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Identification of Crosses Heterotic over Standard Check for Earliness and High Oil Content in Sunflower (*Helianthus annuus* L)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

To estimate the extent of heterosis in sunflower for earliness and oil content, ninety-six hybrids were tested in line × tester mating fashion consisting of six CMS lines and sixteen testers (10 R × R S_3 high oil content restorer lines and 6 R × R S_4 early restorer lines) were evaluated in a simple lattice design, simultaneously parents were also evaluated in RCBD design at Main Agricultural Research Station, Hebbal, Bangalore during summer 2020-21. Analysis of variances revealed that the genotypes, parents, lines, crosses and parent *vs* crosses showed highly significant differences for earliness and oil content. The high oil content hybrids *viz.,* CMS 903A × 5-2-1 (79.50 days) and CMS 903A × 44-2-1 (80 days), and early hybrids *i.e.,* CMS 903A × 2-3-1-2 (76 days) and NDCMS4A × 2-3-1-2 (78.50 days) recorded good mean performance and high significant heterosis for earliness in a negative direction over the standard check KBSH-44 (National check). With regard to the oil content, the high oil content hybrids like NDCMS2A × 30-10-1 (41.63%), CMS 903A × 38-4-1 (41.61%) and CMS 234A × 38-4-1 (41.61%), in the case of early hybrids *viz.,* CMS 911A × 25-2-4-2 (41.11%), CMS 911A × 4-1-3-1 (39.69%) and CMS 911A × 2-3-1-2 (39.59%) were showed good mean performance and highest significant standard heterosis over the standard checks like KBSH-44 and KBSH-53. Similarly, regarding the seed yield plant^{-1} (g), the hybrids *viz.,* CMS 911A ×

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8-5-5-1[E] (70.60g), CMS 234A × 31-1-1[H] (66.20g) and CMS 1103A × 30-10-1[H] (65.95g) were manifested desirable mean performance and also higher significant heterosis over standard check KBSH-44.

Keywords: Combining ability; heterosis; hybrids; sunflower.

1. INTRODUCTION

Sunflower (*Helianthus* spp.) is one of the major vegetable oil sources in the world belonging to Asteraceae family with 2n=2x=34 chromosomes. It is originated in North America and largely grown in Ukraine, Russia, European Union, Argentina, China and India. It is an important source of edible and nutritious oil (about 38-50% by composition) and is a rich source of linoleic acid and oleic acid which helps to remove cholesterol deposition in the coronary arteries and thus is good for heart patients [1].

Sunflower is an all-season crop, cultivated throughout the world and is ranked fourth among edible vegetable oilseed crops in terms of acreage and production. In India, it is cultivated in an area of 2.28 lakh ha with a production of 2.13 lakh tonnes and the productivity of 931 kg/ha. Karnataka contributes an area of about 1.29 lakh ha with the production of 1.03 lakh tonnes and productivity is about 802 kg/ha [2].

Development of a heterotic hybrid is one of the objectives of the most sunflower breeding programs worldwide. The significant landmark in Sunflower hybrid breeding was started economically after the finding of Cytoplasmic Male Sterility by Leclercq in 1969 [3] and identification of the gene for the fertility restoration by Kinman (1970) [4], which brings the interest from population breeding to heterosis breeding [5].

The development of heterosis leads to the recognition of pollination control systems like, Cytoplasmic- nuclear Genetic Male Sterility system (CGMS). CGMS system is now generally known as PET 1 CGMS system. In India the first CGMS-based sunflower hybrid *viz.,* BSH-1 was developed and released for commercial production in 1980 [6].

One of the most effective methods to inflate the yield of sunflower is through utilization of heterosis by using three-line hybrids. The performance of a heterotic hybrid is dependent on combining ability of its parents [7] and [8]. Kaya and Atakisi (2004), stated that superior hybrids were developed by crossing inbred CMS (female) lines with restorer lines which has higher values of General Combining Ability (gca) and Specific Combining Ability (sca) [9].

