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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 3127-3130

www.thepharmajournal.com
Received: 07-09-2022
Accepted: 08-10-2022

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Standard heterosis studies for seed yield and yield contributing traits in sunflower (*Helianthus annuus* L.)

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Abstract
The present investigation entitled "Standard Heterosis studies for seed yield and yield contributing traits in Sunflower (*Helianthus annuus* L.). four CMS lines and eight restorer lines were crossed in line x tester design to produce 32 hybrids during *kharif*- 2021-22 and these 32 hybrids along with two checks were evaluated for days to 50 percent flowering, day to maturity, plant height (cm), head diameter (cm), seed filling percentage (%), 100 seed weight (g), volume weight (g/100ml), hull content (%), seed yield per plant (g) and oil content (%). The range of heterosis over best check LSFH-171 was from (-52.81) per cent CMS-47A x IR-1-1 to (30.67) per cent CMS-234A x MRHA-2. Whereas for another check LSFH-35 was from (-50.88) per cent CMS-47A x IR-1-1 to (36.02) per cent CMS-234A x MRHA-2 for seed yield per plant. For oil content the range of standard heterosis over check LSFH-171 was from (3.62) per cent CMS-234A x EC-502036 to (37.06) per cent CMS-249A x IR-1-1 and for other check LSFH-35 was from (-21.67) per cent CMS-234A x EC-502036 to (3.61) per cent CMS-249A x IR-1-1.

The magnitude of heterosis over the check LSFH-171 and LSFH-35 for most of the characters in the present study were highly appreciable. Among the hybrids CMS-234A X MRHA-2, CMS-249A X RHA-1-1, CMS-47A X MRHA-2, CMS-234A X RHA-1-1 and CMS-10A X MRHA-2 was most promising for seed yield /plant (g) on the basis of per se performance, highest significant standard heterosis for seed yield and yield contributing traits.

Keywords: plant height, performance, CMS-234A

Introduction

The sunflower (*Helianthus annuus* L.) is important oil seed crop it is an annual flowering plant which belongs to the family *Asteraceae* with chromosome number 2n=34. The genus *Helianthus* is grown as a crop for its edible oil. Under this genus there are 67 species, cultivated in different forms like oilseed crops, ornamental, landscaping etc. and is extensively grown in Russia, USA, China and India. Sunflower is one of the most important oilseed crops in India and ranks fifth after soybean, mustard, groundnut and sesame as edible oil source. BSH-1 was the first sunflower hybrid created by 'Heterosis breeding' and released in India in 1980.

Sunflowers were grown on 2.240 lakh hectares in India in 2019-20, with a total production of 2.045 lakh tonnes. The average yield was one of the lowest in the world, at 913 kg/ha. (2019-2020), Anonymous. Sunflower is grown on 0.278 lakh hectares in Maharashtra, with a yield of 0.121 lakh tonnes and a productivity of 436 kg/ha. Karnataka, Maharashtra, Andhra Pradesh and Tamil Nadu are the important sunflower growing states. It is rich source of edible oil (40 to 50%) and is considered as good quality oil from health point of view, due to high concentration of polyunsaturated fatty acids (55 to 60% linoleic acid, 25 to 30% oleic acid), which are known to reduce the risk of coronary disease by reducing the cholesterol in blood plasma.

Sunflower is a native of North America but commercialization of the plant took place in Russia. In India, as an oilseed crop, it was introduced in 1969, prior to which it was used as an ornamental plant. Commercial cultivation in India started in 1972 in few hectares land in southern states because of wider adaptability, photoperiod insensitivity, short duration, high yield. A land mark in sunflower breeding was discovery of cytoplasmic male sterility by Leclereq (1969) [9] and restorer genes in wild type sunflower cultivar (Kinman, 1970) [6]. In sunflower, the cytoplasmic male sterility (CMS) system, which involves the use of CMS line (A), maintainer line (B) and fertility restorer line (R) has allowed breeders to exploit heterosis and heterosis breeding in heterosis breeding programme, large number of hybrids are produced and evaluated to exploit hybrid vigor.

Materials and Methods

The present studies on heterosis in sunflower (*Helianthus annuus* L.) were conducted during *rabi*- 2021-22 at Oilseeds Research Station, Latur. The crossing programme carried out in line x tester design during *Kharif*-2021. The experimental material for study included 4 CMS lines (CMS-10A, CMS-47A, CMS-234A, CMS-249A) and 8 restore lines (IR-1-1, RHA-1-1, MRHA-2, 12R-1, ID-51-32, EC-279309-1, EC-502036, EC-625730) to produce 32 hybrids along with 2 checks (LSFH-171 and LSFH-35) were evaluated in RBD design. The morphological observations on ten quantitative characters were recorded by selecting randomly three plants in each plot and in each replication. The heterosis of these 32 hybrids were evaluated and compared with checks.

