Received: 04 Jun 2019 | Revised: 12 May 2020 | Accepted: 18 May 2020

Electronic Journal of Plant Breeding

Research Article

Economic heterosis in sunflower (*Helianthus annuus* L.): Seed yield and yield attributing traits in newly developed hybrids

S. S. Lakshman[1], N. R. Chakrabarty[2] and P. C. Kole[3]

[1]AICRP-Sunflower,
[2&3]Department of Genetics and Plant Breeding, Institute of Agriculture, Palli Siksha Bhavana, West Bengal, India.
E-Mail: lakshmanshyam_ss@yahoo.co.in

Abstract

Present investigation was carried out to spot out the best parent combinations giving high degree of useful heterosis for economic traits like seed yield and other yield attributing characters for sunflower breeding programme. Economic/ Standard heterosis is the measure of heterosis in terms of superiority over the standard check(s) / hybrid(s). The degree of heterosis varied for important useful characters among different crosses. Presence of high heterosis in certain crosses and low in others suggested that the nature of gene action varied with genetic architecture of the parents. For seed yield (kg/ha),the range of significant heterosis was observed from -21.4 per cent (CMS-10A XR-6D-1) to +19.0 per cent (P-2-7-1A X R 601958) along with two hybrids namely P-2-7-1A X R 601958 (19.0 %) and CMS-10 A X R-104 (12.4%) over standard check LSFH-171. The range of economic heterosis over DRSH-1 was recorded from -7.8 per cent (CMS-10A XR-6D-1) to 39.6 per cent (P-2-7-1A X EC-601958) with a total of twelve hybrids registering significant positive heterosis over DRSH-1. Among them, P-2-7-1A X EC-601958958(39.6 %), CMS-10 A X R-104(31.8)%), P-89-1A XEC-601958(22.4%) and CMS-302A X EC-512682(20.0 %) were found to be a superior crosses. For oil yield (kg/ha), significant heterosis was observed from -21.8 per cent (P-89-1A X R-630) to 22.60 per cent (P-2-7-1A X R 601958) along with the five hybrids such as P-2-7-1A X R 601958(22.6%), P-89-1A X EC-601958 (15.9%), P-2-7-1A X R-6D-1(15.6 %) and P-89-1A X R-104 (11.3 %), over standard check LSFH-171. Whereas, the significant heterosis over DRSH-1was recorded from -19.5 per cent (P-89-1A X R-630) to 26.2 per cent (P-2-7-1A X R 601958). The four crosses such as P-2-7-1A X R 601958 (22.6%, 26.2%), P-89-1A XEC-601958 (15.9 %,19.3%), P-2-7-1A X R-6D-1(15.6 %, 14.9%) and P-89-1A X R-104 (11.3 %,14.6%) recorded the highest significant heterosis over both the checks LSFH-171 and DRSH-1 for the traits namely seed yield and oil content respectively.

Keywords
Sunflower, Economic heterosis, Seed yield, Oil yield, Yield attributing traits

INTRODUCTION

Sunflower (*Helianthus annus* L.) is the fourth important oilseed crop in the world. It belongs to the genus *Helianthus*, family Asteraceae. Sunflower seeds contain 38 to 42 % edible oil which is used for culinary purposes. Sunflower oil is considered as premium oil as compared to other vegetable oils because of its light yellow colour, flavour, high smoke point and high level of linoleic acid (55 – 60 %). Sunflower was introduced to India in 1969 from USSR for its distinct advantages *viz.,* photoinsensitivity, wider adaptability, short duration, better oil quality with high polyunsaturated fatty acid content (PUFA) and high seed multiplication ratio, Gupta(2014). However, its large scale cultivation was started from 1972 onwards with the introduction of Russian varieties. In India, sunflower is cultivated over an area of 5.2 lakh hectares with a production and productivity of 3.35 lakh tonnes and 0.64 t ha-1 , respectively (Anon., 2016). Sunflower is being grown over 70 per cent of area across Karnataka, Maharashtra and Andhra Pradesh. It occupies an area of about 3.6 lakh hectare with a production of 2.1 lakh tonnes and productivity of 0.57 t ha-1 in Karnataka (Anonymous, 2017). Sunflower hybrid breeding was started economically in discovering **CMS** by Leclercq in 1969 and restorer genes by Kinman in 1970. Line × tester analysis is an extension of this method in which several testers are used (Kempthorne 1957). In India, the sunflower is grown on about 0.7 million ha (Anonymous, 2017) and mostly grown in the states of Karnataka, Maharastra, AP and Tamil Nadu with potential scope of growing in the non-traditional areas like West Bengal (Dutta, 2011).

Exploitation of heterosis on commercial for a particular locally requires isolation of suitable inbred and development of hybrids. To accomplish this task, one has to know the genetic diversity of the available germplasm and the combining ability of the parents. For improving the yield potential of varieties and hybrids, the decision should be made on the choice of the right parent for hybridization.

In addition to ascertaining overall specific combining ability status of cross combinations, it is also equally important to ascertain the overall heterotic status of the cross combinations across the traits. The overall heterotic status of the cross combinations is estimated as like the same method followed for overall specific combining ability status based on the rank sum of hybrid (mid-parent heterosis) across the traits compared with the final norm for the heterosis.

MATERIALS AND METHODS

Present study was conducted during *kharif* season of 2015-16 and in *Rabi* 2016-2017. Experimental materials (CMS A with respective maintainer and Restorer lines) were collected from ICAR-IIOR, Hyderabad India and other AICRP- Coordinating Centre through AICRP-System, on the basis of their diverse origin, growth habit, phenology and adaptation. Thirteen sunflower genotypes (4 CMS lines and 9 Restorer lines) were grown in a randomized complete block design with 2 replications in a plot size of 1.8 m x3.0m. Each plot had three rows with spacing of 60 cm x30 cm.