A hybrid sunflower breeding system that could measure the gca of parental lines and sca of the hybrids at an early stage in their development would clearly be useful. An early generation testing system enables plant breeders to discard most undesirable inbreds and saves substantial resources in terms of time, labor and resources, and also helps in the identification and production of superior hybrids [10], [11] and [12]. The development of a higher frequency of heterotic CMS-based hybrids for commercial development is dependent on the availability of a large quantity of fertility- restorer lines (R-lines). Heterosis is explained as the advantage of F_1 hybrids over their inbred parents involved in the crosses. The main requirement of a model hybrid is to identify parental lines and combine their desirable genes to produce better F_1 hybrids.

Keeping this in view, the current study was undertaken to assess heterotic effects of ninety-six newly developed F_1 sunflower hybrids and to identify the heterotic crosses over the standard check for earliness and high oil content.

2. MATERIALS AND METHODS

Six CMS lines and 16 testers (10 R × R S_3 high oil content and 6 R ×R S_4 early restorer lines) were sown in the field to effect crossing in a Line × Tester fashion (Kempthorne, 1957) [13] during late *kharif* 2020 in order to obtain F_1's at the experimental plot of Zonal Agricultural Research Station, UAS, GKVK, Bengaluru. The resultant 96 F_1 hybrids along with four check hybrids (KBSH-44, KBSH-53, KBSH-78 and RSFH-1887) were evaluated using a simple lattice design (10×10 involving hybrids and checks) with two replications during summer 2020-21. While 22 parental lines were evaluated following RCBD with two replications during summer 2020-21 at the experimental plot of Main Agricultural Research Station, Hebbal, Bengaluru. Each genotype was sown in two rows of 3-meter length with a spacing of 60 cm between rows and

30 cm between plants within a row. All the recommended agronomic practices were followed for raising a crop under protective irrigation. Observations were recorded in each entry on randomly selected five plants for ten characters *viz*; days to 50% flowering, days to maturity, plant height (cm), head diameter (cm), stem diameter (cm), volume weight (g/100 ml), seed yield plant^{-1} (g), 100 grain weight, oil content (%) and oil yield plant^{-1}(g). The mean values of the inbred lines and F_1 hybrids were used to calculate the values of the combining abilities and assess the gene effects for morpho-physiological and yield traits using the line × tester method [14]. Utilization of standard heterosis is important for the commercial development of hybrids.

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance for Combining Ability

The variance due to crosses was recorded highly significant for all the characters under study (Table 1). The variances due to lines were significant for days to 50% flowering, days to maturity, head diameter and 100 seed weight. Variances due to testers were significant for all the traits. The line × tester interaction variance. was highly significant for all the. traits under the study. It was evident that the variance due to lines, testers, line × tester interaction showed significant for the. most of the traits. The significance due to line × tester variance specified the presence of heterosis possible for the individual traits was also described by Nehru et al. [15], Mohanasundaram et al. [16], Nandini [17], Meena et al. [18], Singh and Kumar [19], Budihal [20] and Divya [21].

3.2 Perse Performance of Parents and Hybrids

The prime basis of selection is based on the parental as well as hybrid *per se* performance. The results of *per se* performances of parents and hybrids along with checks highlight the seed parent *i.e.,* the line CMS 234 B recorded highest seed yield plant^{-1} about 30 g plant^{-1} and NDCMS 4B had documented the highest oil content of 38.37%. Among the high oil content testers, 31-1-1 [H] was better performing for head diameter, stem diameter, seed yield plant^{-1} and volume weight and for early maturing testers, 21-9-5-2 [E] was found to be good performing for head diameter, stem diameter, seed yield plant^{-1}, 100 seed weight, volume weight (g/100ml) and oil content.

The high oil content hybrids *viz.,* CMS 903A × 5-2-1 (79.50 days) and CMS 903A × 44-2-1 (80 days), whereas early hybrids *i.e.,* CMS 903A × 2-3-1-2 (76 days) and CMS 1103A × 2-3-1-2 (77 days) were recorded highest mean performance for days to 50% flowering and days to maturity.