Results and Discussion

The negative heterosis was considered desirable for days to 50 % flowering, days to maturity, plant height and hull content. While positive heterosis is desirable for rest of the characters in sunflower for successful heterosis breeding programme in any crop, there are two important strategies involved i.e., presence of significant heterotic effect in the hybrids and feasibility of hybrid seed production. Sunflower is highly cross pollinated in nature; (Due to protandry and self-incompatibility mechanism) hence it provides tremendous scope for commercial exploitation of heterosis breeding by using cyto-restorer system. (Madrap and Makne 1993) [10], Sugoor RK, (1992) [17] and Gangappa *et al.*, (1997) [4]. Though heterotic vigour could be exploited by development of hybrids but commercialization of hybrids depends on the superiority over the standard checks. In other words, the standard heterosis of the newly developed hybrids is of prime importance for its adoption by farmers. Generally, the per se performance of the parents is found to be closely related with high heterotic hybrids. The magnitude of heterosis over the check LSFH-171 and LSFH-35 for most of the characters in the present study were highly appreciable.

Among the hybrid *viz.* CMS-47A x ID-51-32 (-2.42, -4.72**) and CMS-47A x EC-279309-1 (-2.42, -4.72**) showed the significant heterosis for days to 50 per cent flowering for days to maturity CMS-10A x EC-502036 (-2.69*, -4.23**) and CMS-47A x EC-279309-1 (-2.15, -3.70**). The crosses CMS-10A x ID-51-32 (-5.87**, -6.14**) and CMS-10A x 12R-1(-5.28**, -5.56**) recorded desirable significant negative heterosis over both the checks for plant height.

For head diameter CMS-234A x MRHA-2 (9.94, 14.33), CMS-249A x RHA-1-1 (8.97, 13.33), CMS-47A x MRHA-2 (7.69, 12.00) show the non-significant positive heterosis over both the checks for seed filling percent the cross CMS-234A x MRHA-2 (8.94**, 12.47**), CMS-47A x MRHA-2 (8.83**, 12.36**), CMS-249A x RHA-1-1 (8.39**, 11.91**) and CMS-47A x ID-51-32 (5.98*, 9.42**) showed significant standard heterosis over both checks.

For 100-seed weight the hybrids *viz.*, CMS-249A x RHA-1-1 (12.35**, 15.46**), CMS-234A x MRHA-2 (10.87**, 13.95**), CMS-47A x EC-502036 (8.15*, 10.29**), CMS-249A x ID-51-32 (5.23, 8.15*) found high heterotic effect over both checks the crosses CMS-234A x MRHA-2 (19.12**, 22.73**), CMS-249A x RHA-1-1 (11.76**, 15.15**), CMS-47A x EC-279309-1(10.29**, 13.64**) was found significant heterosis for volume weight over both checks LSFH-171 and LSFH-35. Among the hybrid only one hybrid CMS-47A x MRHA-2 (-1.05) found non-significant negative heterosis for hull content over check LSFH-171. out of 32 hybrids eleven crosses show the desirable negative significant heterosis over the check LSFH-35 for hull content.

All the hybrid found to be highly significant positive heterosis over check LSFH-171, while out of 32 hybrid five crosses CMS-249A x IR-1-1 (3.61**), CMS-249A x ID-51-32 (3.01**), CMS-234A x MRHA-2 (2.97**), CMS-234A x IR-1-1 (2.63**) and CMS-47A x EC-502036 (2.26*) recorded significant positive standard heterosis over check LSFH-35 for oil content.

The hybrids *viz.*, CMS-234A x MRHA-2 (30.67**, 36.02**), CMS-249A x RHA-1-1 (23.60**, 28.65**), CMS-47A x MRHA-2 (23.15**, 28.19**), CMS-234A x RHA-1-1 (22.25**, 27.25**) CMS-10A x MRHA-2 (17.98**, 22.81**) recorded positive significant heterosis over both the check LSFH-171 and LSFH-35.