The hybridization programme was undertaken in 2015 and 2016 at *kharif* season at AICRP-Sunflower, Nimpith centre. Hybridization was started at the onset of flowering among the parents based on flowering synchrony. The female lines used in this hybridization programme were Cytoplasmic Male Sterile lines (CMS). Pollination of selected CMS flowers were carried out by collecting pollen from heads bagged prior to flowering. The bagging of male and female flowers was done a day prior to flowering to prevent contamination and spilling of the pollen. Pollen grains were applied by a camel hair brush which were dipped in the pollen and gently drawn over the receptive surface of the stigmas at morning from 9AM to 11AM. The pollination was repeated for five to six days (in alternate days) in each of the combination to ensure sufficient seed set. After pollination, again flowers were bagged and tagged properly till harvesting.

The hybridization programme was undertaken in 2015 and 2016 at *kharif* season at AICRP-Sunflower, Nimpith centre. All the CMS A lines were maintained by crossing with corresponding maintainer (CMS-B) lines whereas the maintainer (CMS-B) lines were maintained by selfing. Hybridization was started at the onset of flowering among the parents based on flowering synchrony. The female lines used in this hybridization programme were Cytoplasmic Male Sterile lines (CMS).In crossing block, the CMS lines were raised in one block and the restorer lines were raised in the adjacent block. Pollination of selected CMS flowers were carried out by collecting pollen from heads bagged prior to flowering. The bagging of male and female flowers was done a day prior to flowering to prevent contamination and spilling of the pollen. Pollens were collected from selected flowering heads in paper bags by a light tap of the head. Pollen grains were applied by a camel hair brush which were dipped in the pollen and gently drawn over the receptive surface of the stigmas at morning from 9AM to 11AM. The pollination was repeated for five to six days (in alternate days) in each of the combination to ensure sufficient seed set. After pollination, again flowers were bagged and tagged properly till harvesting.

RESULTS AND DISCUSSIONS

Heterosis breeding has been commercially exploited in sunflower and is expected to enhance the productivity further. Heterosisis the increase or decrease in vigour of F_1over its mid or better parental value. One of the objectives of present study was to estimate the extent of heterosis for various characters and to isolate promising hybrids over standard check hybrids for seed yield and oil content for commercial exploitation. The nature and magnitude of heterosis for seed yield and its component characters is helpful in heterosis breeding. The maximum utilization of heterosis is possible when the variance due to both additive and non additive gene actions are fully exploited since they play a significant role in determining the magnitude of expression of yield and its component.
Main objectives of estimation of economic heterosis in the present investigation was to identify the best combination of parents giving high degree of useful heterosis for seed yield and other yield attributing character for their utilization in the future sunflower breeding programme. Heterosis was measured as per cent increase or decrease of F_1 over standard check hybrid (Standard heterosis) for all the characters. In the present investigation the degree of heterosis varied from cross to cross for all the characters. Considerably high heterosis in certain crosses and low in the others suggested that the nature of gene action varied with the genetic architecture of the parents. *Per se* Performance of the newly developed hybrids are presented in **Table 1.** The results on economic heterosis for twelve different yield attributing characters and best superior hybrids for twelve different yield attributing characters were presented in **Table 2.**

Standard/Economic heterosis Main objectives of estimation of economic heterosis in the present investigation

Table 1. Performance *per se* of the sunflower hybrids (F1) for yield contributing traits

