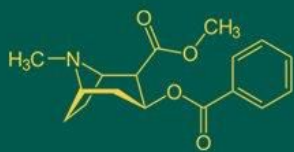


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## Heterotic response of hybrids for yield and its contributing characters in sunflower (*Helianthus annuus* L.)

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### Abstract

The prevailing investigation was undertaken with the goals to study the heterosis for seed yield and its components traits in sunflower. Six female lines were crossed with eight male lines in order to obtain 48 F<sub>1</sub>s. The crosses and parents with checks, have been evaluated in a Randomized Block design with two replications, at experimental farm at Oilseeds research station, Latur. Data had been recorded on ten characters. The analysis of all the characters under study indicated significant differences among the genotypes, parents, hybrids and parent's *vs* hybrids which indicated the presence of substantial genetic variability among the genotypes for the characters studied. The hybrids *viz.*, CMS-47 A x EC-601924, CMS-112 A x AKSF-15R, CMS-47 A x AKSF-15R, CMS-112 A x EC-601924 and CMS-47 A x R-274 recorded excessive significant heterosis in desirable direction over both standard check LSFH-171 and KBSH- 44 for yield and yield component traits.

**Keywords:** Sunflower, heterosis, mid parent heterosis, better parent heterosis

### Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crops in the world and ranked third after soybean and rapeseed in the production of oil globally. Earlier it was domesticated as a food crop in North America but commercial cultivation of sunflower started in 1969 after its introduction from former USSR. Because of its light-yellow colour, pleasant flavour, high level of linoleic acid (55-60%), low oleic acid (25-30%), fairly high oil content of poly unsaturated fatty acids (PUFA) and absence of linolenic acid, it is considered as premium source of oil compared to the other vegetables oils (Atlagic, 1996) [5]. It contains vitamin K and E (Anonymous, 2021) [2]. During the year 2020-21 area under sunflower cultivation in India was 218.18 lakh ha with production of 365.65 lakh tonnes and productivity of 1269 kg/ha. In Maharashtra area under sunflower cultivation was 0.02 million ha with production of about 0.01 million tonnes and average productivity of 507 kg/ha. (Anonymous, 2021) [1]. With the increase in demand for edible oils, there is need to develop new sunflower hybrids suited to different agro-climatic zones of Maharashtra with improved seed yield and oil content. The phenomenon of heterosis is directly related to hybrid Vigour which in turns plays an important role in the expression of seed yield. In view of the above facts, the present study was undertaken to estimate the average heterosis, heterobeltiosis and standard heterosis for seed yield and yield contributing characters.

### Materials and Methods

Six CMS lines *viz.*, DSF-2 A, CMS-148 A, CMS-47 A, CMS-597 A, CMS-103 A, CMS-112 A and eight restorer lines *viz.*, RHA-1055, EC-601951-1, EC-601924, R-274, LTRR-341, AKSF-15R, BK-R-1, R-856 were planted during *Kharif*-2023 at Oilseeds Research Station, Latur and crossing was performed in line x tester fashion to produce 48 hybrids. During evaluation, the 48 hybrids along with their parents and two standard checks *viz.*, LSFH-171 and KBSH-44 were evaluated in a Randomized Block Design replicated twice during *Rabi* 2023-2024.

Observations were recorded for ten quantitative characters in each entry on randomly selected five plants *viz.* plant height (cm), head diameter (cm), seed filling (%), 100 seed weight, volume weight (g/100 ml), hull content (%) oil content (%) and seed yield per plant

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(g) except days to 50 per cent flowering and days to maturity which were recorded on plot basis. Data obtained were subjected to line x tester analysis. Heterosis for various traits was estimated as percent increase or decrease of the hybrid over best standard check as per the procedure suggested by Fonesca and Patterson (1968) [7].

## Results and Discussion

The analysis of variance for various characters under study is presented in Table 1. The variation among treatments was highly significant for all of the characters. This indicates presence of substantial genetic variability for the characters studied. The parents revealed highly significant variation for plant height, seed filling and seed yield per plant. The hybrids revealed highly significant variation for all the characters under study. The comparison of parent vs hybrids showed significant differences for all the characters except days to maturity, hull content and oil content.