The most promising hybrids identified were CMS-234A X MRHA-2, CMS-249A X RHA-1-1, CMS-47A X MRHA-2, CMS-234A X RHA-1-1 and CMS-10A X MRHA-2 was most promising for seed yield /plant (g) on the basis of per se performance, highest significant standard heterosis and also possess high SCA effects. The hybrid CMS-234A x MRHA-2 can be exploited commercially based on highest significant standard heterosis for seed yield per plant (g) and oil content (%). Similar results for heterosis were found earlier by Chandra *et al.* (2013) [3], Yamgar *et al.* (2015) [18], Spoorthi *et al.* (2016) [16], Sapkale *et al.* (2016) [14], Rathi *et al.* (2016) [13], Singh *et al*. (2017) [15], Kulkarni *et al.* (2017) [7], Lakshman *et. al.*, (2018) [8], Ramaraju *et al.* (2019) [12], Ailwar *et al.* (2020) [1] and Karande *et al.* (2020) [5].

Table 1: Heterosis (%) for ten characters in sunflower.

Sr. No.	Hybrids	Days to 50% flowering		Days to maturity		Plant height (cm)		Head diameter (cm)	
		LSFH-171	LSFH-35	LSFH-171	LSFH-35	LSFH-171	LSFH-35	LSFH-171	LSFH-35
1	CMS-10A x IR-1-1	14.52**	11.81**	6.45**	4.76**	12.61**	12.28**	-26.28**	-23.33
2	CMS-10A x RHA-1-1	3.23	0.79	-0.54	-2.12	5.87**	5.56**	1.28	5.33
3	CMS-10A x MRHA-2	2.42	0.00	3.76**	2.12	8.50**	8.19**	4.49	8.67
4	CMS-10A x 12R-1	4.03*	1.57	1.61	0.00	-5.28**	-5.56**	-9.29	-5.67
5	CMS-10A x ID-51-32	4.03*	1.57	0.54	-1.06	-5.87**	-6.14**	-22.12**	-19.00*
6	CMS-10A x EC-279309-1	15.32**	12.60**	3.76**	2.12	4.11*	3.80*	-11.54	-8.00
7	CMS-10A x EC-502036	-0.81	-3.15	-2.69*	-4.23**	0.59	0.29	-16.99**	16.67
8	CMS-10A x EC-625730	13.71**	11.02**	6.45**	4.76**	18.18**	17.84**	-26.28**	-23.33**
9	CMS-47A x IR-1-1	14.52**	11.81**	6.99**	5.29**	31.67**	31*29**	-29.49**	-26.67**
10	CMS-47A x RHA-1-1	8.87**	6.30**	2.69*	1.06	15.84**	15.50**	2.56	6.67
11	CMS-47A x MRHA-2	8.87**	6.30**	2.69*	1.06	28.15**	27.78**	7.69	12.00
12	CMS-47A x 12R-1	2.42	0.00	-0.54	-2.12	4.40*	4.09*	-22.44**	-19.33**

13	CMS-47A x ID-51-32	-2.42	-4.72**	-0.54	-2.12	16.72**	16.37**	-0.64	3.33
14	CMS-47A x EC-279309-1	-2.42	-4.72**	-2.15	-3.70**	2.93	2.63	6.41	10.67
15	CMS-47A x EC-502036	-0.81	-3.15	-1.08	-2.65*	7.92**	7.60**	6.09	-2.33
16	CMS-47A x EC-625730	15.32**	12.60**	7.53**	5.82**	38.12**	37.72**	-24.36**	-21.33**
17	CMS-234A x IR-1-1	10.48**	7.87**	3.76**	2.12	29.33**	28.95**	-20.19	-17.00*
18	CMS-234A x RHA-1-1	-2.42	-4.72**	1.61	0.00	1.47	1.17	6.73	11.00
19	CMS-234A x MRHA-2	0.00	-2.36	2.69*	1.06	7.04**	6.73**	9.94	14.33
20	CMS-234A x 12R-1	2.42	0.00	0.00	-1.59	-2.05	-2.34	-17.95**	-14.67**
21	CMS-234A x ID-51-32	-1.61	-3.94*	0.54	-1.06	12.32**	11.99**	2.24	6.33
22	CMS-234A x EC-279309-1	4.03*	1.57	-0.54	-2.12	3.52	3.22	-16.99**	-13.67
23	CMS-234A x EC-502036	4.84*	2.36	0.54	-1.06	0.88	0.58	-17.74**	-11.33
24	CMS-234A x EC-625730	12.90**	10.24**	6.45**	4.76**	25.81**	25.44**	-30.77**	-28.00**
25	CMS-249A x IR-1-1	11.29**	8.66**	2.69*	1.06	40.76**	40.35**	5.45	9.67
26	CMS-249A x RHA-1-1	9.68**	7.09**	1.61	0.00	19.65**	19.30**	8.97	13.33
27	CMS-249A x MRHA-2	10.48**	7.87**	3.76**	2.12	21.99**	21.64**	0.32	4.33
28	CMS-249A x 12R-1	10.48**	7.87**	2.15	0.53	17.01**	16.67**	1.28	5.33
29	CMS-249A x ID-51-32	4.03*	1.57	1.61	0.00	15.54**	15.20**	4.49	8.67
30	CMS-249A x EC-279309-1	7.26**	4.72**	1.08	-0.53	9.97**	9.65**	-9.29	-5.67
31	CMS-249A x EC-502036	8.87**	6.30**	0.54	-1.06	20.53**	20.18**	7.69	12.00
32	CMS-249A x EC-625730	15.32**	12.60**	9.14**	7.41**	46.92**	46.49**	-19.87**	-12.67*