With regard to the seed yield, CMS 911A × 8-5-5-1 [E] (70.60 g plant^{-1}), CMS 234A × 31-1-1 [H] (66.20 g plant^{-1}), CMS 1103A × 30-10-1 [H], NDCMS 4A × 30-10-1 [H] and NDCMS 2A × 30-10-1[H] crosses were recorded highest seed yield plant^{-1}. Whereas, NDCMS2A × 30-10-1 [H] had documented the highest oil content of 41.63% followed by CMS 903A × 38-4-1 [H] (41.61%) and CMS 234A × 38-4-1 [H] (41.41%). In reference to the early hybrids, CMS 911A × 25-2-4-2 [E] recorded the highest oil content about 41.11%.

3.3 Heterosis

Heterosis is the increase or decrease of vigour in F_1 over its mid or better parental value. The superiority of F_1 over best commercial check is commonly called standard heterosis. Standard heterosis plays an important role in the commercial development of hybrids over their checks.

3.3.1 Standard heterosis

The current task was to develop crosses to maintain the yield level of the National check, KBSH 44 and oil content near or above that of KBSH-53 (Local check) and KBSH-78 (Early check hybrid). Heterosis of 96 crosses were noticed for seed yield and its attributing traits and indicated as *per cent* decrease or increase over the check hybrids *viz*., KBSH-44, KBSH-53 and KBSH-78. The top high oil content and early hybrids based on estimates of standard heterosis was delineated in Table 2.1, 2.2 and 2.3. The outcome regarding the standard heterosis of crosses were briefed below.

3.3.2 Days to 50% flowering

All the 96 hybrids in the investigation recorded significant heterosis in negative direction over KBSH-44 for the trait days to 50% flowering. Among the high oil content hybrids, CMS 903A × 5-2-1 [H] showed the highest significant negative heterosis with -20.16% over standard check

KBSH- 44 followed by CMS 903A× 44-2-1 [H] (-19.35%) and CMS 903A × 34-3-1 [H] (-19.35%) which exhibited significant heterosis in negative direction. Among the early hybrids, CMS 903A × 2-3-1-2 [E] manifested high significant heterosis of -25.81% over the standard check, KBSH-44 subsequently NDCMS 4A × 2-3-1-2 [E] (-24.19%) and CMS 1103A× 2-3-1-2 [E] (-23.39%).

3.3.3 Days to maturity

All 96 hybrids in the experiment exhibited significant heterosis in negative direction for the trait days to maturity and none of the hybrids were showed significant positive heterosis over the check KBSH-44. The high oil content hybrids, CMS 903A × 5-2-1 [H] showed desirable heterotic crosses over National check, KBSH-44 as it recorded the highest significant negative heterosis of -13.59% subsequently CMS 903A × 44-2-1 [H] (-13.04%). With reference to the early hybrids, CMS 903A × 2-3-1-2 [E] was found to be standard heterosis as it showed significant negative heterosis of -17.39% followed by NDCMS 4A × 2-3-1-2 [E] (-16.30%) and CMS 1103A× 2-3-1-2 [E] (-15.80%).

3.3.4 Plant height (cm)

Among the 96 hybrids, 78 cross combinations showed significant negative heterosis. With regard to the high oil content hybrids, CMS 1103A × 34-3-1 [H] exhibited high significant negative heterosis of -27.86% over standard check KBSH-44. In case of early hybrids NDCMS 4A × 39-6-5-1 [E] recorded highest significant negative heterosis with -24.50% over standard check KBSH-44.

3.3.5 Head diameter (cm)

Of the 96 crosses, only nine cross combinations displayed significant heterosis over KBSH-44 in desirable direction among which the high oil content hybrids of CMS 911A × 31-1-1 [H] noticed highest significant positive heterosis of 16.50%. With regarding the early hybrids, CMS 911A × 21-9-5-2 [E] manifested desirable heterosis for head diameter as it noted high significant heterosis of 32.69%.