Sl. No	Hybrid combination	50% Flow.	Pl. Ht (cm)	Hd. Dia. (cm)	Seed Yield (kg/ha)	Seed Yield/pl	No. of Filled Grain/ Hd	Auto gamy %	100 seed wt(g)	100 Kernel Wt (g)	Hull Cont. (%)	Vol. Wt. (g/ 100cc)	Oil%	Oil Yield (Kg/ha)
1.	P-2-7-1A X R-6D-1	70.15	150.95	15.60	1927.8	34.74	789.23	87.17	5.45	3.67	37.00	39.85	37.55	723.9
2.	P-2-7-1A X R-12-96	66.15	155.18	15.15	1739.0	31.33	528.47	85.20	5.97	3.79	36.58	37.95	35.55	618.2
3.	P-2-7-1A X R-630	65.65	143.35	14.10	1692.8	30.50	679.80	84.22	4.65	2.91	39.25	37.82	35.50	600.9
4.	P-2-7-1A X R 601958	**73.15**	**159.62**	**15.10**	**2303.4**	41.50	**691.55**	**88.15**	**6.25**	**4.15**	**34.70**	36.35	**34.53**	795.4
5.	P-2-7-1A X EC-601978	69.70	150.32	14.15	1837.0	33.10	597.35	87.17	**6.04**	3.95	36.23	37.53	35.33	649.0
6.	P-2-7-1A XR-138-2	66.15	146.75	**15.40**	1932.8	34.83	628.58	87.17	5.37	3.44	36.52	37.70	35.10	678.4
7.	P-2-7-1A X R-1-1	67.65	145.95	13.70	1622.0	29.23	444.45	89.15	**6.63**	4.41	34.15	36.58	35.50	575.8
8.	P-2-7-1A x R -107	70.15	159.40	14.40	1798.0	32.40	563.75	88.15	5.44	3.53	36.03	37.52	35.70	641.9
9.	P-2-7-1A X R -104	66.20	145.00	13.82	1752.8	31.58	480.75	89.15	**6.58**	4.35	34.10	37.05	35.80	627.5
10	P-89-1A XR-6D-1	64.20	142.90	13.62	1573.0	28.34	558.50	88.15	4.93	3.12	36.33	39.73	37.50	589.9
11.	P-89-1A XR-12-96	67.68	161.52	14.10	1817.7	32.75	637.83	85.20	5.10	3.22	36.32	38.75	36.70	667.1
12.	P-89-1A X R-630	64.20	150.70	14.30	1484.5	26.75	604.05	80.28	5.01	3.22	37.48	38.10	34.15	507.0
13.	P-89-1A XEC-601958	72.15	153.43	15.10	2020.0	36.40	**772.65**	86.20	4.70	3.12	33.95	38.00	**37.10**	749.4
14.	P-89-1A X EC-601978	68.65	145.73	13.50	1682.00	30.31	606.00	90.12	5.36	3.59	33.67	37.82	**37.67**	633.6
15.	P-89-1A XR-138-2	64.15	152.90	13.20	1660.7	29.92	556.30	80.28	5.13	3.27	37.92	40.30	36.50	606.2
16.	P-89-1A X R-1-1	70.15	148.65	15.30	1910.2	34.42	703.90	84.22	4.80	2.84	41.50	38.13	35.75	682.9
17.	**89-1A XR-107**	68.65	160.40	14.30	1647.5	29.68	679.92	89.15	4.49	2.78	38.45	38.82	35.50	584.9
18.	P-89-1A X R-104	70.15	161.95	15.20	1967.7	35.45	799.10	84.22	4.45	2.76	36.80	39.30	36.70	722.1
19.	CMS-10A XR-6D-1	62.68	160.65	14.20	1521.7	27.42	677.03	87.67	4.10	2.50	39.25	39.80	35.25	536.4
20.	CMS-10A X R-12-96	71.15	167.95	**15.65**	1982.7	35.72	810.50	84.22	4.55	2.80	38.15	37.35	34.57	685.4
21.	CMS-**10 A XR-630**	66.32	159.80	13.82	1798.0	32.40	658.22	83.25	5.31	3.70	30.85	32.95	36.80	661.7
22.	CMS-10A X EC-601958	71.00	147.10	14.20	1859.0	33.50	793.32	86.20	4.76	3.14	38.30	37.53	34.20	635.8
23.	CMS-10A X EC-601978	70.00	152.90	15.40	1848.0	33.30	787.45	88.15	4.59	2.84	39.07	37.95	34.95	645.9
24.	CMS-10 AXR-138-2	63.00	161.00	14.80	1622.0	29.23	538.75	78.30	5.39	3.71	32.33	36.12	36.90	598.5
25.	CMS-10A XR-1-1	63.50	156.15	14.40	1547.0	27.87	527.67	**89.15**	5.36	3.57	34.10	37.55	36.90	570.8
26.	CMS-**10A X R-107**	65.50	152.10	14.03	1673.5	30.15	606.70	87.17	4.95	3.57	28.84	35.65	36.47	630.4
27.	CMS-10 A X R-104	69.50	157.90	**15.40**	2175.2	39.18	701.03	86.20	5.62	3.28	35.68	37.60	34.55	751.5
28.	CMS-107 A X R-6D-1	67.50	162.30	14.70	1791.7	32.28	734.28	84.22	4.55	3.06	33.67	35.38	35.55	636.9
29.	CMS-107A X R-12-96	73.50	178.55	**15.80**	1643.0	29.60	677.8	85.20	4.30	2.61	40.55	38.10	32.95	541.4
30.	CMS-107A XR-630	70.50	175.88	15.40	1864.5	33.59	781.50	80.28	4.26	2.61	39.62	40.20	35.70	665.6
31	CMS-107 AX EC-601958	70.50	148.65	13.82	1781.7	32.10	556.95	**89.15**	5.74	3.90	33.42	38.17	36.80	655.7
32	CMS-107A X EC-601978	70.50	145.10	13.30	1778.0	32.04	563.50	**89.25**	5.60	3.85	32.28	37.12	36.30	645.4
33	CMS-107A X R-138-2	66.50	168.05	14.40	1610.7	29.02	636.28	**89.10**	4.70	3.11	34.67	36.77	37.40	602.4
34	CMS-107A X R-1-1	65.50	161.10	15.30	1622.0	29.23	588.58	86.22	5.26	3.57	33.38	35.71	34.53	560.1
35	CMS-107A XR-107	69.50	168.98	15.40	1685.7	30.37	629.25	85.20	4.85	3.14	37.10	36.62	35.45	597.6
36	CMS-107A X R-104	70.62	176.00	15.65	1638.7	29.53	515.20	84.78	**5.76**	**4.16**	30.97	40.28	36.42	596.8
	G. Mean	68.0	146.6	14.6	1772.5	31.94	641.8	85.9	5.1	3.3	36.1	36.5	35.4	626.7
	Lowest	62.68	142.90	13.20	1484.5	26.75	444.45	80.28	4.10	2.50	28.84	32.95	32.95	507.6
	Highest	73.50	178.50	**15.80**	**2303.4**	41.50	810.50	**90.12**	**6.63**	**4.41**	41.50	**40.30**	37.55	795.5
	Lowest	10A XR-6D-1	P-89-1A XR-6D-1	P-89-1A XR-138-2	P-89-1A X R-630	P-89-1A X R-630	P-2-7-1A X R-1-1	107A XR-630	10A XR-6D-1	10A XR-6D-1	**10A X R-107**	**10 A XR-630**	107A X R-12-96	P-89-1A X R-630
	Highest	107A X R-12-96	107A X R-12-96	107A X R-12-96	P-2-7-1A X R 601958	P-2-7-1A X R 601958	10A X R-12-96	P-89-1A X EC-601978	P-2-7-1A X R-1-1	P-2-7-1A X R-1-1	P-89-1A X R-1-1	P-89-1A XR-138-2	P-2-7-1A X R-6D-1	P-2-7-1A X R 601958
	LSFH-171(Ch-1)	83.0	186.0	15.8	1936	34.9	634.22	87.5	5.12	3.14	38.7	36.28	32.6	648.2
	DRSH-1(CH-2)	79.0	175.7	14.5	1650	29.7	557.36	85.2	5.56	3.73	35.5	39.56	38.2	630.1