Table 1 Cont...

Sr. No.	Hybrids	Seed filling (%)		100 Seed weight(g)		Volume weight(g/100ml)		Hull content (%)	
		LSFH-171	LSFH-35	LSFH-171	LSFH-35	LSFH-171	LSFH-35	LSFH-171	LSFH-35
1	CMS-10A x IR-1-1	-13.48**	-10.67**	-46.52**	-45.04**	-19.12**	-16.67**	33.68**	4.61
2	CMS-10A x RHA-1-1	-3.74	-0.62	-21.59**	-19.41**	3.68	6.82	16.21**	-9.06*
3	CMS-10A x MRHA-2	3.50	6.85*	3.52	6.39*	-8.82*	-6.06	18.95**	-6.92
4	CMS-10A x 12R-1	-9.21**	-6.27*	-31.64**	-29.75**	-10.29*	-7.58	9.47	-14.33**
5	CMS-10A x ID-51-32	-1.24	1.96	-4.01	-1.34	-11.76**	-9.09*	51.58**	18.62**
6	CMS-10A x EC-279309-1	-18.67**	-16.03**	-50.04**	-48.66**	-13.24**	-10.61*	61.05**	26.03**
7	CMS-10A x EC-502036	-1.45	1.75	-30.09**	-28.15**	-7.35	-4.55	23.16**	-3.62
8	CMS-10A x EC-625730	-20.69**	-18.12**	-40.15**	-38.49**	-25.00**	-22.73**	38.32**	8.24
9	CMS-47A x IR-1-1	-29.71**	-27.43**	-45.79**	-44.29**	-19.12**	-16.67**	43.16**	12.03**
10	CMS-47A x RHA-1-1	0.09	3.33	-5.81	-3.19	-1.47	1.52	12.00*	-12.36**
11	CMS-47A x MRHA-2	8.83**	12.36**	0.57	3.36	5.88	9.09*	-1.05	-22.57**
12	CMS-47A x 12R-1	4.37	7.75**	-30.17**	-28.24**	-7.35	-4.55	27.37**	-0.33
13	CMS-47A x ID-51-32	5.98*	9.42**	1.64	4.45	3.68	6.82	7.79	-15.65**
14	CMS-47A x EC-279309-1	-6.81*	-3.79	-0.90	1.85	10.29*	13.64**	31.58**	2.97
15	CMS-47A x EC-502036	-3.42*	-0.29	5.23	8.15*	10.29*	13.64**	16.21**	-9.06*
16	CMS-47A x EC-625730	-23.13**	-20.63**	-48.00**	-46.55**	-23.53**	-21.21**	42.11**	11.20*
17	CMS-234A x IR-1-1	2.73	6.06*	-22.73**	-20.59**	-5.88	-3.03	12.00*	-12.36**
18	CMS-234A x RHA-1-1	-2.77	0.38	-22.73**	- 20.59**	5.88	9.09*	6.32	-16.80**
19	CMS-234A x MRHA-2	8.94**	12.47**	10.87**	13.95**	19.12**	22.73**	16.21**	-9.06*
20	CMS-234A x 12R-1	4.59	7.98**	-25.27**	-23.19**	-4.41	-1.52	16.84**	-8.57
21	CMS-234A x ID-51-32	3.23	6.58*	-1.06	1.68	2.94	6.06	27.37**	-0.33
22	CMS-234A x EC-279309-1	3.76	7.12*	-30.66**	-28.74**	-1.47	1.52	18.95**	-6.92
23	CMS-234A x EC-502036	-10.58**	-7.68**	-26.82**	-24.79**	-19.12**	-16.67**	31.58**	2.97
24	CMS-234A x EC-625730	-18.96**	-16.33**	-49.22**	-47.82**	-26.47**	-24.24**	44.21**	12.85**
25	CMS-249A x IR-1-1	-0.41	2.81	-3.27	-0.59	-4.41	-1.52	21.05**	-5.27
26	CMS-249A x RHA-1-1	8.39**	11.91**	12.35**	15.46**	11.76**	15.15**	7.37	-15.98**
27	CMS-249A x MRHA-2	-2.00	1.17	-4.91	-2.27	2.94	6.06	16.21**	-9.06*
28	CMS-249A x 12R-1	-15.11**	-12.36**	-28.78**	-26.81**	-4.41	-1.52	8.42	-15.16**
29	CMS-249A x ID-51-32	-5.64*	-2.58	5.23	8.15*	1.47	4.55	12.63*	-11.86*
30	CMS-249A x EC-279309-1	1.77	5.07	-22.16**	-20.00**	-2.94	0.00	18.95**	-6.92
31	CMS-249A x EC-502036	2.34	5.65*	-5.97	-3.36	5.88	9.09	10.11	-13.84**
32	CMS-249A x EC-625730	-21.13**	-18.57**	-43.34**	-41.76**	-29.41**	-27.27**	58.95**	24.38**