3.3.6 Stem diameter (cm)

Only two high oil content hybrids out of 96 cross combination showed significant heterosis *i.e.,* CMS 1103A × 30-10-1[H] had recorded the highest significant positive heterosis of 7.24%. and only one early hybrid *i.e.,* CMS 911A × 21-9-5-2 [E] showed significant positive heterosis with 7.14% over the check KBSH-44.

3.3.7 Seed yield plant^{-1} (g)

Out of 96 hybrids, 56 cross combinations recorded significant positive heterosis, among which the high oil content hybrids of CMS 234A × 31-1-1 [H] has shown highest significant positive heterosis with 53.24% over the National check KBSH-44, subsequently CMS 1103A × 30-10-1[H] (52.66%) and NDCMS4A × 30-10-1 [H] (50.69%). While, NDCMS 4A × 39-2-1 [H] noticed highest significant negative heterosis of -46.30%. In reference to the early hybrids, CMS 911A × 8-5-5-1 [E] noted highest significant positive heterosis with 63.43% followed by CMS 234A × 8-5-5-1 [E] (41.90%) and CMS 234A X 2-3-1-2 [E] (40.74%). The significant positive heterosis of crosses based on diverse CGMS system over the check KBSH-44 was also studied by Ambati (2010) [22] and Nandini (2013) [17].

3.3.8 Volume weight (g/100 ml)

Among the 96 hybrids only eight high oil content cross combination showed good heterosis, out of which CMS 234A × 31-1-1 [H] had recorded high significant positive heterosis of 21.59% over the National check KBSH-44 and only nine early hybrids manifested the highest significant positive heterosis of which CMS 234A × 2-3-1-2 [E] (18.82%) observed desirable heterosis over the check KBSH-44.

3.3.9 Hundred seed weight (g)

There were only 7 cross combinations out of 96 hybrids which exhibited better heterosis over the National check KBSH-44. The high oil content hybrids, CMS 903A × 30-10-1 [H] had the highest significant positive heterosis of 55.73%. With regard to the early hybrids, only four hybrids among which CMS 1103A × 8-5-5-1 [E] had the highest significant positive heterosis of 31.42% over the check KBSH-44.

3.3.10 Oil content (%) and oil yield plant^{-1}(g)

Among the 96 hybrids, eighty-nine crosses exhibited significant positive heterosis over the National check KBSH-44. While, only four crosses and forty-seven crosses were recorded significant positive heterosis over the local

Table 1. Analysis of variance for combining ability

		Mean sum of squares								
Source of variation	**Df**	**Days to 50% flowering**	**Days to maturity**	**Plant Height (cm)**	**Head Diameter (cm)**	**Stem Diameter (cm)**	**Seed yield plant^{-1} (g)**	**Volume Weight (g/100ml)**	**100 seed weight (g)**	**Oil content (%)**
Replication	1	0.75	0.63	0.10	5.13 **	0.05	14.21	41.76 ***	0.78	1.96 ***
Crosses	95	10.53 ***	10.71 ***	356.83 ***	3.73 ***	0.10 ***	155.01 ***	28.71 ***	1.65 ***	7.14***
Line Effect	5	11.52 **	13.21 ***	323.46	18.67***	0.14	152.52	43.96	7.94***	9.14
Tester Effect	15	49.64***	49.63 ***	1169.26***	6.12**	0.24 ***	378.26***	61.43 **	2.96 ***	12.71 *
Line × Tester Effect	75	2.64 ***	2.76***	196.58***	2.26 ***	0.07 ***	110.52 ***	21.15 ***	0.97***	5.89***
Error	95	0.92	0.95	6.52	0.67	0.02	9.01	3.55	0.35	0.07
Total	191	5.70	5.80	180.72	2.22	0.06	81.65	16.27	1.0	3.60

** Significant @ P=0.05 **Significant @ P=0.01 *** Significant @ P=0.001*

Table 2.1. Top five high oil content and early hybrids based on estimates of standard heterosis (%) for seed yield plant^{-1}