The highest range of mid parent heterosis in hybrids from CMS-47 A x EC-601951-1 (8.86%) to CMS-47 x RHA-1055 (-8.33%) for days to 50 per cent flowering was noticed with seventeen hybrids showing significant negative heterotic values, whereas positive substantial heterosis was observed in six hybrids above mid parent. Twenty-eight hybrids showed significant negative heterobeltiosis and it was ranged from (-11.36%) CMS-597 A x R-274 to (8.4%) CMS-47 A x EC-601951-1. Based on the best check LSFH-171, the standard heterosis ranged from CMS-47 A x RHA-1055 (-12%) to CMS-112 A x R-856 (4.8%). In comparison to the best check LSFH-171, the crosses CMS-47 A x RHA-1055 (-12%) followed by CMS-47 A x R-274 (-9.60%), DSF-2 A x RHA-1055 (-8.80%) and CMS-112 A x RHA-1055 (-8.8%) showed desirable negative standard heterosis.

For days to maturity, range of mid parent heterosis among crosses varied from CMS-103 A x R-274 (-2.59%) to CMS-47 A x BK-R-1 (2.61%) with five crosses displaying significant negative heterosis for days to maturity. The range of heterobeltiosis was CMS-103 A x R-274 (-2.87%) to CMS-47 A x BK-R-1 (1.72%). None of the cross showed positively significant heterobeltiosis. The four crosses were represented negatively significant heterobeltiosis. Standard heterosis over check LSFH-171 ranged from CMS-103 A x R-274 (-6.11%) to CMS-112 A x R-856 (-1.67%) and over check KBSH-44 ranged from (-5.06%) CMS-103 A x R-274 to (-0.56%) CMS-112 A x R-856. The high heterotic early maturity hybrids CMS-103 A x R-274 (-6.11, -5.06), DSF-2 A x R-274 (-5, -3.93) and CMS-47 A x R-274 (-4.44, -3.37) showed considerable negative heterosis when compared to both LSFH-171 and KBSH-44 checks.

For plant height, none of the cross showed negative mid parent heterosis and it ranged from CMS-112 A x R-274 (13.69%) to CMS-47 A x EC-601924 (54.24%). The heterobeltiosis ranged from CMS-112 A x R-274 (-1.21%) to CMS-47 A x EC-601924 (41.7%). Not a single cross showed negative significant heterobeltiosis. Among all 48 hybrids, 43 crosses revealed positive significant heterosis over better parent. Standard heterosis range over the check LSFH-171 was CMS-103 A x RHA-1055 (-30.82%) up to CMS-597 A x LTRR-341 (2.57%). Likewise, heterosis over best check KBSH-44 ranged from CMS-103 A x RHA-1055 (-13.07%) to CMS-597 A x LTRR-341 (28.88%).

For head diameter, positive heterosis is preferred. The heterosis over mid parent ranged from CMS-597 A x R-856 (92%) to CMS-112 A x BK-R-1 (-13.51%). Total forty crosses expressed positive significant heterosis over mid parent. Not a single cross showed negative heterosis and 40 crosses recoded positively significant mid parent heterosis. The range of heterobeltiosis estimated was CMS-597 A x R-856 (77.78%) up to CMS-112 A x BK-R-1 (-14.29%). Twenty-four positively significant and zero negatively significant heterotic crosses were found over better parent. The heterosis over best check LSFH-171 ranged from DSF-2 A x AKSF-15R (0.68%) to CMS-112 A x BK-R-1 (-34.25%). As with check KBSH-44, the useful heterosis ranged from CMS-112 A x BK-R-1 (-19.33%) to DSF-2 A x AKSF-15R (25.53%). Just one cross, DSF-2 A x AKSF-15R (0.68%), was shown to be positively desirable over best check LSFH-171 out of the 48 crosses.

It is desired to have significant positive heterosis for seed filling percent. The mid parent heterosis ranged from CMS-47 A x EC-601924 (81.62%) to CMS-112 A x BK-R-1 (-15.19%). Out of 48 hybrids; forty-four revealed positive and one revealed negative mid parent heterosis. The heterosis estimated over better parent ranged from CMS-597 A x R-856 (67.72%) to CMS-112 A x BK-R-1 (-24.37%). Out of 48 hybrids; forty hybrids revealed positive and two hybrids revealed negative significant heterobeltiosis. Over both the checks, the hybrids CMS-47 A x EC-601924 (19.73, 31.05), CMS-112 A x AKSF-15R (18.18, 29.35), CMS-47 A x AKSF-15R (13.19, 23.89), and CMS-112 A x EC-601924 (10.74, 21.2) showed highly positive significant heterosis.

