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Study the Economic Heterosis Study for Seed Yield, Oil Yield and Yield Attributing Traits in Newly Developed Hybrids in Sunflower (*Helianthus annuus* L.)

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ABSTRACT

Main objectives of estimation of economic heterosis in the present investigation was to spot out the best combination of parent (F_1S) giving high degree of useful (economic) heterosis for seed yield and other yield attributing characters for their future use in sunflower breeding program. Heterosis was measured as percent increase or decrease of F_1 over standard check hybrid (Standard heterosis) for all the traits. Economic / Standard heterosis is measure the heterosis in terms of superiority over the standard check (s) / hybrid (s). 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. For seed yield (kg/ha), the range of significant heterosis over KBSH-53 and DRSH-1 were observed –33.6% and –18% respectively (CMS–850A × R–12-96) to 5.9% and 14.6% respectively (ARM-249-1A × EC-601939). ARM-249-1A × EC-601939 along with the five hybrids PET-2-7-1A × EC-623011 (11.6%), CMS-343A ×R-101 (9.9%), PET-2-7-1A × EC-601968 (9.9%) and P-89-1A × R-1-1 (8.6%) having significant positive economic heterosis over DRSH-1 for seed yield (kg/ha). The perusal of data revealed that the range of economic heterosis over check-1 (KBSH-53) was 5.4% (CMS-16A × EC-603011) to 13.7% (CMS-2A × EC-601958) along with 15 hybrids having significant positive economic heterosis over KBSH-53. The cross combinations viz., CMS-2A × EC-601958 (13.7%), P-89-1A × RHA-1-1 (13.1%), CMS-302A × EC601939 (13.1%), PET-2-7-1A × EC-601725 (12.5%) and CMS-302A × EC-601958 (12.5%) were the promising hybrids in regards to seed oil content. The range of economic heterosis over DRSH-1 was -7.8% (CMS-16A × EC-603011) to-0.5% (CMS-2A × EC-601958) percent but no one recorded significant positive economic heterosis over check-2 (DRSH-1) in regards to seed oil content. The cross combination viz., ARM-249-1A × EC-601939 (10.8%, 8.8%) along with the four hybrids PET-2-7-1A × EC-623011 (9.6%, 7.6%), P-89-1A × RHA-1-1 (9.4%, 7.5%), CMS-343A × R-101 (9.2%, 7.3%) and PET-2-7-1A × EC-601968 (8.3%, 6.4%) recorded highest significant heterosis over both the checks KBSH-53 and DRSH-1 for oil yield (kg/ha).

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

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INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the fourth important oilseed crop in world next to soybean, groundnut and rapeseed. It belongs to the genus *Helianthus*, family Asteraceae. Sunflower contains 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 color, flavor, high smoke point, high level of linoleic acid (55 – 60%) and low oleic acid (25–30%).

Oilseeds occupy a pride place in Indian economy, since the requirement of oils is increasing rapidly day by day due to increase in population and consumption of oils. To overcome this problem and to meet the requirement of *per capita* consumption, the output of oilseeds has to be increased by increasing productivity. In order to bridge the gap between demand and supply of oilseeds in the country, sunflower (*Helianthus annuus* L.) which was introduced in India in 1969 from USSR a crop of all seasons was taken up owing to its distinct advantages viz., photoinsensitivity, wider adaptability, short duration, better oil quality with high polyunsaturated fatty acid content (PUFA) and high seed multiplication ratio. However, its large scale cultivation was started from 1972 onwards with the introduction of four 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% of area across Karnataka, Maharashtra and Andhra Pradesh (Padmaiah et al. 2015). 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 2017-18, Allard 1960). Exploitation of heterosis on commercial for a particular locally requires isolation of suitable in bred 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.

Line × tester mating design is an appropriate method to identify superior parents and hybrids based on general and specific combining ability respectively and to study nature of gene action. This design provides information on more number of parents with limited number of single crosses. 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

This was conducted during *kharif* season of 2015-2016 and again repeated in *rabi* of 2016-2017. Experimental materials (CMS A with respective maintainer and Restorer lines) were collected from ICAR–IIOR, Hyderabad India and other AICRP - Coordinating Center through AICRP-System, on the basis of their diverse origin, growth habit, phenology and adaptation.

