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# SCREENING OF GENOTYPES FOR *ALTERNARIA* BLIGHT RESISTANCE IN SUNFLOWER (*HELIANTHUS ANNUUS*. L)

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**ABSTRACT**

An investigation was undertaken was undertaken to assess the magnitude of resistance to *Alternaria* blight using new interspecific derived lines. The material consisted of four cytoplasmic male sterile (CMS) lines and 12 restorer lines crossed in all possible combinations during summer 2011. Total of 16 parents and 48 hybrids along with four check hybrids were evaluated in randomized block design with two replications at MARS, Dharwad during *kharif*2011. At flowering stage, among the 16 parents, CMS-17A, PS-1070 and ID-25 shown moderate resistance reaction and among 48 hybrids, CMS-17A ´ PS1070 and CMS-17A ´ ID-25 showed moderate resistance reaction. At maturity stage, although, none of the parents showed tolerant to *Alternaria* leaf spot reaction while only one hybrid CMS-17A ´ PS1070 recorded some degree of tolerant reaction. Among the parents, CMS-17A and PS-1070 recorded lowest 'r' value and AUDPC value and CMS-607A and RES- 834-1 recorded highest 'r' value and AUDPC value and among the hybrids, CMS-17A based hybrids recorded the lowest 'r' value and AUDPC value indicates the slow blighters. Among the 48 hybrids, CMS-17A ´ PS1070, CMS-17A ´ ID-25 and CMS-1030A ´ ID-25 were recorded as potential hybrids for yield and *Alternaria*disease reaction

## INTRODUCTION

Sunflower is infected by a large number of disease causing pathogens resulting in severe economic losses in yields. Occurrence of widespread diseases was identified as one of the major constraint of low productivity sunflower. Of these *Alternaria* blight is an important fungal disease of sunflower and it is caused by *Alternaria* helianthi (Hansf) which induce pre and post emergence mortalities and seed limiting blight/ rots in the field (Shobharani and Ravikumar, 2003).The disease causes characteristics leaf spot with concentric rings on the leaf. The leaf may turn yellow, then brown and fall off. Older leaves are usually affected before the disease works up the plant. This disease, which in severe cases can lead to complete defoliation, is most damaging on sunflower (Sunil kumar et al., 2013). The spots are mostly irregular and collapse to cover a large leaf area (Rajput and Solanki, 2013). Although the exact estimate of yield losses due to these diseases of sunflower is not known, the potential and actual losses estimated for the major diseases revealed that in case of *Alternaria* blight it was 90% (Agrawat et al., 1979; Balasubramanyam and kolte, 1980). In Northern Karnataka, *Alternaria* leaf blight is known to cause more than 80 percent of the yield loss in sunflower under severe epiphytotic conditions (Hiremath, 1990).To date no complete resistance against *Alterneria* is available in cultivated sunflower or any related germplasm even though the differences in susceptibility exist. Breeding for resistance to *Alternria* leaf spot faces the challenge of a gene pool containing only moderate levels of resistance. There is a strong need to identify genotypes resistant to *Alternaria* isolates of the geographical region and identify potential hybrid with genes for resistance/tolerance to *Alternaria helianthi*. So the present investigation was made to identify the resistant/tolerant genotype against *Alternaria* blight disease in sunflower helps to identify *Alternaria* disease resistant genotypes in sunflower.

## MATERIALS AND METHODS

An investigation was undertaken was undertaken to assess the magnitude of resistance to *Alternaria* blight using new interspecific derived lines. The material consisted of four cytoplasmic male sterile (CMS) lines and 12 restorer lines crossed in all possible combinations during summer 2011. A field experiment was conducted during kharif 2011-12 at the Main agricultural research station, college of agriculture, dharwad, Karnataka, India to screen the genotypes for *Alternaria* blight resistance.