For 100 seed weight, range of heterosis over mid parent revealed from DSF-2 A x AKSF-15R (63.36%) up to DSF-2 A x R-274 (-28.92%). Out of 48 hybrids; thirty-seven revealed positive and three revealed negative mid parent heterosis. DSF-2 A x R-856 (42.14%) to DSF-2 A x R-274 (-49.83%) showed the range of heterobeltiosis. Standard heterosis over best check LSFH-171 ranged from (-53.57%) DSF-2 A x R-274 to (19.44%) CMS-47 A x EC-601924. Likewise, heterosis over the second check KBSH-44 ranged from (-43.59%) DSF-2 A x R-274 to (45.13%) CMS-47 A x EC-601924. Out of the 48 hybrids, only one hybrid CMS-47 A x EC-601924 (19.44%) exhibited positive significant heterosis and forty-six exhibited negative significant heterosis over best check LSFH-171.

After reviewing the data, it was determined that the mid parent heterosis ranged from CMS-597 A x R-274 (37.58%) to CMS-112 A x LTRR-341 (-6.1%) among all the hybrids for volume weight. Twenty-eight positively significant and zero negatively significant heterotic crosses found over mid parent. The heterobeltiosis was ranged from CMS-47 A x RHA-1055 (27.16%) to CMS-112 A x AKSF-15R (-11.49%). Total twenty crosses showed positive substantial better parent heterosis and two negative better parent heterosis. Over the check LSFH-171 useful heterosis was ranged from CMS-103 A x R-856 (-8.54%) up to CMS-597 A x R-274 (31.71%). In the same way, the useful heterosis range over the best check KBSH-44 was from CMS-597 A x R-274 (16.13%) to CMS-103 A x R-856 (-19.35%). Twenty crosses demonstrated positive significant heterosis over both checks LSFH-171 and KBSH-44. None of the cross showed negative heterosis over LSFH-171 but four showed over KBSH-44.

**Table 1:** Top 5 heterotic crosses for different character in sunflower

|                       | <b>Parameters</b>     |   | <b>MP</b>                                                                                                 | <b>BP</b>                                                                                                  | <b>SCH-1</b>                                                                                          | <b>SCH-2</b>                                                                                          |
|-----------------------|-----------------------|---|-----------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| Days to 50% flowering | Range of heterosis    |   | -8.33 to 8.86                                                                                             | -11.36 to 8.4                                                                                              | -12 to 4.8                                                                                            | -14.73 to 1.55                                                                                        |
|                       | Mean heterosis        |   | -1.21                                                                                                     | -3.39                                                                                                      | -3.40                                                                                                 | -6.39                                                                                                 |
|                       | No. of Signi. hybrids | + | 6                                                                                                         | 4                                                                                                          | 2                                                                                                     | 0                                                                                                     |
|                       |                       | - | 17                                                                                                        | 28                                                                                                         | 26                                                                                                    | 36                                                                                                    |
|                       | Top crosses           |   | CMS-47 x RHA-1055<br>CMS-597 x RHA-1055<br>DSF-2 x AKSF-15R<br>DSF-2 x RHA-1055<br>CMS-112 x RHA-1055     | CMS-597 x R-274<br>CMS-597 x RHA-1055<br>CMS-597 x EC-601924<br>CMS-47 x RHA-1055<br>DSF-2 x AKSF-15R      | CMS-47 x RHA-1055<br>CMS-47 x R-274<br>DSF-2 x RHA-1055<br>CMS-112 x RHA-1055<br>DSF-2 x EC-601924    | CMS-47 x RHA-1055<br>CMS-47 x R-274<br>DSF-2 x RHA-1055<br>CMS-112 x RHA-1055<br>DSF-2 x EC-601924    |