https://doi.org/10.37992/2020.1102.079

was to spot out the best combination of parent giving high degree of useful heterosis for seed yield and other yield attributing character for their prospects for future use in sunflower breeding programme. Heterosis was measured as per cent increase or decrease of F_1 over standard check hybrid (Standard heterosis) for all the characters. Apart from indicating gene interaction, the measurement of heterosis over better parental value has relatively less importance than standard heterosis. Therefore, it is better to measure heterosis in terms of superiority over the standard check hybrid rather than over better parent. In the present investigation the degree of heterosis varied from cross to cross for all the characters. Considerably high heterosis in certain crosses and low in the others suggested that the nature of gene action varied with the genetic architecture of the parents. *Per se* performance of the newly developed hybrids were presented as under Table 1. The results on economic heterosis for twelve different yield attributing characters and Best superior hybrids for twelve different yield attributing characters were presented as under **Table 2.**

Table 2. List of the best Sunflower hybrids as per the Economic herterosis.

Trait		**Hybrid**	**Superiority over SC-1 (LSFH-1)(%)**	**Hybrid**	**Superiority over SC-2 (DRSH-1) (%)**
Days to 50% Flowering	Lowest	CMS-10A XR-6D-1	-24.5	CMS-10A XR-6D-1	-20.7
		CMS-10 A X R-138-2	-24.5	CMS-10 AXR-138-2	-20.3
		CMS-10A XR-1-1	-23.5	CMS-10A XR-1-1	-19.6
		P-89-1A XR-6D-1	-22.7	P-89-1A XR-6D-1	-18.8
		P-89-1A XR-138-2	-22.7	P-89-1A XR-138-2	-18.8
		89-1A X R-630	-22.7	P-89-1A X R-630	-18.7
	Highest	P-2-7-1A X R 601958	-11.9	P-2-7-1A X R 601958	-7.4
Plant height(cm)	Lowest	P-89-1A XR-6D-1	-23.2	P-89-1A XR-6D-1	-18.7
		P-2-7-1A X R-630	-22.9	P-2-7-1A X R-630	-18.4
		P-2-7-1A X R -104	-22.0	P-2-7-1A X R -104	-17.5
		P-2-7-1A X R-1-1	-21.5	P-2-7-1A X R-1-1	-16.9
		CMS-107A XR-630	-5.4	CMS-107A XR-630	0.1
Head Diameter(cm)	Lowest	P-89-1A XR-138-2	-13.7	P-89-1A XR-138-2	-9.0
	Highest	P-2-7-1A XR-138-2	7.2	P-2-7-1A XR-138-2	13.1
		CMS-107A X R-12-96	3.3	CMS-107A X R-12-96	9.0
				10A X R-12-96	7.9
				10A X EC-601978	6.2
				10A X R-104	6.2
Seed Yield (Kg/ha)	Lowest	CMS-10A XR-6D-1	-21.4	CMS-10A XR-6D-1	-7.8
	Highest	P-2-7-1A X R 601958	19.0	P-2-7-1A X R 601958	39.6
		CMS-10 A X R-104	12.4	CMS-10 A X R-104	31.8
				P-89-1A XEC-601958	22.4
				CMS-302A x EC-512682	20.0
				P-89-1A X R-104	19.4
				P-2-7-1A XR-138-2	17.1
No. of filled seeds/ head	Lowest	P-2-7-1A X R-1-1	-34.8	P-2-7-1A X R-1-1	-17.0
	Highest	CMS-10A X R-12-96	19.0	CMS-10A X R-12-96	51.4
		P-89-1A X R-104	17.3	P-89-1A X R-104	49.3
		10A X EC-601958	16.4	CMS-10A X EC-601958	48.2
		P-2-7-1A X R-6D-1	15.8	P-2-7-1A X R-6D-1	47.7
		P-89-1A XEC-601958	13.4	P-89-1A XEC-601958	44.3
Seed Filling %	Lowest	CMS-10 AXR-138-2	-8.5	CMS-10 AXR-138-2	-10.2
	Highest	P-89-1A X EC-601978	5.3	P-89-1A X EC-601978	3.3
		CMS-107A X EC-601978	4.3	CMS-107A X EC-601978	2.4

Continued….

Table 2. List of the best hybrids as per the Economic herterosis.