Hybridization and pollination

The hybridization program and pollination program was undertaken in 2015 and 2016 at *kharif* season at AICRP - Sunflower, RAKVK, Nimpith Center. All the CMS A lines were maintained by crossing with corresponding maintainer (CMS-B) lines where as the maintainer (CMS-B) lines were maintained by selfing itself. Hybridization was started at the onset of flowering among the parents based on flowering synchrony. The female parents (lines) used in this hybridization program were Cytoplasmic Male Sterile (CMS) lines (Leclercq 1969). In crossing block, the CMS lines were raised in one block and the male pollen donor lines (restorer lines) were raised in the adjacent block. Pollination of selected CMS flowers were carried out by collecting pollen from heads which were already bagged prior to flowering. The bagging was done a day before over male and female flowers to prevent contamination and to avoid spilling the pollen. Pollens were collected from selected flowering heads into paper bags by a light tap of the hand on the back 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 9 AM to 11 AM. 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 keeping till harvesting.

Field evaluation

Field evaluation was done at 2015-2016 and 2016-2017 at *rabi* season at AICRP-Sunflower, Nimpith. All the F_1S, (newly developed hybrids) 15 F_1 hybrids including two national checks (DRSH-1 and KBSH-53 were developed by using 4 CMS lines and 9 testers) were evaluated along with the two national check hybrids KBSH-53 and DRSH-1 in a Randomized Complete Block Design with 2 replications in a plot size of 3.0 m × 3.0 m in two consecutive years at AICRP-Sunflower, Nimpith Center. Three irrigations were provided during the cropping period. A total of 15 sunflower hybrids were evaluated including the two national check hybrids, KBSH-53 and DRSH-1 in Randomized Complete Block Design with three replications (Chandirakala et al. 2015, Dutta 2011). The soil texture was clay loam in On station plots. Three irrigations were provided during the cropping period. One foliar spray was given with Boron @ 2 g/l of water in ray floret stage. The row per plot were five in number with a row spacing of 60 cm and plant to plant was 30 cm. Uniform dose of fertilizer @ 80 kg N, 40 kg P_2O_5 and 40 kg K_2O per ha was applied. The germinated seed of sunflower used as the planting materials and one per hill were maintained throughout the cropping period. The data were recorded in ten randomly selected plants from each plot of all replications on the following characters viz., days to 50% flowering, plant height at harvest (cm), head diameter per plant (cm), seed weight per head (g), 100 seed weight (g), husk weight (g) and hull content (%), volume weight (seed weight in gram per 100 ml) and oil content (%). The seed yield (kg/ha), oil percentage and oil yield (kg/ha) were estimated on plot basis. The mean values were subjected to statistical analysis (Kmpthorne 1957, Kinman 1970).

RESULTS AND DISCUSSION

Heterosis breeding has been commercially exploited in sunflower and is expected to enhance productivity-further. Heterosis is the increase or decrease in vigor of F_1 over 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. For our purposes, we will define heterosis or hybrid vigor as the difference between the hybrid and the mean of the two parents (Falconer and Mackay 1996) that is mid-parent heterosis and better-parent heterosis which is preferred in some circumstances, particularly in self-pollinated crops, for which the goal is to find a better hybrid than either of the parents. 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 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 program. Heterosis was measured as percent 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.

Standard / Economic heterosis

Main objectives of estimation of economic heterosis in the present investigation was to spot out the best

Table 1. Station hybrid trial 5 : Preliminary evaluation of new single cross hybrids.