Hybrid combination	**Mean seed Yield plant^{-1} (g)**	**Standard Heterosis (%) over KBSH-44**	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Head diameter (cm)**	**Stem diameter (cm)**	**Volume weight (g/100ml)**	**100 seed weight (g)**	**Oil content (%)**	**Oil yield plant^{-1} (g)**
CMS 234A × 31-1-1 [H]	66.20	53.24 **	-16.94**	-11.41**	-4.3**	1.29	-5.36	21.59**	27.22**	8.69**	66.62**
CMS1103A × 30-10-1 [H]	65.95	52.66 **	-16.13**	-10.87**	-23.76**	0.78	7.14	-4.77	4.05	6.54**	62.52**
NDCMS4A × 30-10-1 [H]	65.10	50.69 **	-18.55**	-12.50**	-5.01**	3.88	-12.50	5.76	4.28	10.45**	66.44**
NDCMS2A × 34-3-1[H]	63.60	47.22 **	-18.55**	-12.50**	-5.75**	3.88	-15.85*	3.31	-5.66	6.44**	56.70**
NDCMS2A × 27-2-1 [H]	63.50	46.99 **	-15.32**	-1.33**	-14.76**	-0.84	-14.7*	-1.23	-6.35	16.68**	71.55**
CMS 911A × 8-5-5-1 [E]	70.60	63.43**	-16.13**	-11.96**	-7.52**	14.24**	-12.28	10.49*	-0.92	9.54**	79.06**
CMS 234A × 8-5-5-1 [E]	61.30	41.90**	-17.74**	-11.96**	-20.57**	-13.92*	-25.89**	14.13**	-2.91	9.07**	54.84**
CMS 234A × 2-3-1-2 [E]	60.80	40.74**	-22.58**	-15.22**	-11.68**	-10.36	-17.86**	18.82**	2.68	11.04**	56.30**
CMS 903A × 2-3-1-2 [E]	60.64	40.36**	-25.81**	-17.39**	-9.57**	5.15	-7.14	9.04*	18.58*	9.37**	53.55*
CMS 911A × 21-9-5-2 [E]	60.25	39.47**	-18.55**	-12.50**	-5.19**	32.69**	7.14	3.59	5.73	10.98**	54.79**
SEM±	0.90	2.78	1.02	1.02	2.59	0.83	0.14	1.97	0.60	0.30	104.12
CD at P=0.05	2.49	5.52	2.02	2.03	5.14	1.65	0.29	3.92	1.19	0.60	206.70
CD at P=0.01	3.27	7.31	2.68	2.69	6.80	2.19	0.38	5.19	1.57	0.79	273.68

Table 2.2. Top five high oil content & early hybrids based on estimates of standard heterosis (%) for Oil content (%)

Hybrid combination	Mean oil content (%)	Standard heterosis (%) over KBSH-44 (NC)		Standard heterosis over KBSH-53 (LC)		Standard heterosis over KBSH-78 (LC)	
		Oil content	Oil yield	Oil content	Oil yield	Oil content	Oil yield
NDCMS 2A × 30-10-1 [H]	41.63	22.06**	58.87 **	3.06**	51.65 **	11.97**	13.40 **
CMS 903A × 38-4-1 [H]	41.61	22.01**	-6.77	3.01**	-11.01	11.92**	-33.45 **
CMS 234A × 38-4-1 [H]	41.41	21.43**	19.74 **	2.53**	14.30 *	11.39**	-14.53 **
CMS 1103A × 38-4-1[H]	40.70	19.34**	17.97 *	0.76	12.61	9.47**	-15.79 **
NDCMS 4A × 31-1-1[H]	40.02	17.33**	70.30 **	-0.94	62.56 **	7.63**	21.56 **
CMS 911A × 25-2-4-2[E]	41.11	20.54**	38.43 **	1.77*	32.13 **	10.57**	-1.19
CMS 911A× 4-1-3-1[E]	39.69	16.36**	57.33 **	-1.76*	50.17 **	6.74**	12.30 *
CMS 911A × 2-3-1-2 [E]	39.59	16.07**	39.74 **	-2.01**	33.39 **	6.47**	-0.25
CMS 911A × 39-6-5-1 [E]	39.45	15.67**	29.10 **	-2.34**	23.23 **	6.11**	-7.85
CMS 903A × 25-2-4-2 [E]	39.10	14.65**	33.51 **	-3.21**	27.44 **	5.16**	-4.70
SEM±	0.19	0.30	104.12	0.30	104.12	0.30	104.12
CD at P=0.05	0.53	0.60	206.70	0.60	206.70	0.60	206.70
CD at P=0.01	0.70	0.79	273.68	0.79	273.68	0.79	273.68