Trait		Hybrid	Superiority over SC-1 (LSFH-1)(%)	Hybrid	Superiority over SC-2 (DRSH-1) (%)
100Seed Weight (g)	Lowest	CMS-10A XR-6D-1	-19.9	CMS-10A XR-6D-1	-26.3
	Highest	P-2-7-1A X R-1-1	29.5	P-2-7-1A X R-1-1	19.2
		P-2-7-1A X R -104	28.5	P-2-7-1A X R -104	18.3
		P-2-7-1A X EC- 601958	22.1	P-2-7-1A X R 601958	12.4
100 seed Kernel Weight (g)	Lowest	CMS-10A XR-6D-1	-20.4	CMS-10A XR-6D-1	-33.0
	Highest	P-2-7-1A X R-1-1	40.4	P-2-7-1A X R-1-1	18.2
		P-2-7-1A X R -104	38.5	P-2-7-1A X R -104	16.6
		P-2-7-1A X R 601958	32.2	P-2-7-1A X R 601958	11.3
Hull Cont (%)	Lowest	CMS-10A X R-107	-25.5	CMS-10A X R-107	-18.7
		CMS-10 A XR-630	-20.3	CMS-10 A XR-630	-13.1
		CMS-107A X R-104	-20.0	CMS-107A X R-104	-12.8
		CMS-107A X EC-601978	-16.6	CMS-107A X EC-601978	-9.1
		P-89-1A X EC-601978	-13.0	P-89-1A X EC-601978	-5.2
	Highest	P-89-1A X R-1-1	7.2	P-89-1A X R-1-1	16.9
Volume. Weight(g/100cc)	Lowest	CMS-10 A XR-630	-9.2	CMS-10 A XR-630	-16.7
		CMS-107A X R-104	12.5	CMS-107A X R-104	3.2
	Highest	P-89-1A XR-138-2	11.1	P-89-1A XR-138-2	1.9
		CMS-107A XR-630 (10.8)	10.8	CMS-107A XR-630	1.6
		CMS-10A XR-6D-1(9.7)	9.7		
		P-89-1A XR-104(8.3)	8.3		
Oil%	Lowest	CMS-107A X R-12-96	1.1	CMS-107A X R-12-96	-13.7
		CMS-10A X R-107	15.6	CMS-10A X R-107	-1.4
	Highest	P-89-1A X EC-601978	15.6	P-89-1A X EC-601978	1.4
		P-2-7-1A X R-6D-1	15.2	P-2-7-1A X R-6D-1(-1.7)	-1.7
		P-89-1A XR-6D-1	15.0	P-89-1A XR-6D-1	-1.8
		P-89-1A XEC-601958	13.8	P-89-1A XEC-601958	-2.9
Oil Yield(kg/ha)	Lowest	89-1A X R-630	-21.8	89-1A X R-630(-19.5)	-19.5
		P-2-7-1A X R 601958	22.6	P-2-7-1A X R 601958(26.2)	26.2
	Highest	P-89-1A XEC-601958	15.9	P-89-1A XEC-601958 (19.3)	19.3
		P-2-7-1A X R-6D-1	11.6	P-2-7-1A X R-6D-1 (14.9)	14.9
		P-89-1A X R-104	11.3	P-89-1A X R-104(14.6)	14.6

Negative heterosis for days to 50 per cent flowering with high seed yield is desirable for developing hybrids with dwarf plant type. All the hybrids had significant negative heterosis over LSFH-171.The range of economic heterosis over LSFH-171 was -24.5 per cent (CMS-10A XR-6D-1,CMS-10 A X R-138-2) to -11.9 (P-2-7-1A X R 601958) per cent. 10 hybrids recorded significant negative heterosis for both the checks. Seven earliest flowering hybrids were CMS-850 AX EC-602060 (-34.6 %), CMS-850A X EC-623011 (-34.6 %), CMS-16AXEC-602060(-32.5 %), CMS-16A X EC-601958(-32.5%), P-89-1A X R-6D-1(-22.7%), P-89-1A XR-138-2(-22.7 %) and 89-1A X R-630 (-22.7 %). The range of standard heterosis over second check (DRSH-1) was -20.70 per cent (CMS-10A XR-6D-1) & to -7.4 per cent (P-2-7-1A X R 601958). Seven earliest flowering hybrids over DRSH-1 were CMS-10A XR-6D-1(-20.7%), CMS-10 AXR-138-2(-20.3%), CMS-10A X R-1-1(-19.6%), P-89-1A XR-6D-1 (-18.8%) & P-89-1A XR-138-2(-18.8%) & P-89-1A X R-630(-18.7%).

Plant height (cm): Negative heterosis for plant height is desirable for developing hybrids with dwarf plant type. Out of 32 hybrids twenty one hybrids had significant negative heterosis over check-1(LSFH-171). The range of standard heterosis over LSFH-171 from -23.2 per cent (P-89-1A XR-6D-1) to -5.4 per cent (CMS-107A X R-630). Four promising hybrids were P-89-1A XR-6D-1(-23.2%), P-2-7-1A X R-630 (-22.9 %), P-2-7-1A X R -104(-22.0%), and P-2-7-1A X R-1-1(-21.5%).The range of standard heterosis over check-2 from -18.7 per cent (P-89-1A XR-6D-1) to -0.1 per cent (CMS-107A X R-630). The total

20 hybrids had registered significant negative heterosis. The cross combinations *viz.,* P-89-1A XR-6D-1(-23.2%, -18.7%), P-2-7-1A X R-630(-22.9 %, -18.4%), P-2-7-1A X R -104(-22.0%,-17.5%), and P-2-7-1A X R-1-1(-21.5%, -16.9%) recorded highest significant negative heterosis over both the checks LSFH-171 and DRSH-1 for this trait respectively.