Cross combination	Days to 50% flow-ering	Plant height (cm)	Head diame-ter (cm)	Seed yield (kg/ha)	Seed filling (%)	100 seed wt (g)	Hull con-tent (%)	Oil (%)	Oil yield (kg/ha)
PET-2-7-1A×EC-623011	75	163	15.5	1800	89.5	6.8	30.8	37.2	669.6
PET-2-7-1A×EC-601968	74	161	15.2	1780	91.0	4.9	38.8	37.2	662.2
PET-2-7-1A×R-12-96	73	168	15.0	1680	91.0	5.7	29.3	36.6	614.9
PET-2-7-1A×R-272	63	156	13.6	1520	86.0	5.3	33.6	37.1	563.9
PET-2-7-1A×EC-601725	67	144	14.1	1550	51.0	5.8	28.4	37.8	585.9
CMS-343A×R-101	80	198	15.0	1780	92.0	5.8	29.3	37.5	667.5
P-89-1A × RHA-1-1	74	169	15.6	1760	92.5	4.6	37.0	38.0	668.8
ARM-249-1A×EC-601939	78	195	16.3	1860	91.5	5.2	34.6	36.4	677.0
CMS-16A×EC-603011	74	185	16.2	1740	88.5	6.0	28.3	35.4	616.0
CMS-10A×EC-608220	73	166	15.3	1680	92.0	4.2	31.0	37.2	625.0
CMS-2A×NW-31	71	171	13.8	1640	87.0	5.1	33.3	36.6	600.2
CMS-302A×RHA-138-2	69	152	14.6	1720	92.0	5.0	34.0	37.8	650.2
CMS-302A×EC-601958	68	142	14.1	1600	90.0	4.7	34.0	37.4	598.4
CMS-2A×EC-601958	68	155	15.1	1605	93.0	5.1	29.4	38.2	613.1
CMS-302A×EC-601939	70	157	14.8	1640	88.0	4.8	31.2	37.8	619.9
KBSH-53 (C)	82	203	15.8	1820	87.8	4.8	33.3	33.6	611.5
DRSH-1 (C)	78	193	14.4	1620	89.5	5.5	34.8	38.4	622.1
CD at 5%	1.8	9.2	0.6	71.2	0.7	0.4	2.6	0.7	34.2
CV (%)	5.6	9.6	6.8	9.4	6.4	7.6	7.8	6.1	9.2

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 program. Heterosis was measured as percent 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 superior hybrids for twelve different yield attributing characters were presented as under Table 2.

The data pertaining to seed yield and other yield attributing traits for these test hybrids along with the checks are presented in Table 1. For seed yield, hybrids ARM-249-1A × EC-601939 (1860 kg/ha), P-2-7-1A ×EC-623011 (1800 kg/ha), P-2-7-1A ×EC-601968 and 343A × R-101 (1780 kg/ha), P-89-1A ×RHA-1-1 (1760 kg/ha), 249A × EC-601939 (1760 kg/ha), CMS-16A × EC-603011 (1740 kg/ha) were found promising compared to the checks KBSH-53 (1820 kg /ha) and DRSH-1 (1620 kg/ha) respectively. For oil yield (kg/ha), hybrids ARM-249-1A × EC-601939 (677 kg / ha), P-2-7-1A × EC-623011 (670 kg/ha), P-89-1A × RHA-1-1 (668 kg/ha), CMS-343A ×R-101 (667 kg/ha), P-2-7-1A × EC - 601968 (662 kg /ha), CMS-302A XR-138-2 (650 kg/ha) were found promising compared to the checks KBSH-53 (611 kg/ha) and DRSH-1 (622 kg/ha) respectively.

For seed yield (kg/ha), the range of significant heterosis over KBSH-53 was observed from–33.6% (CMS-850A ×R-12-96) percent to 5.9% (ARM-249-1A ×EC-601939). Along with the two hybrids P-2-7-1A × R 601958 (19.0%) and CMS-10 A × R-104 (12.4%) having significant positive standard heterosis over KBSH-53, whereas, the range of economic heterosis over DRSH-1 was-18.0% (CMS-850A × R-12-96) to 14.8% (ARM-249-1A × EC-601939) and

Table 2. Economic heterosis for yield and yield attributing traits in sunflower hybrids.