| Days to maturity      | Range of heterosis    |   | -2.59 to 2.61                                                                                             | -2.87 to 1.72                                                                                              | -6.11 to -1.67                                                                                        | -5.06 to -0.56                                                                                        |
|                       | Mean heterosis        |   | -0.17                                                                                                     | -0.66                                                                                                      | -3.43                                                                                                 | -2.35                                                                                                 |
|                       | No. of Signi. hybrids | + | 2                                                                                                         | 0                                                                                                          | 0                                                                                                     | 0                                                                                                     |
|                       |                       | - | 5                                                                                                         | 4                                                                                                          | 40                                                                                                    | 24                                                                                                    |
|                       | Top crosses           |   | CMS-103 x R-274<br>CMS-597 x EC-601924<br>CMS-148 x EC-601924<br>CMS-112 x RHA-1055<br>CMS-112 x LTRR-341 | CMS-103 x R-274<br>CMS-148 x EC-601924<br>CMS-597 x EC-601924<br>CMS-103 x EC-601924<br>CMS-112 x RHA-1055 | CMS-103 x R-274<br>DSF-2 x R-274<br>CMS-148 x EC-601924<br>CMS-597 x EC-601924<br>CMS-103 x EC-601924 | CMS-103 x R-274<br>DSF-2 x R-274<br>CMS-148 x EC-601924<br>CMS-597 x EC-601924<br>CMS-103 x EC-601924 |
| Plant height          | Range of heterosis    |   | 13.69 to 54.24                                                                                            | -1.21 to 41.7                                                                                              | -30.82 to 2.57                                                                                        | -13.07 to 28.88                                                                                       |
|                       | Mean heterosis        |   | 29.98                                                                                                     | 21.94                                                                                                      | -15.65                                                                                                | 5.98                                                                                                  |
|                       | No. of Signi. hybrids | + | 48                                                                                                        | 43                                                                                                         | 0                                                                                                     | 20                                                                                                    |
|                       |                       | - | 0                                                                                                         | 0                                                                                                          | 43                                                                                                    | 4                                                                                                     |
|                       | Top crosses           |   | CMS-112 x R-274<br>CMS-103 x RHA-1055<br>CMS-112 x AKSF-15R<br>CMS-103 x AKSF-15R<br>CMS-112 x BK-R-1     | CMS-112 x R-274<br>CMS-103 x AKSF-15R<br>CMS-112 x BK-R-1<br>CMS-112 x LTRR-341<br>CMS-597 x R-274         | CMS-103 x RHA-1055<br>CMS-103 x EC-601924<br>CMS-103 x R-274<br>CMS-103 x BK-R-1<br>DSF-2 x BK-R-1    | CMS-103 x RHA-1055<br>CMS-103 x EC-601924<br>CMS-103 x R-274<br>CMS-103 x BK-R-1<br>DSF-2 x BK-R-1    |