Significant and desirable (positive) standard heterosis for head diameter was observed in two cross combination. No hybrid manifested significant positive heterosis over check-1(LSFH-171). The range of standard heterosis for check-1 (LSFH-171) was observed from -13.7 (P-89-1A XR-138-2(**-13.7)** to 7.2 (P-2-7-1A XR-138-2(7.2) per cent and only one cross combination, i.e. P-2-7-1A XR-138-2(7.2%) manifested significant positive heterosis over check-1(LSFH-171). Top three promising hybrids recorded were P-2-7-1A XR-138-2(13.1%), CMS-107A X R-12-96 (9.0%) CMS-10A X R-12-96(7.9%) and CMS-10A X EC-601978(6.2%), CMS-10A X R-104(6.2%) recorded as promising hybrid over check-2 (DRSH-1). The range of standard heterosis for check-2 was observed from -9.0 per cent (P-89-1A X R-138-2**)** to 13.1 (P-2-7-1A XR-138-2) per cent.

Number of filled seeds per head is important for getting higher seed yield. Hence significant positive heterosis is desirable. Total 4 hybrids manifested significant positive heterosis over check-1(LSFH-171). The range of standard heterosis was - 34.8 per cent (P-2-7-1A X R-1-1) to 19.0 per cent (CMS-10A X R-12-96).Five promising hybrids manifested significant positive heterosis over check-1 were CMS-10A X R-12-96 (19.0 %), P-89-1A X R-104(17.3%), CMS-10A X EC-601958(16.4 %), P-2-7-1A X R-6D- 1(15.4%) and P-89-1A XEC-601958 (13.4 %). In case of check-2, standard heterosis ranged from -12.4 per cent (CMS-16A X R-12-96) to 51.0 (CMS-10A X R-12-96) per cent. Total sixteen hybrids recorded significant positive heterosis over check-2. Five promising hybrids *viz.,*CMS-10A X R-12-96 (19.0 %,51.4%), P-89-1A X R-104(17.3%,49.3%), CMS-10A X EC-601958(16.4 %, 48.2%) P-2-7-1A X R-6D- 1(15.4%, 47.7%) and P-89-1A XEC-601958(13.4 %, 44.3%) were recorded highest significant positive heterosis over both the checks LSFH-171 and DRSH-1 for this traits respectively.

More number of filled seeds per head is important for getting higher seed yield. Hence significant positive heterosis is desirable. Total 4 hybrids manifested significant positive heterosis over check-1(LSFH-171). The range of standard heterosis was -8.5 (CMS-10 AXR-138-2) to **5.3** (P-89-1A X EC-601978(5.3) per cent. Only one cross combination, i.e. P-89-1A X EC-601978 (5.3%) manifested significant positive heterosis over check-1(LSFH-171).In case of check-2 standard heterosis ranged from -10.2 CMS-10 AXR-138-2(-10.2)) to 3.30 per cent (P-89-1A X EC-601978). No hybrids recorded significant positive heterosis over check-2.

The range of standard heterosis for over check-1 was – 19.9 per cent. (CMS-10A X R-6D-1) to 29.5 (P-2-7-1A X R-1-1(29.5) per cent. The estimate of standard heterosis revealed that three hybrids have manifested significant positive heterosis over check-1(LSFH-171). The cross combinations P-2-7-1A X R-1-1(29.5%), P-2-7-1A X R -104 (28.5%) and P-2-7-1A X R 601958(22.1%) manifested significant positive heterosis over check-1. The range of standard heterosis for over check-2 was –26.3 per cent (CMS-10A XR-6D-1-26.3) to 19.2 (P-2-7-1A X R-1-1(19.2) per cent. In case of check-2 five hybrids exhibited significant positive standard heterosis. Three crosses *viz.,* P-2-7-1A X R-1-1(29.5%,19.2%), P-2-7-1A X R -104 (28.5%, 18.3%) and P-2-7-1A X R 601958(22.1%, 12.4%) recorded the highest significant positive heterosis over both checks LSFH-171 and DRSH-1 for this trait respectively.

The range of standard heterosis for 100 seed kernel weight (g) over check-1 was - 29.41 per cent (CMS-10A XR-6D-1) to 40.4 (P-2-7-1A X R-1-1) per cent. The estimate of standard heterosis revealed that three hybrids have manifested significant positive heterosis over check-1(LSFH-171). The cross combinations P-2-7-1A X R-1-1(40.4%), P-2-7-1A X R -104(38.5%) and P-2-7-1 A X R 601958(32.1%) have manifested significant positive heterosis over check-1. The range of standard heterosis for 100 seed kernel weight (g) over check-1 was – 33.01 per cent (CMS-10A XR-6D-1) to 18.2 (P-2-7-1A X R-1-1(18.2) per cent. In case of check-2 five hybrids exhibited significant positive standard heterosis. The cross combinations P-2-7-1A X R-1-1(40.4%, 18.2%), P-2-7-1A X R-104(38.5%, 16.6%) and P-2-7-1A X R 601958(32.1% 11.3%) recorded the highest significant positive heterosis over both checks LSFH-171 and DRSH-1 for this trait respectively.

The perusal of data revealed that the range of standard heterosis over check-1 was -25.5 per cent (CMS-10A X R-107) to 7.2 per cent (P-89-1A X R-1-1) and five hybrids registered significant negative heterosis over check-1(LSFH-171). The estimate of standard heterosis revealed that five cross combinations have manifested significant negative heterosis over check-1(LSFH-171) were CMS-10A X R-107(-25.5 %), CMS-10 A X R-630 (-20.3%) CMS-107A X R-104 (-20.0%), CMS-107A X EC-601978(-16.6) and P-89-1A X EC-601978(-13.0%) respectively. The range of standard heterosis over check-2 was – 18.7 per cent (CMS-10A X R-107(-25.5) to 16.9 per cent (P-89-1A X R-1-1) and four promising cross combination were CMS-10A X R-107(-18.7 %), CMS-10 A XR-630 (-13.1 %), CMS-107A X R-104 (-12.8%) and CMS-107A X EC-601978(-9.1%) showed negatively significant heterosis over check-2 for this trait.