Sl. No.	Hybrid combination	Days to 50% flowering SC-1	SC-2	Plant height (cm) SC-1	SC-2	Head diameter (cm) SC-1	SC-2	Seed yield (kg/ha) SC-1	SC-2	Autogamy (seed filling %) SC-1	SC-2
1.	PET-2-7-1A × EC-623011	– 8.5*	– 3.8	– 19.7**	– 15.5**	– 1.9	7.6**	2.5	11.1**	1.9	0.0
2.	PET-2-7-1A × EC-601968	–9.8*	– 5.1*	– 20.7**	– 16.6**	– 3.8	5.6*	1.4	9.9*	3.6	1.7
3.	PET-2-7-1A × R-12-96	– 11.0**	– 6.4*	– 17.2**	– 13.0**	– 5.1*	4.2	– 4.3	3.7	3.6	1.7
4.	PET-2-7-1A × R-272	– 23.2**	– 19.2**	– 23.2**	– 19.2**	– 13.9**	– 5.6*	– 13.4**	– 6.2*	– 2.1	– 3.9
5.	PET-2-7-1A × EC-601725	– 18.3**	– 14.1**	– 29.1**	– 25.4**	– 10.8**	– 2.1	– 11.7**	– 4.3	– 41.9**	– 43.0**
6.	CMS-343A× R-101	– 2.4	2.6	– 2.5	2.6	– 5.1*	4.2	1.4	9.9**	4.8	2.8
7.	P-89-1A× RHA-1-1	– 9.8*	– 5.1*	– 16.7**	– 12.4**	– 1.3	8.3*	0.2	8.6*	5.4*	3.4
8.	ARM-249-1A× EC-601939	–4.9	0.0	– 3.9	1.0	3.2	13.2**	5.9*	14.8**	4.2	2.2
9.	CMS-16A× EC-603011	– 9.8*	– 5.1*	– 8.9*	– 4.1	2.5	12.5**	– 0.9	7.4*	0.8	– 1.1
10.	CMS-10A× EC-608220	– 11.0**	– 6.4*	– 18.2**	– 14.0**	– 3.2	6.3*	– 4.3	3.7	4.8	2.8
11.	CMS-2A× NW-31	–13.4**	– 9.0*	– 15.8**	– 11.4**	– 12.7**	– 4.2	– 6.6*	1.2	– 0.9	– 2.8
12.	CMS-302A× RHA-138-2	– 15.9**	– 11.5**	– 25.1**	– 21.2**	– 7.6*	1.4	– 2.1	6.2*	4.8	2.8
13.	CMS-302A × EC-601958	– 17.1**	– 12.8**	– 30.0**	– 26.4**	– 10.0**	– 2.1	– 8.9*	– 1.2	2.5	0.6
14.	CMS-2A× EC-601958	– 17.1**	– 12.8**	– 23.6**	– 19.7**	– 4.4	4.9	– 8.6*	– 0.9	5.9	3.9
15.	CMS-302A× EC-601939	– 14.6**	– 10.3**	– 22.7**	– 18.7**	– 6.3*	2.8	– 6.6*	1.2	0.2	– 1.7
	Lowest	–23.2	– 19.2	– 30.0	– 26.4	– 12.7	– 4.2	– 13.4	– 6.2	– 41.9	– 43.0
	Highest	–2.4	2.6	– 2.5	2.6	3.2	13.2	5.9	14.8	5.9	3.9

Table 2. Continued.

Sl. No.	Hybrid combination	100 seed weight SC-1	SC-2	Hull content (%) SC-1	SC-2	Oil % SC-1	SC-2	Oil yield (kg/ha) SC-1	SC-2
1.	PET-2-7-1A ×EC-623011	41.7**	23.6**	– 7.5*	– 11.5**	10.7**	– 3.1	9.6*	7.6*
2.	PET-2-7-1A ×EC-601968	2.1	– 10.9**	16.5**	11.5**	10.7**	– 3.1	8.3*	6.4*
3.	PET-2-7-1A ×R-12-96	18.8**	3.6	– 12.0**	– 15.8**	8.9*	– 4.7	0.6	– 1.2
4.	PET-2-7-1A ×R-272	10.4**	– 3.6	0.9	– 3.4	10.4**	– 3.4	– 7.7*	– 9.4**
5.	PET-2-7-1A ×EC-601725	20.8**	5.5*	– 14.7**	– 18.4**	12.5**	– 1.6	– 4.1	– 5.8*
6.	CMS-343A×R-101	20.8**	5.5*	– 12.0**	– 15.8**	11.6**	– 2.3	9.2*	7.3*
7.	P-89-1A×RHA-1-1	– 4.2	– 16.4**	11.1**	6.3*	13.1**	– 1.0	9.4*	7.5*
8.	ARM-249-1A×EC-601939	8.3*	– 5.5*	3.9	– 0.6	8.3*	– 5.2	10.8**	8.8*
9.	CMS-16A×EC-603011	25.0**	9.1*	– 15.0**	– 18.7**	5.4*	– 7.8	0.8	– 1.0
10.	CMS-10A×EC-608220	– 12.5**	– 23.6**	– 6.9*	– 10.9**	10.7**	– 3.1	2.3	0.5
11.	CMS-2A×NW-31	6.3*	– 7.3*	0.0	– 4.3	8.9*	– 4.7	– 1.8	– 3.5
12.	CMS-302A×RHA-138-2	4.2	– 9.1*	2.1	– 2.3	12.5**	– 1.6	6.4*	4.5
13.	CMS-302A ×EC-601958	– 2.1	– 14.5**	2.1	– 2.3	11.3**	– 2.6	– 2.1	– 3.8
14.	CMS-2A×EC-601958	6.3*	– 7.3*	– 11.7**	– 15.5**	13.7**	– 0.5	0.3	– 1.5

Table 2. Continued.