|                 | <b>Parameters</b>     |   | <b>MP</b>                                                                                              | <b>BP</b>                                                                                                 | <b>SCH-1</b>                                                                                               | <b>SCH-2</b>                                                                                               |
|-----------------|-----------------------|---|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| Head diameter   | Range of heterosis    |   | -13.51 to 92                                                                                           | -1.21 to 41.7                                                                                             | -30.82 to 2.57                                                                                             | -19.33 To 23.53                                                                                            |
|                 | Mean heterosis        |   | 32.12                                                                                                  | 20.19                                                                                                     | -13.11                                                                                                     | 6.59                                                                                                       |
|                 | No. of Signi. hybrids | + | 40                                                                                                     | 24                                                                                                        | 0                                                                                                          | 12                                                                                                         |
|                 |                       | - | 0                                                                                                      | 0                                                                                                         | 29                                                                                                         | 3                                                                                                          |
|                 | Top crosses           |   | CMS-597 x R-856<br>CMS-148 x R-856<br>CMS-597 x EC-601951-1<br>DSF-2 x R-856<br>CMS-47 x R-856         | CMS-597 x R-856<br>CMS-597 x EC-601951-1<br>CMS-148 x R-856<br>DSF-2 x R-856<br>CMS-47 x R-856            | DSF-2 x AKSF-15R<br>CMS-112 x AKSF-15R<br>CMS-112 x EC-601924<br>CMS-597 x R-856<br>CMS-47 x EC-601924     | DSF-2 x AKSF-15R<br>CMS-112 x AKSF-15R<br>CMS-112 x EC-601924<br>CMS-597 x R-856<br>CMS-47 x EC-601924     |
| Seed filling    | Range of heterosis    |   | -15.19 to 81.62                                                                                        | -24.37 to 67.72                                                                                           | -36.03 to 19.73                                                                                            | -29.99 to 31.05                                                                                            |
|                 | Mean heterosis        |   | 38.23                                                                                                  | 28.25                                                                                                     | -6.49                                                                                                      | 2.34                                                                                                       |
|                 | No. of Signi. hybrids | + | 44                                                                                                     | 40                                                                                                        | 5                                                                                                          | 15                                                                                                         |
|                 |                       | - | 1                                                                                                      | 2                                                                                                         | 22                                                                                                         | 7                                                                                                          |
|                 | Top crosses           |   | CMS-47 x EC-601924<br>CMS-597 x R-856<br>CMS-597 x EC-601951-1<br>CMS-597 x LTRR-341<br>CMS-47 x R-274 | CMS-597 x R-856<br>CMS-597 x EC-601951-1<br>CMS-47 x EC-601924<br>CMS-47 x R-856<br>CMS-597 x LTRR-341    | CMS-47 x EC-601924<br>CMS-112 x AKSF-15R<br>CMS-47 x AKSF-15R<br>CMS-112 x EC-601924<br>CMS-47 x R-274     | CMS-47 x EC-601924<br>CMS-112 x AKSF-15R<br>CMS-47 x AKSF-15R<br>CMS-112 x EC-601924<br>CMS-47 x R-274     |
| 100 seed weight | Range of heterosis    |   | -28.9 To 63.36                                                                                         | -49.83 to 42.14                                                                                           | -53.57 to 19.44                                                                                            | -43.59 to 45.13                                                                                            |
|                 | Mean heterosis        |   | 19.48                                                                                                  | 5.90                                                                                                      | -24.19                                                                                                     | -7.88                                                                                                      |
|                 | No. of Signi. hybrids | + | 37                                                                                                     | 21                                                                                                        | 1                                                                                                          | 11                                                                                                         |
|                 |                       | - | 3                                                                                                      | 11                                                                                                        | 46                                                                                                         | 26                                                                                                         |
|                 | Top crosses           |   | DSF-2 x AKSF-15R<br>DSF-2 x R-856<br>CMS-47 x EC-601924<br>CMS-597 x EC-601951-1<br>CMS-103 x AKSF-15R | DSF-2 x R-856<br>CMS-47 x EC-601924<br>CMS-597 x EC-601951-1<br>CMS-103 x BK-R-1<br>CMS-103 x EC-601951-1 | CMS-47 x EC-601924<br>CMS-112 x EC-601924<br>CMS-47 x RHA-1055<br>CMS-112 x AKSF-15R<br>CMS-112 x RHA-1055 | CMS-47 x EC-601924<br>CMS-112 x EC-601924<br>CMS-47 x RHA-1055<br>CMS-112 x AKSF-15R<br>CMS-112 x RHA-1055 |