*[H]: High oil content hybrids [E]: Early hybrids; * Significant @ P=0.05 **Significant @ P=0.01 *** Significant @ P=0.001*

Table 2.3. Top five high oil content & early hybrids based on estimates of standard heterosis (%) for earliness

Hybrid combination	Days to 50% flowering Mean	Days to Maturity Mean	Standard heterosis (%) over KBSH-44 (NC)		Standard heterosis over KBSH-53 (LC)		Standard heterosis over KBSH-78 (LC)	
			Days to 50% flowering	Days to maturity	Days to 50% flowering	Days to maturity	Days to 50% flowering	Days to maturity
CMS 903A × 5-2-1 [H]	49.50	79.50	-20.16**	-13.59%	-24.43**	-16.75**	-10.00**	-6.47**
CMS 903A × 44-2-1 [H]	50.50	80.00	-19.40**	-13.04%	-23.70**	-16.23**	-9.09**	-5.90**
CMS 903A × 34-3-1 [H]	50.00	81.00	-19.35**	-13.03**	-23.66**	-16.21**	-9.08**	-5.88**
CMS 234A × 44-2-1 [H]	50.00	80.50	-19.34**	-13.02**	-23.64**	-16.20**	-9.07**	-5.85**
CMS 911A × 34-3-1[H]	50.50	81.00	-18.55**	-12.50**	-22.90**	-15.71**	-8.18**	-5.29**
CMS 903A × 2-3-1-2 [E]	46.00	76.00	-25.81**	-17.39%	-29.77**	-20.42**	-16.36**	-10.29**
NDCMS 4A × 2-3-1-2 [E]	47.00	78.50	-24.19**	-16.30**	-28.24**	-19.37**	-14.55**	-9.41**
CMS 1103A× 2-3-1-2 [E]	47.50	77.00	-23.39**	-15.80**	-27.50**	-18.90**	-13.66**	-8.83**
NDCMS 2A × 2-3-1-2 [E]	47.50	77.50	-23.39**	-15.76**	-27.48**	-18.85**	-13.64**	-8.82**
CMS 911A × 2-3-1-2 [E]	48.00	78.00	-22.58**	-15.22**	-26.72**	-18.32**	-12.73**	-8.24**
CD at P=0.05	4.42	0.68	2.02	2.03				
CD at P=0.01	5.81	0.90	2.68	2.69				

*[H]: High oil content hybrids [E]: Early hybrids; * Significant @ P=0.05 **Significant @ P=0.01 *** Significant @ P=0.001*

checks, KBSH-53 and KBSH-78 respectively. The high oil content hybrids of NDCMS 2A × 30-10-1 [H] had noticed highest significant positive heterosis over three checks KBSH-44, KBSH-53 and KBSH-78 with 22.06%, 3.06% and 11.97% respectively, followed by CMS 903A × 38-4-1[H] (22.01%, 3.01% and 11.92%) and CMS 234A × 38-4-1 [H] (21.43%, 2.53% and 11.39%). With respect to the early hybrids, only CMS 911A × 25-2-4-2[E] showed significant positive heterosis over three checks with 20.54%, 1.77% and 10.57%, respectively. While, CMS 911A × 4-1-3-1[E] and CMS 911A × 2-3-1-2 [E] had only significant positive heterosis over the National check KBSH-44 and local check KBSH-78 (Table 2.2).