Sl. No.	Hybrid combination	100 seed weight SC-1	100 seed weight SC-2	Hull content (%) SC-1	Hull content (%) SC-2	Oil % SC-1	Oil % SC-2	Oil yield (kg/ha) SC-1	Oil yield (kg/ha) SC-2
15.	CMS-302A×EC-601939	0.0	– 12.7**	– 6.3*	– 10.3*	12.5**	– 1.6	1.4	– 0.4
	Lowest	– 12.5	– 23.6	– 15.0	– 18.7	5.4	– 7.8	– 7.7	– 9.4
	Highest	41.7	23.6	16.5	11.5	13.7	– 0.5	10.8	8.8

a total of eight hybrids registered significant positive heterosis over DRSH-1 among them the superior crosses were, PET-2-7-1A × EC-623011 (11.1%), CMS-343A ×R-101 (9.9%), P-2-7-1A×EC-601968 (9.9%), P-89-1A×RHA-1-1 (8.6%), respectively (Table 3).

Days to 50% flowering. Negative heterosis for days to 50% flowering with high seed yield is desirable for developing hybrids with dwarf plant type. Out of 32 hybrids, all the hybrids had significant negative heterosis over check-1 (KBSH-53) the same trait. The range of economic heterosis over check-1 (KBSH-53) was –34.6% (PET-2-7-1A × R-272) to –2.5% (CMS-343A × R-101). Four hybrids recorded significant negative heterosis for both the checks. Four other earliest flowering hybrids were PET-2-7-1A × EC-601725 (–18.3%), CMS-302A × EC-601958 (–17.1%), CMS-2A × EC-601958 (–17.1%) and CMS-302A × RHA-138-2 (–15.9%). The range of economic heterosis over second check (DRSH-1) was –19.2% (PET-2-7-1A × R-272) to 2.6% (CMS-343A × R-101). Other four earliest flowering hybrids over second check (DRSH-1) were PET-2-7-1A × EC-601725 (–14.1%), CMS-302A × EC-601958 (–12.8%), CMS-2A×EC-601958 (–12.8%) and CMS-

Table 3. List of the best hybrids as per the economic heterosis.

Trait		Hybrid	SC-1 (LSFH-1)	SC-2 (DRSH-1)
Days to 50% flowering	Lowest	PET-2-7-1A × R-272	–23.2	– 19.2
		PET-2-7-1A × EC-601725	– 18.3	– 14.1
		CMS-302A × EC-601958	– 17.1	– 12.8
		CMS-2A × EC-601958	– 17.1	– 12.8
		CMS-302A × RHA-138-2	–15.9	– 11.5
	Highest	CMS-343A × R-101	–2.5	2.6
Plant height (cm)	Lowest	CMS-302A × EC-601958	– 30.0	–26.4
		PET-2-7-1A × EC-601725	– 29.1	–25.4
		CMS-302A × RHA-138-2	–25.1	–21.2
		CMS-2A × EC-601958	– 23.6	– 19.7
		PET-2-7-1A × R-272	–23.2	– 19.2
	Highest	CMS-343A × R-101	–2.5	2.6
Head diameter (cm)	Lowest	CMS-2A × NW - 31	–20.0	– 12.2
	Highest	ARM-249-1A × EC-601939	3.2	13.2
		CMS-16A × EC-603011	2.5	12.5
		PET-2-7-1A × EC-623011	– 1.9	7.6
Seed yield (kg/ha)	Lowest	CMS-850A × R-12-96	– 33.6	– 18.0
	Highest	ARM-249-1A × EC-601939	5.9	14.8
		PET-2-7-1A × EC-623011	2.5	11.1
		CMS-343A × R-101	1.4	9.9
		PET-2-7-1A × EC-601968	1.4	9.9
		P-89-1A × RHA-1-1	0.2	8.6
Seed filling (%)	Lowest	PET-2-7-1A × EC-601725	– 41.9	–43.0
	Highest	P-89-1A × RHA-1-1	5.4	3.4
		CMS-343A × R-101	4.8	2.8
		ARM-249-1A × EC-601939	4.2	2.2

Table 3. Continued..