|               | <b>Parameters</b>     |   | <b>MP</b>     | <b>BP</b>       | <b>SCH-1</b>   | <b>SCH-2</b>    |
|---------------|-----------------------|---|---------------|-----------------|----------------|-----------------|
| Volume weight | Range of heterosis    |   | -6.1 to 37.58 | -11.49 to 27.16 | -8.54 to 31.71 | -19.35 to 16.13 |
|               | Mean heterosis        |   | 12.43         | 7.40            | 7.08           | -5.57           |
|               | No. of Signi. hybrids | + | 28            | 20              | 20             | 4               |
|               |                       | - | 0             | 2               | 0              | 20              |

|              |                       |                                                                                                          |                                                                                                          |                                                                                                            |                                                                                                            |
|--------------|-----------------------|----------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
|              | Top crosses           | CMS-597 x R-274<br>DSF-2 x R-274<br>CMS-47 x R-274<br>CMS-47 x RHA-1055<br>DSF-2 x RHA-1055              | CMS-47 x RHA-1055<br>CMS-597 x R-274<br>CMS-47 x R-274<br>DSF-2 x R-274<br>CMS-597 x AKSF-15R            | CMS-597 x R-274<br>CMS-47 x R-274<br>DSF-2 x R-274<br>CMS-47 x RHA-1055<br>CMS-112 x R-274                 | CMS-597 x R-274<br>CMS-47 x R-274<br>DSF-2 x R-274<br>CMS-47 x RHA-1055<br>CMS-112 x R-274                 |
| Hull content | Range of heterosis    | -15.62 to 3.49                                                                                           | -22.31 to 3.32                                                                                           | -21.73 to -0.48                                                                                            | -21.22 to 0.16                                                                                             |
|              | Mean heterosis        | -6.76                                                                                                    | -9.71                                                                                                    | -12.01                                                                                                     | -11.44                                                                                                     |
|              | No. of Signi. hybrids | +                                                                                                        | 0                                                                                                        | 0                                                                                                          | 0                                                                                                          |
|              |                       | -                                                                                                        | 35                                                                                                       | 41                                                                                                         | 41                                                                                                         |
|              | Top crosses           | CMS-148 x EC-601924<br>CMS-597 x R-274<br>CMS-148 x AKSF-15R<br>DSF-2 x EC-601924<br>CMS-597 x EC-601924 | CMS-148 x EC-601924<br>CMS-148 x AKSF-15R<br>DSF-2 x EC-601924<br>CMS-597 x EC-601924<br>CMS-47 x BK-R-1 | CMS-47 x EC-601924<br>DSF-2 x EC-601924<br>CMS-148 x EC-601924<br>CMS-112 x EC-601924<br>CMS-47 x RHA-1055 | CMS-47 x EC-601924<br>DSF-2 x EC-601924<br>CMS-148 x EC-601924<br>CMS-112 x EC-601924<br>CMS-47 x RHA-1055 |
| Oil content  | Range of heterosis    | -6.49 to 28.65                                                                                           | -14.04 to 23.29                                                                                          | 0.91 to 45.15                                                                                              | -0.3 to 43.41                                                                                              |
|              | Mean heterosis        | 11.87                                                                                                    | 5.63                                                                                                     | 24.66                                                                                                      | 23.17                                                                                                      |
|              | No. of Signi. hybrids | +                                                                                                        | 41                                                                                                       | 29                                                                                                         | 47                                                                                                         |
|              |                       | -                                                                                                        | 2                                                                                                        | 8                                                                                                          | 0                                                                                                          |
|              | Top crosses           | CMS-148 x EC-601924<br>CMS-597 x R-274<br>CMS-148 x AKSF-15R<br>CMS-103 x R-856<br>DSF-2 x EC-601924     | CMS-597 x R-274<br>CMS-148 x BK-R-1<br>CMS-47 x EC-601924<br>CMS-103 x AKSF-15R<br>CMS-148 x R-856       | CMS-47 x EC-601924<br>DSF-2 x EC-601924<br>CMS-148 x EC-601924<br>CMS-112 x EC-601924<br>CMS-47 x RHA-1055 | CMS-47 x EC-601924<br>DSF-2 x EC-601924<br>CMS-148 x EC-601924<br>CMS-112 x EC-601924<br>CMS-47 x RHA-1055 |

|                      | Parameters            | MP                                                                                                       | BP                                                                                                       | LSFH-171                                                                                               | KBSH-44                                                                                                |
|----------------------|-----------------------|----------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Seed yield per plant | Range of heterosis    | -59.17 to 366.51                                                                                         | -72.38 to 282.1                                                                                          | -72.38 to 47.62                                                                                        | -68.31 to 69.4                                                                                         |
|                      | Mean heterosis        | 99.25                                                                                                    | 63.70                                                                                                    | -9.80                                                                                                  | 3.49                                                                                                   |
|                      | No. of Signi. hybrids | +                                                                                                        | 39                                                                                                       | 32                                                                                                     | 6                                                                                                      |
|                      |                       | -                                                                                                        | 3                                                                                                        | 4                                                                                                      | 22                                                                                                     |
|                      | Top crosses           | CMS-47 x R-856<br>CMS-597 x R-856<br>CMS-597 x EC-601951-1<br>CMS-47 x EC-601951-1<br>CMS-47 x EC-601924 | CMS-47 x EC-601951-1<br>CMS-47 x R-856<br>CMS-597 x EC-601951-1<br>CMS-597 x R-856<br>CMS-47 x EC-601924 | CMS-47 x EC-601924<br>CMS-112 x AKSF-15R<br>CMS-47 x AKSF-15R<br>CMS-47 x R-274<br>CMS-112 x EC-601924 | CMS-47 x EC-601924<br>CMS-112 x AKSF-15R<br>CMS-47 x AKSF-15R<br>CMS-47 x R-274<br>CMS-112 x EC-601924 |

