.98% (SVCMS-4 x SVSR-6) to 16.32% (SVCMS-2 x SVSR-5). Among hybrids for economic heterosis 7 hybrids exhibited significant positive heterosis over the standard check LSFH-171. This result similar to Karasu *et al*. (2010) [9], Neelima and Raffi (2013) [14] and Bhoite *et al.* (2018) [2].

The quantum of heterobeltiosis for leaf area ranged from 65.32% (SVCMS-1 x SVSR-4) to 136.06% (SVCMS-2 x SVSR-7). The spectrum of variation for standard heterosis ranged -18.15% (SVCMS-1 x SVSR-1) to 12.94% (SVCMS-1 x SVSR-5) for leaf area. Total 11 hybrids found positive economic heterosis for leaf area. The spectrum of variation for better parent heterosis for chlorophyll content ranged from 18.03% (SVCMS-1 x SVSR-4) to 85.19% (SVCMS-2 x SVSR-5) and for economic heterosis -10.61% (SVCMS-1 x SVSR-2) to 30.65% (SVCMS-4 x SVSR-4). Among hybrids for economic heterosis 8 hybrids exhibited significant positive heterosis over the standard check LSFH-171. This finding confirmed with Ahmed *et al*. (2005) [1] for leaf area and Tyagi *et al*. (2020) [20] for chlorophyll content.

Based on the per se performance and extent of heterosis, best crosses *viz*., SVCMS-4 x SVSR-4 and SVCMS-4 x SVSR-5 posses good seed yield per plant, head diameter, seed volume weight and chlorophyll content over best check LSFH-171. For leaf area hybrid SVCMS-1 x SVSR-5 found excellent. These better performing crosses can be used for exploiting hybrid vigour and need to be evaluated for stability parameter.

Table 2: Estimates of heterosis (%) over better parent (BP) and standard heterosis (SH) over respective check in sunflower

Sr. No.	Genotype	Head diameter (cm)		Seed yield per plant (g)		Seed volume weight (g/100 ml)		Chlorophyll content (SPAD value)		Leaf area (cm^2)	
		BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
1	SVCMS-1 X SVSR-1	11.20**	-7.92*	37.72**	-4.48	36.81**	-4.66	28.07**	-10.36	66.18**	-18.15*
2	SVCMS-1 X SVSR-2	12.62**	-6.33	34.60*	-7.53	18.44**	-7.74	27.97**	-10.61	122.91**	-13.49
3	SVCMS-1 X SVSR-3	19.25**	4.49	31.20*	3.51	31.21**	5.50	26.92**	2.17	88.68**	0.24
4	SVCMS-1 X SVSR-4	9.06*	-6.62	16.50	-7.82	25.43**	-4.76	18.03*	-9.93	65.32**	-13.85
5	SVCMS-1 X SVSR-5	50.49**	26.63**	74.97**	28.61**	51.37**	13.53**	78.10**	24.80**	110.64**	12.94
6	SVCMS-1 X SVSR-6	38.86**	-0.45	61.90**	-6.76	40.43**	-2.15	43.54**	-9.33	104.29**	-11.19
7	SVCMS-1 X SVSR-7	51.47**	5.56	87.17**	6.22	51.54**	5.60	65.26**	1.69	110.17**	-3.01
8	SVCMS-2 X SVSR-1	20.62**	-0.12	36.43**	-4.18	22.05**	-5.50	37.14**	-4.01	79.79**	-11.44
9	SVCMS-2 X SVSR-2	25.49**	4.37	38.02**	-3.06	22.04**	-4.94	36.92**	-4.36	97.40**	-8.92
10	SVCMS-2 X SVSR-3	32.91**	16.46**	47.29**	16.21	39.56**	12.22*	41.86**	14.20*	101.23**	6.91
11	SVCMS-2 X SVSR-4	40.41**	20.22**	59.50**	26.20**	41.45**	9.51	64.49**	25.52**	106.33**	7.51
12	SVCMS-2 X SVSR-5	53.88**	29.49**	87.17**	37.57**	50.24**	16.32**	85.19**	29.76**	106.98**	10.98
13	SVCMS-2 X SVSR-6	13.35**	-6.37	33.13*	-6.50	19.88**	-7.18	30.85**	-9.01	95.21**	-9.93
14	SVCMS-2 X SVSR-7	50.05**	23.94**	78.52**	25.38**	42.17**	10.07*	69.13**	17.60**	136.05**	8.93
15	SVCMS-3 X SVSR-1	19.83**	-0.78	40.15**	-2.80	34.48**	-5.04	36.69**	-4.32	92.25**	-5.31
16	SVCMS-3 X SVSR-2	29.37**	7.60*	55.53**	6.85	32.81**	3.45	48.30**	3.59	105.70**	-4.75
17	SVCMS-3 X SVSR-3	38.00**	20.92**	60.19**	26.39**	40.95**	13.34*	51.01**	21.56**	100.08**	6.30
18	SVCMS-3 X SVSR-4	10.02*	-5.80	30.35*	3.14	30.34**	-1.03	27.84**	-2.45	80.58**	-5.90
19	SVCMS-3 X SVSR-5	37.38**	15.60**	65.42**	21.59*	39.55**	4.66	73.17**	21.34**	97.95**	6.14
20	SVCMS-3 X SVSR-6	20.39**	-1.84	63.07**	-2.61	36.72**	-3.45	53.08**	-1.27	104.27**	-5.42
21	SVCMS-3 X SVSR-7	18.99**	-2.98	68.45**	0.60	40.42**	-0.84	47.66**	-4.76	106.14**	-4.55
22	SVCMS-4 X SVSR-1	20.37**	-0.33	40.20**	-2.76	39.16**	-0.56	40.79**	-1.45	91.12**	-5.37
23	SVCMS-4 X SVSR-2	9.23*	-9.15**	35.36*	-7.00	16.65*	-9.14	24.36**	-13.13*	73.91**	-13.90
24	SVCMS-4 X SVSR-3	28.30**	12.42**	36.31**	7.54	32.48**	6.53	31.76**	6.07	94.17**	3.16
25	SVCMS-4 X SVSR-4	52.53**	30.60**	83.10**	44.87**	52.46**	15.76**	71.22**	30.65**	109.73**	9.29
26	SVCMS-4 X SVSR-5	39.22**	17.16**	68.27**	23.68*	47.64**	10.73*	74.04**	21.95**	99.57**	7.00
27	SVCMS-4 X SVSR-6	16.26**	-7.43*	42.91**	-5.96	25.98**	-9.98	35.23**	-10.54	72.81**	-14.44
28	SVCMS-4 X SVSR-7	18.47**	-5.68	57.32**	3.53	30.03**	-7.09	35.93**	-10.08	77.83**	-11.95
	S.E.(d) ±	0.478	0.552	2.850	3.291	1.549	1.789	1.687	1.948	30.48	39.81
	CD @ 5%	0.959	1.108	5.715	6.599	3.106	3.586	3.382	3.905	69.12	79.82

*,** Significant at 5% level. BP, SC indicates better parent and standard check LSFH-171, respectively

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