Trait		Hybrid	SC-1 (LSFH-1)	SC-2 (DRSH-1)
100 seed weight (g)	Lowest	CMS-10A × EC-608220	– 12.5	–23.6
	Highest	PET-2-7-1A × EC-623011	41.7	23.6
		CMS-16A × EC-603011	25.0	9.1
		PET-2-7-1A × EC-601725	20.8	5.5
		CMS-343A × R-101	20.8	5.5
Hull cont %	Lowest	CMS-16A × EC-603011	– 15.0	– 18.7
		PET-2-7-1A × EC-601725	– 14.7	– 18.4
		CMS-343A × R-101	– 12.0	– 15.8
		CMS-2A × EC-601958	– 11.7	– 15.5
	Highest	PET-2-7-1A × EC-601968	16.5	11.5
Oil %	Highest	CMS-2A × EC-601958	13.7	–0.5
		P-89-1A ×RHA-1-1	13.1	– 1.0
		CMS-302A × EC-601939	12.5	– 1.6
		CMS-302A × RHA-138-2	12.5	– 1.6
		PET-2-7-1A × EC-601725	12.5	– 1.6
		CMS-302A × EC-601958	11.3	– 2.6
	Lowest	CMS-16A × EC-603011	5.4	– 7.8
Oil yield (kg/ha)	Highest	ARM-249-1A × EC-601939	10.8	8.8
		PET-2-7-1A × EC-623011	9.6	7.6
		P-89-1A × RHA-1-1	9.4	7.5
		CMS-343A ×R-101	9.2	7.3
		PET-2-7-1A × EC-601968	8.3	6.4
	Lowest	PET-2-7-1A × R-272	–7.7	– 9.4

302A ×RHA-138-2 (–11.5%) respectively.

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 exhibited significant negative heterosis over check-1 (KBSH-53). The range of economic heterosis over LSFH-17-1 from –30.1% (CMS-302A × EC-601958) to –2.5% (CMS-343A × R-101). Other four promising hybrids were PET-2-7-1A × EC-601725 (–29.1%), CMS-302A × RHA-138-2 (–25.1%), CMS-2A × EC-601958 (23.6%) and PET-2-7-1A × R-272 (–23.2%). The range of economic heterosis for plant height over DRSH-1 (check-2) from –26.4% (CMS-302A × EC-601958) to 2.6% (CMS-343A × R-101) and total 7 hybrids had registered significant negative heterosis. The cross combinations viz., CMS-302A × EC-601958 (–31.0%, –26.4%) PET-2-7-1A × EC-601725 (–29.1%, –25.4%), CMS-302A ×RHA-138-2 (–25.1%, –21.2%), CMS-2A ×EC-601958 (–23.6%, –19.7%) and PET-2-7-1A × R-272 (–23.2%, –19.2%) recorded highest significant negative heterosis over both the checks KBSH-53 and DRSH-1 for this trait respectively.

Head diameter (cm)

Significant and desirable (positive) economic heterosis for head diameter was observed in three cross combination. No hybrid manifested significant positive heterosis over check-1 (KBSH-53). The range of economic heterosis for check-2 (DRSH-1) was observed from –12.2% (CMS-2A × NW-31) to13.2% (ARM-249-1A × EC-601939). Top three promising hybrids recorded were ARM-249-1A × EC-601939 (13.2%), CMS-16A × EC-603011 (12.5%) and PET-2-7-1A × EC-623011 (7.6%) recorded as promising hybrid over DRSH-1.

100 seed weight (g)

The range of economic heterosis for over check-1 was –12.5% (CMS-10A × EC- 608220) to 41.7% (PET-2-7-1A × EC-623011). The estimate of economic heterosis revealed that four hybrids have manifested significant positive heterosis over check-1 (KBSH-

53). The cross combinations PET-2-7-1A ×EC-623011 (41.7%), CMS-16A × EC-603011 (25.0%), PET-2-7-1A ×EC-601725 (20.8%) and CMS-343A × R-101 (20.8%) were recorded as promising hybrids. In case of check-2 (DRSH-1), five hybrids exhibited significant positive economic heterosis for hull content. Four crosses viz., PET-2-7-1A × EC-623011 (41.7%, 23.6%), CMS-16A × EC-603011 (25.0%, 9.1%), PET-2-7-1A × EC-601725 (20.8%, 5.5%) and CMS-343A × R-101 (20.8%, 5.5%) recorded highest significant positive heterosis over both checks KBSH-53 and DRSH-1 for this trait respectively.