Out of 96 cross combination, seventy-two hybrids had significant positive heterosis for oil yield plant^{-1}(g) over National check KBSH-44. Whereas, sixty-four cross combinations showed significant positive heterosis for oil yield plant^{-1}(g) over local check KBSH-53. Among the high oil content hybrids, NDCMS 2A × 27-21[H] exhibited highest significant positive heterosis over standard check KBSH-44 and KBSH-53 with 71.55% and 63.75% respectively, subsequently NDCMS 4A × 31-1-1[H] (70.30%, 62.56%) and CMS 234A × 31-1-1[H] (66.62%, 59.05%). With regards to the early hybrids, CMS 911A × 8-5-5-1[E] manifested highest positive significant heterosis over both the checks *viz.,* KBSH-44 and KBSH-53 with standard heterosis values of 79.06% and 70.93%, respectively, followed by CMS 911A × 4-1-3-1[E] (57.33%, 50.17%) and CMS 234A × 2-3-1-2[E] (56.30%, 49.20%).

Most of the hybrid combinations registered significance for earliness compared to standard checks. The cross combination based on tester 2-3-1-2[E] as a male parent expressed higher standard heterosis across the seed parents. Similar results were reported by Sunitha (2015) [23]. The high oil content hybrids of CMS 903A × 5-2-1 [H] showed to derive short days to 50 % flowering as well as early to mature followed by CMS 903A × 44-2-1 [H] and CMS 903A × 34-3-1 [H]. With reference to the early hybrids, CMS 903A × 2-3-1-2 [E] exhibited early flowering and early maturity over the standard check KBSH-44. While, for the oil content NDCMS 2A × 30-10-1 [H] and CMS 911A × 25-2-4-2[E] were found to be desirable heterotic crosses over three checks *viz.,* KBSH-44, KBSH-53 and KBSH-78.

As far as standard heterosis is concerned for oil content, eighty-nine crosses exhibited higher standard heterosis over the National check KBSH-44 and only four crosses and forty-seven crosses were recorded significant positive heterosis over the local checks KBSH-53 and KBSH-78. Attaining higher standard heterosis for seed yield, oil content and most of the yield attributing traits in the experimental hybrids with the use of CMS line derived from PET1 have also been made by Ambati [22], Meena et al. [18], Nandini [17] and Tyagi [24].

The maximum exploitation of heterosis is possible when the variance due to both additive and non-additive gene actions are fully utilized since they play an important role in establishing the magnitude of expression of yield and its component traits. The values regarding standard heterosis of CMS lines-based crosses exhibited varied extent of magnitude and direction of heterosis for the hybrids for each character. Similar observations were made by Nandini [17] and Dhillon and Tyagi [25].

4. CONCLUSION

Among the resultant 96 hybrids, CMS 903A × 5-2-1[H] (79.50 days), CMS 903A × 44-2-1[H] (80 days), CMS 903A × 2-3-1-2[E] (76 days) and NDCMS4A × 2-3-1-2[E] (78.50 days) recorded good mean performance and high significant heterosis for earliness in negative direction over the standard check KBSH-44 (National check). With regard to the oil content, NDCMS2A × 30-10-1[H] (41.63%), CMS 903A × 38-4-1[H] (41.61%), CMS 911A × 25-2-4-2[E] (41.11%) and CMS 911A × 4-1-3-1[E] (39.69%) showed good mean performance and highest significant standard heterosis over the standard checks like KBSH-44 and KBSH-53. Similarly, with reference to the seed yield plant^{-1} (g), the hybrids *viz.,* CMS 911A × 8-5-5-1[E] (70.60g), CMS 234A × 31-1-1[H] (66.20g) and CMS 1103A × 30-10-1[H] (65.95g) manifested desirable mean performance and also higher significant heterosis over standard check KBSH-44. Hence, these crosses are required for their superiority by extensive testing like multi-location trials.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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