The perusal of data revealed that the range of standard heterosis over check-1(LSFH-171) was - 9.2 (CMS-10 A X R-630) to 12.5 per cent (CMS-107A X R-104) along with five hybrids recorded significant positive standard heterosis over LSFH-171. The cross combinations *viz.,* CMS-107A X R-104(12.5%), P-89-1A XR-138-2(11.1%)

, CMS-107A XR-630 (10.8%), CMS-10A XR-6D-1(9.7%) and P -89-1A XR-104 (8.3%) were manifested significant positive heterosis over check-1, whereas the range of standard heterosis over check-2 was from -16.70 per cent (CMS-10 A XR-630(-16.7) to 1.2 per cent (CMS-107A X R-104). No cross combination manifested a significant positive heterosis over check-2.

The perusal of data revealed that the range of standard heterosis over check-1(LSFH-171) was 1.10 per cent (CMS-107A X R-12-96(1.1) to 15.6 per cent (CMS-10A X R-107(15.6) along with 8 hybrids having significant positive standard heterosis over check-1(LSFH-171). The cross combinations *viz.*, P-2-7-1A X EC-601958(15.0%), P-2-7-1AXEC-601978(14.4%), CMS-302A X EC-601958(13.9%), P-89-1A X R-6D-1(15.0%) and P-89-1A XEC-601958(13.9%) cross combinations were manifested significant positive heterosis over check-1. The range of standard heterosis over check-2 was -13.7 per cent (CMS-107A X R-12-96(1.1) to 1.4 (CMS-10A X R-107(15.6) per cent. No cross combination manifested a significant positive heterosis over check-2 (DRSH-1) for this trait.

The range of significant heterosis over check-1(LSFH-171) was observed from -21.4% (CMS-10A XR-6D-1) per cent to 19.0 (P-2-7-1A X R 601958) per cent per cent along with the two hybrid having significant positive standard heterosis over check-1(LSFH-171). P-2-7-1A X R 601958(19.0%) and CMS-10A X R-104(12.4%), were the best two hybrids with significant positive heterosis over check-1(LSFH-171). Whereas, the range of significant heterosis over check-2(DRSH-1) was -7.8 per cent (CMS-10A XR-6D-1) to 39.6 per cent (P-2-7-1A X EC-601958). Total twelve hybrids registered significant positive heterosis over check-2. The six cross combination *viz.,* P-2-7-1A X EC-601958958(39.6 %), CMS-10 A X R-104(31.8)%), P-89-1A XEC-601958(22.4%) and CMS-302A X EC-512682(20.0 %), P-89-1A X R-104(19.4%) and P-2-7-1A XR-138-2(17.1%) recorded the highest significant heterosis over check DRSH-1 for this trait.

The range of significant heterosis over check-1(LSFH-171) was observed from -21.8 per cent (P-89-1A X R-630) to 22.60 per cent (P-2-7-1A X R 601958**)** along with the five hybrids having significant positive standard heterosis. P-2-7-1A X R 601958(**22.6**%), P-89-1A X EC-601958 (15.9%), P-2-7-1A X R-6D-1(15.6 %) and P-89-1A X R-104 (11.3 %) were the top four hybrids with significant positive heterosis over check-1. Whereas, the range of significant heterosis over check-2 was -19.5 per cent (P-89-1A X R-630 to 26.2 per cent (P-2-7-1A X R 601958). Total seven hybrids registered significant positive heterosis over check-2. The four cross combination *viz.,* P-2-7-1A X R 601958 (**22.6**%,26.2%), P-89-1A XEC-601958 (15.9 %,19.3%), P-2-7-1A X R-6D-1(15.6 %, 14.9%) and P-89-1A X R-104(11.3 %,14.6%) recorded highest significant heterosis over both the checks LSFH-171 and DRSH-1 for this trait. P-89-1A X R-630, P-2-7-1A X R 601958, P-89-1A X EC-601958, P-2-7-1A X R-6D-1, P-89-1A X R-104.

Prevalence of significant standard heterosis for seed yield has also been reported by Manivannan *et al.* (2005). Attaining a higher standard heterosis for seed yield in the experimental hybrids with the use of CMS lines / tester lines have also been made by Meena *et al.* (2013), Chandra *et al.* (2013) and Supriya *et al* (2017). The significant positive heterosis of hybrids based on diverse CGMS system over national check hybrid KBSH-44 was also reported by Nandini *et al.* (2017) and Jondhale *et al* (2012) for studying the combining ability in sunflower. The presence of significant positive heterosis among the newly developed sunflower hybrid sand superiority of *H. praecox* based hybrids was also in line with studies by Nandini *et al.* (2017) and Tyagi *et al* (2013). Mohanasundaram *et al.* 2010 noticed the standard heterosis of for seed yield and for oil content. Similar findings were reported by Tyagi *et al.* (2018). Prevalence of significant standard heterosis for seed yield has also been reported by Thakare *et al.* (2015). Attaining higher standard heterosis for seed yield in the experimental hybrids with the use of CMS lines / tester lines have also been made by Meena *et al.* (2013), Chandra *et al.* (2013) and Supriya *et al.* (2017). Attaining higher standard heterosis for seed yield and most of the yield contributing traits in the experimental hybrids with the use of diverse CMS lines have also been made by Nandini *et al.* (2017) and Manivannan *et al.* (2015). Standard heterosis over best check *i.e.* DRSH-1 for seed yield and oil content Rathi *et al.* (2016). The results regarding standard heterosis of diverse CMS lines based hybrids showed varied extent of magnitude and direction of heterosis for the crosses for each trait. The results regarding economic heterosis of diverse CMS lines based hybrids showed varied extent of magnitude and direction of heterosis for the crosses for each trait. Similar findings were reported by Lakshman *et.al.* (2018).