**Table 2:** Top three heterotic hybrids for different characters over standard checks

| Characters            | Heterotic crosses over |        |                     |        |
|-----------------------|------------------------|--------|---------------------|--------|
|                       | LSFH-171               |        | KBSH-44             |        |
|                       | Crosses                | Values | Crosses             | Values |
| Days to 50% flowering | CMS-47 x RHA-1055      | -12    | CMS-47 x RHA-1055   | -14.73 |
|                       | CMS-47 x R-274         | -9.6   | CMS-47 x R-274      | -12.4  |
|                       | DSF-2 x RHA-1055       | -8.8   | DSF-2 x RHA-1055    | -11.63 |
| Days to maturity      | CMS-103 x R-274        | -6.11  | CMS-103 x R-274     | -5.06  |
|                       | DSF-2 x R-274          | -5     | DSF-2 x R-274       | -3.93  |
|                       | CMS-148 x EC-601924    | -5     | CMS-148 x EC-601924 | -3.93  |
| Plant height (cm)     | CMS-103 x R-274        | -29.42 | CMS-103 x R-274     | -11.31 |
|                       | CMS-103 x EC-601924    | -29.81 | CMS-103 x EC-601924 | -11.81 |
|                       | CMS-103 x RHA-1055     | -30.82 | CMS-103 x RHA-1055  | -13.07 |
| Head diameter (cm)    | DSF-2 x AKSF-15R       | 0.68   | DSF-2 x AKSF-15R    | 23.53  |
|                       | --                     |        | CMS-112 x AKSF-15R  | 22.69  |
|                       | ---                    |        | CMS-112 x EC-601924 | 21.85  |
| Seed Filling (%)      | CMS-47 x EC-601924     | 19.73  | CMS-47 x EC-601924  | 31.05  |
|                       | CMS-112 x AKSF-15R     | 18.18  | CMS-112 x AKSF-15R  | 29.35  |
|                       | CMS-47 x AKSF-15R      | 13.19  | CMS-47 x AKSF-15R   | 23.89  |
| 100 Seed weight       | CMS-47 x EC-601924     | 19.44  | CMS-47 x EC-601924  | 45.13  |
|                       | ---                    |        | CMS-112 x EC-601924 | 21.22  |
|                       | ---                    |        | CMS-47 x RHA-1055   | 11.28  |
| Volume weight         | CMS-597 x R-274        | 31.71  | CMS-597 x R-274     | 16.13  |
|                       | CMS-47 x R-274         | 30.49  | CMS-47 x R-274      | 15.05  |
|                       | DSF-2 x R-274          | 26.83  | DSF-2 x R-274       | 11.83  |
| Hull Content (%)      | CMS-47 x EC-601924     | -21.73 | CMS-47 x EC-601924  | -21.22 |
|                       | DSF-2 x EC-601924      | -19.49 | DSF-2 x EC-601924   | -18.97 |
|                       | CMS-148 x EC-601924    | -19.33 | CMS-148 x EC-601924 | -18.81 |
| Oil Content (%)       | CMS-47 x EC-601924     | 45.15  | CMS-47 x EC-601924  | 43.41  |
|                       | DSF-2 x EC-601924      | 40.57  | DSF-2 x EC-601924   | 38.89  |
|                       | CMS-148 x EC-601924    | 40.22  | CMS-148 x EC-601924 | 38.54  |

|                          |                    |       |                    |       |
|--------------------------|--------------------|-------|--------------------|-------|
| Seed yield per plant (g) | CMS-47 x EC-601924 | 47.62 | CMS-47 x EC-601924 | 69.4  |
|                          | CMS-112 x AKSF-15R | 47.62 | CMS-112 x AKSF-15R | 69.4  |
|                          | CMS-47 x AKSF-15R  | 42.86 | CMS-47 x AKSF-15R  | 63.93 |

**Table 3:** Top heterotic crosses for seed yield per plant and showing significant and desirable heterosis for other traits

| Hybrids              | Seed yield/ plant (g) | Heterosis over best check (%) | Heterosis over best check for related traits |                     |
|----------------------|-----------------------|-------------------------------|----------------------------------------------|---------------------|
|                      |                       |                               | Significant heterosis                        | Desirable heterosis |
| Single Cross Hybrids |                       |                               |                                              |                     |
| CMS-47 x EC-601924   | 52.7                  | 47.62**                       | DF, SF, 100 SW, VW, HC, OC, SYPP             | DM, PH, HD          |
| CMS-112 x AKSF-15R   | 52.7                  | 47.62**                       | DM, PH, HD, SF, HC, OC, SYPP                 | DF                  |
| CMS-47 x AKSF-15R    | 51                    | 42.86**                       | SF, 100 SW, HC, OC, SYPP                     | DF, DM              |
| CMS-47 x R-274       | 49.3                  | 38.10**                       | DF, DM, SF, VW, HC, OC, SYPP                 | --                  |
| CMS-112 x EC-601924  | 45.9                  | 28.57**                       | DM, SF, OC, HC, SYPP                         | DF                  |