Table 1 Cont...

Sr. No.	Hybrids	Oil content (%)		Seed yield/plant	
		LSFH-171	LSFH-35	LSFH-171	LSFH-35
1	CMS-10A x IR-1-1	17.24**	-11.38**	-31.57**	-28.77**
2	CMS-10A x RHA-1-1	30.00**	-1.74	-6.07	-2.22
3	CMS-10A x MRHA-2	27.97**	-3.27**	17.98**	22.81**
4	CMS-10A x 12R-1	29.12**	-2.40*	-16.63**	-13.22*
5	CMS-10A x ID-51-32	26.96**	-4.03**	-43.48**	-41.17**
6	CMS-10A x EC-279309-1	21.64**	-8.06**	-50.22**	-48.19**

7	CMS-10A x EC-502036	18.91**	-10.12**	-23.60**	-20.47**
8	CMS-10A x EC-625730	12.22**	-15.17**	-49.10**	-47.02**
9	CMS-47A x IR-1-1	17.62**	-11.09**	-52.81**	-50.88**
10	CMS-47A x RHA-1-1	16.86**	-11.66**	-1.12	2.92
11	CMS-47A x MRHA-2	20.69**	-8.77**	23.15**	28.19**
12	CMS-47A x 12R-1	26.26**	-4.56**	-32.70**	-29.94**
13	CMS-47A x ID-51-32	32.45**	0.12	7.42	11.81*
14	CMS-47A x EC-279309-1	29.89**	-1.82	13.48*	18.13**
15	CMS-47A x EC-502036	35.29**	2.26*	10.11	14.62*
16	CMS-47A x EC-625730	16.61**	-11.85**	-43.15**	-40.82**
17	CMS-234A x IR-1-1	35.77**	2.63**	-33.03**	-30.29**
18	CMS-234A x RHA-1-1	20.99**	-8.54**	22.25**	27.25**
19	CMS-234A x MRHA-2	36.22**	2.97**	30.67**	36.02**
20	CMS-234A x 12R-1	30.57**	-1.30	-27.75**	-24.80**
21	CMS-234A x ID-51-32	31.68**	-0.46	17.42**	22.22**
22	CMS-234A x EC-279309-1	23.93**	-6.32**	1.01	5.15
23	CMS-234A x EC-502036	3.62**	-21.67**	-25.96**	-22.92**
24	CMS-234A x EC-625730	12.24**	-15.16**	-45.39**	-43.16**
25	CMS-249A x IR-1-1	37.06**	3.61**	9.33	13.80*
26	CMS-249A x RHA-1-1	17.73**	-11.01**	23.60**	28.65**
27	CMS-249A x MRHA-2	25.76**	-4.94**	-24.04**	-20.94**
28	CMS-249A x 12R-1	26.89**	-4.08*	-7.53	-3.74
29	CMS-249A x ID-51-32	36.28**	3.01**	10.03	14.54*
30	CMS-249A x EC-279309-1	32.33**	0.03	-15.39**	-11.93*
31	CMS-249A x EC-502036	27.29**	-3.78**	17.53**	22.34**
32	CMS-249A x EC-625730	19.38**	-9.76**	-40.90**	-33.48**

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