Hull content (%)

The perusal of data revealed that the range of economic heterosis over KBSH-53 was 15.7% (CMS-16A × EC-603011) to 16.5% (PET-2-7-1A × EC-601968) and five hybrids registered significant negative heterosis over check-1 (KBSH-53). The estimate of economic heterosis revealed that five hybrids have manifested significant negative heterosis over KBSH-53 viz., CMS-16A × EC-603011 (–15.7%), PET-2-7-1A × EC-601725 (–14.7%), CMS-343A × R-101 (–12.0%) and CMS-2A × EC-601958 (–11.7%) respectively. The range of economic heterosis over DRSH-1 was –18.7% (CMS-16A × EC-603011) to 11.5% (PET-2-7-1A × EC-601968) and five hybrids viz., CMS-16A × EC-603011 (–18.7%), PET-2-7-1A × EC 601725 (–18.4%), CMS-343A × R-101 (–15.8%) and CMS -2A × EC-601958 (–15.5%) have manifested significant negative heterosis viz., over check-1 (DRFH-1).

Oil content (%)

The perusal of data revealed that the range of economic heterosis over check-1 (KBSH-53) was 5.4% (CMS-16A × EC-603011) to 13.7% (CMS-2A × EC-601958) along with 15 hybrids having significant positive economic heterosis over KBSH-53. The cross combinations viz., CMS-2A × EC-601958 (13.7%), P-89-1A × RHA-1-1 (13.1%), CMS-302A ×EC601939 (13.1%), PET-2-7-1A × EC-601725 (12.5%) and CMS-302A × EC-601958 (12.5%) were the promising hybrids in regards to seed oil content. The range of economic heterosis over DRSH-1 was –7.8% (CMS-16A × EC-603011) to –0.5% (CMS-2A ×EC-601958) percent but no one recorded significant positive economic heterosis over check-2 (DRSH-1) in regards to seed oil content.

For oil yield (kg/ha), the range of significant heterosis over KBSH-53 was observed from –7.7% (PET-2-7-1A × R-272) to 10.80% (ARM-249-1A × EC-601939). ARM-249-1A × EC-601939 along with the five hybrids PET-2-7-1A ×EC-623011 (9.6%), P-89-1A × RHA-1-1 (9.4%), CMS-343A × R-101 (9.2%) and PET-2-7-1A × EC-601968 (8.3%) having significant positive economic heterosis over KBSH-53 for oil yield, whereas, the range of significant heterosis for oil yield over DRSH-1 was –9.4% (PET-2-7-1A ×R-272) to 8.80% (ARM-249-1A × EC-601939). The cross combination viz., ARM-249-1A × EC-601939 (10.8%, 8.8%) along with the four hybrids PET-2-7-1A × EC-623011 (9.6%, 7.6%), P-89-1A × RHA-1-1 (9.4%, 7.5%), CMS-343A × R-101 (9.2%, 7.3%) and PET-2-7-1A × EC-601968 (8.3%, 6.4%) recorded highest significant heterosis over both the checks KBSH-53 and DRSH-1 for oil yield (kg/ha).

Prevalence of significant standard heterosis for seed yield has also been reported by Manivannan 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. (2015), Supriya et al. (2017), Jondhale et al. (2012). 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). 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 Tyagi et al. (2016), Lakshman et al. (2018).

Parameshwarappa et al. (2008), Mohanasundaram et al. (2010) noticed the standard heterosis of for seed yield and for oil content. 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. (2015), 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. (2013), 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. Similar findings were reported by Tyagi et al. (2016). 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 Nandini et al. (2013), Tyagi et al. (2016), Lakshman et al. (2018).

CONCLUSION

From the study it may be concluded that the cross combination viz., ARM-249-1A × EC-601939 along with the four hybrids PET-2-7-1A × EC-623011, P-89-1A × RHA-1-1, CMS-343A × R-101 and PET-2-7-1A ×EC-601968 recorded highest significant heterosis over both the checks KBSH-53 and DRSH-1 for oil yield (kg/ha). All the above hybrids have manifested significant positive heterosis over both the standard checks, i.e. KBSH-53 and DRSH-1 for oil yield (kg/ha). Therefore, the above said sunflower hybrids 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.

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