HD=Head diameter, SF=Seed filling, SW= 100 Seed weight, VW=Volume weight, HC=Hull content, OC=Oil content, DF=Days to 50% flowering and DM=Days to maturity

For hull content, the analysis of the data showed that the range of heterosis over mid parent was CMS-148 A x EC-601924 (-15.62%) to DSF-2 A x EC-601951-1 (3.49%). Among 48 hybrids, thirty-five showed negative and zero showed positive significant mid parent heterosis. The range of heterosis over better parent estimated was from CMS-148 A x EC-601924 (-22.31%) to DSF-2 A x EC-601951-1 (3.32%). Out of 48 hybrids; forty-one revealed negative and zero revealed negative heterobeltiosis. Forty-three crosses and forty-one crosses demonstrated negative significant heterosis over both checks LSFH-171 and KBSH-44. None of the cross showed positive heterosis over both the checks. Mid parent heterosis for oil content was ranged from CMS-148 A x EC-601924 (28.65%) to DSF-2 A x EC-601951-1 (-6.49%). Among 48 hybrids, forty-one showed positive and two showed negative significant mid parent heterosis. Heterobeltiosis ranged from CMS-597 A x R-274 (23.29%) to CMS-112 A x R-856 (-14.04%). Amongst 48 hybrids, twenty-nine revealed positive and eight revealed negative heterobeltiosis. The range of standard heterosis over check LSFH-171 was from (0.91%) DSF-2 A x EC-601951-1 to (45.15%) CMS-47 A x EC-601924. All the hybrid showed significant positive heterosis over check LSFH-171 except DSF-2 A x EC-601951-1. Out of 48 hybrids, the crosses CMS-47 A x EC-601924 (45.15, 43.31), DSF-2 A x EC-601924 (40.57, 38.89), CMS-148 A x EC-601924 (40.22, 38.54), CMS-112 A x EC-601924 (37.79, 38.12) and CMS-47 A x RHA-1055 (39.06, 37.4) recorded significant positive standard heterosis over both the checks.

For seed yield per plant, mid parent heterosis ranged from CMS-112 A x BK-R-1 (-59.17%) to CMS-47 A x R-856 (366.51%). Out of 48 hybrids, thirty-nine revealed positive and three revealed negative mid parent heterosis. The heterosis over better parent estimated range from CMS-47 A x EC-601951-1 (282.28%) to CMS-112 A x BK-R-1 (-72.38%). Out of 48 hybrids; thirty-two hybrids revealed positive and four hybrids revealed negative heterobeltiosis. The heterosis over check LSFH-171 ranged from (47.62%) CMS-47 A x EC-601924 to (-72.38%) CMS-112 A x BK-R-1. Similarly, heterosis over KBSH-44 ranged from (-68.31%) CMS-112 A x BK-R-1 to (69.4%) CMS-47 A x EC-601924. Out of the 48 hybrids, six crosses demonstrated positive and twenty-two crosses negative significant heterosis over check LSFH-171 and eighteen crosses showed positive and nine crosses showed negative significant heterosis over check KBSH-44. Comparable types of results were reported by Chandra *et al.* (2013) [5], Deshmukh *et al.* (2016) [6], Spoorthy and Nadaf (2016) [17], Rathi *et al.* (2016) [14], Sapkale *et al.* (2016) [15], Shamshad

*et al.* (2016) [16], Lakshman *et al.* (2018) [12], Kulkarni and Supriya (2017) [10], Bhoite *et al.* (2018) [4], Ailwar *et al.* (2020) [1], Karande *et al.* (2020) [9], Tyagi *et al.* (2020) [18], Pole *et al.* (2020) [13], Kumari *et al.* (2022) [11] and Jadhao *et al.* (2023) [8].

### Conclusion

A key factor that determines the breeding strategy in all breeding programme is the quantity of seed produced per plant. While various yield component features may have a direct or indirect influence on yield. The seed yield per plant was shown to be higher in five single crosses: CMS-47 x EC-601924, CMS-112 x AKSF-15R, CMS-47 x AKSF-15R, CMS-47 x R-274 and CMS-112 x EC-601924. These crosses also showed significantly higher heterotic estimations than both checks.

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