From the study it may be concluded that the sunflower hybrids *viz.* P-89-1A X R-630, P-2-7-1A X R 601958, P-89-1A X EC-601958, P-2-7-1A X R-6D-1, P-89-1A X R-104 may be promoted for AICRP Multilocation trial/ Coordinated trial for further evaluating their performance in Eastern India due to their superiority for oil yield (kg/ha) over the best national check sunflower hybrids over the environments and over the years.

ACKNOWLEDGEMENT

The senior author is highly thankful to **AICRP-Sunflower System, IIOR-ICAR, Hyderabad and RAKVK, Nimpith** for continuous financial and academic support and guidance throughout the research programme.

REFERENCES

Anonymous (2017-18). https://www.sunflowernsa.com/stats/worldsupply.

Ann. Report (2016-17). Directors report, Dept. of Ag., GOWB-2016-17:25-26.

Chandra B S, Ranganatha A R G and Kumar S (2013). Heterosis studies for yield and it's components in sunflower hybrids over locations. *Madras Agric. J.,* **100** (13):23-29.

Dutta A. 2011**.**Effects of sowing dates on yield and yield components of hybrid sunflower (*H.annuus L.*) in nontraditional areas of West Bengal. *Journal of Crop and Weed*. **7***(*2)*:* 216-228**.**

Gupta, M.K. Sunflower oil and its applications. 2014. *Lipid Technol*., **26**, 260–263. [CrossRef]

Jondhale, A.S., Goud, I.S. and Praveenkumar, B. (2012). Combining Ability and Gene Action Studies in Diverse CMS Sources in Sunflower (*Helianthus annuus* L.) *International Journal of Science and Research,* **3**(12): 2183-2187.

Lakshman S S., Chakrabarty N R & Kole P C.2018. Economic Heterosis for seed and oil yield in sunflower (Helianthus annuus L.) hybrids over locations in Heterosis Breeding West Bengal. *Indian Agriculturist*. : **62**(1 & 2): 1-8.

Kempthorne O. 1957**.** An Introduction of Genetics Statistics. The Lowa University Press.

Kinman, M.L., 1970.New development in the USDA and State Experiment Station, Sunflower breeding

programme. In: *Proc. of the Fourth Int. Sunflower Conference,* Memphis, Tennessa, pp.181-183.

Leclercq, P., 1969. Line sterile cytoplasmic quechezktournesol. *Ann. AmeliorPlanta,***12**: 99-106.

Meena C R, Meena H P and Snha B 2013. Fertility restoration, combining ability effects and heterosis in sunflower (Helianthus annuus L.) using different CMS sources. *Chilean J. Agric. Res.,* **17**(99): 101-104.

Mohanasundaram K, Manivannan N, and Vindhaiyavarman P. 2010. Combining ability analysis for seed yield and its components in sunflower (*Helianthus annuus* L.). *Elec. J. Pl. Breed.* **4** : 864-865.

Manivannan N, Chandirakala R and Abirami S 2015. Evaluation of new CMS lines for heterosis breeding in sunflower (*Helianthus annuus* L.). *Advances in life sciences* **5** (5): 1909-1912.

Nandini C., Shadakshari Y. G., Pushpa D., Puttarangaswamy K. T. and Kumar V. 2017. Genetic diversity analysis in diversified cms and restorer lines in sunflower (*helianthus annuus* L.) *Int.J.Curr.Microbiol.App. Sci.***6** (10): 3185-3189. [CrossRef]

Supriya S M, Kulkarni V V, Ranganatha C N and Suresha P G 2017. Quantitative Analysis of Oil Yield and Its Components in Newly Developed Hybrids of Sunflower (*Helianthus annuus* L.).,*Int. J. Curr. Microbiol. App. Sci.:***6** (8), 3088-3098. [CrossRef]

Rathi, S.R., Nichal, S.S., Vaidya, E.R., Ratnaparkhi, R.D. and Janjal, S.M. 2016. Combining ability for yield contributing traits and oil content in sunflower (*Helianthus annuus*L.). *International Journal of Tropical Agriculture*. **34** (4): pp.1043-1049.

Thakare S U, Nichal S S, Ingle A U and Tayade S D 2015. Heterosis Studies for Yield Contributing Traits and Oil Content in Sunflower (*Helianthus annuus* L.). *Trends in Bio-sci.* **8** (12): 3010-3017.

Tyagi N., Dhillon S K. and Bajaj R K. 2013. Estimates of heterosis for oil content in sunflower (*Helianthus annuus* L.).***16th Punjab Science Congress. PP-***72.

Tyagi, V., Dhillon, S., Kaushik, P. And Kaur, G. Characterization for Drought Tolerance and Physiological Efficiency in Novel Cytoplasmic Male Sterile Sources of Sunflower (Helianthus annuus L.). *Agronomy 2018*, 8, 232. [CrossRef]