During screening programme, all 48 experimental hybrids along with their parents and commercial checks viz., KBSH1, KBSH 53, KBSH 44 and SB 275 were screened for their reaction against *Alternaria* blight under natural conditions. The intensity of disease in the field was estimated from five randomly selected plants in each genotype which were tagged with labels. Observation on blight disease incidence at 45, 60 and 75 days after sowing were recorded by scoring five plants in each genotype on a 0 to 9 scale of Mayee and Datar (1986) and percent disease index (PDI) was calculated using a formula given by wheeler (1969).

$$PDI = \frac{\text{Sum of disease ratings 100}}{\text{Number of plants rated}} \times \frac{100}{\text{Highest score}}$$

**Table 1: Per cent disease index of *Alternaria*disease at different growth stages**

| Sl. No. | Genotypes | 45 days | | 60 days | | 75 days | |
|---|---|---|---|---|---|---|---|
| | | PDI | Score on 1-9 scale | PDI | Score on 1-9 scale | PDI | Score on 1-9 scale |
| | Female parents | | | | | | |
| 1 | CMS-234 A | 27.53 | 1 | 44.51 | 4 | 95.68 | 9 |
| 2 | CMS-17 A | 16.60 | 1 | 40.51 | 4 | 82.58 | 8 |
| 3 | CMS-607 A | 29.87 | 1 | 46.29 | 5 | 97.01 | 9 |
| 4 | CMS-1030 A | 23.75 | 1 | 44.60 | 5 | 85.91 | 9 |
| | Male parents | | | | | | |
| 1 | SCG-29 | 24.42 | 2 | 44.85 | 4 | 91.46 | 8 |
| 2 | SCG-37 | 17.76 | 2 | 41.62 | 4 | 94.36 | 9 |
| 3 | SCG-73 | 23.25 | 3 | 50.92 | 5 | 90.29 | 9 |
| 4 | RES-834-1 | 23.09 | 2 | 51.59 | 5 | 95.46 | 9 |
| 5 | NDR-4 | 25.08 | 2 | 30.42 | 4 | 95.46 | 9 |
| 6 | R-45 | 24.05 | 3 | 48.40 | 5 | 90.35 | 9 |
| 7 | HRHA-10-3 | 25.15 | 3 | 42.55 | 4 | 90.28 | 8 |
| 8 | RHA-298 | 22.94 | 2 | 53.02 | 5 | 92.07 | 8 |
| 9 | RHA-334 | 25.20 | 3 | 41.65 | 4 | 94.02 | 8 |
| 10 | RHA-43-5 | 14.65 | 1 | 47.85 | 5 | 97.45 | 9 |
| 11 | PS-1070 | 16.38 | 1 | 41.96 | 4 | 87.58 | 8 |
| 12 | ID-25 | 16.43 | 2 | 44.85 | 4 | 85.04 | 9 |
| | Crosses | | | | | | |
| 1 | CMS-234A × SCG-29 | 27.31 | 3 | 47.54 | 4 | 90.91 | 9 |
| 2 | CMS-234A × SCG-37 | 22.64 | 3 | 44.96 | 4 | 82.25 | 8 |
| 3 | CMS-234A × SCG-73 | 25.09 | 3 | 50.37 | 5 | 88.58 | 9 |
| 4 | CMS-234A × RES 834-1 | 21.76 | 3 | 51.98 | 6 | 86.92 | 8 |
| 5 | CMS-234A × NDR-4 | 24.42 | 3 | 49.65 | 5 | 93.47 | 9 |
| 6 | CMS-234A × R-45 | 23.54 | 3 | 51.18 | 6 | 86.30 | 9 |
| 7 | CMS-234A × HRHA-10-3 | 23.09 | 3 | 55.06 | 6 | 86.41 | 9 |
| 8 | CMS-234A × RHA-298 | 25.21 | 3 | 50.62 | 5 | 95.30 | 9 |
| 9 | CMS-234A × RHA-334 | 19.31 | 2 | 45.46 | 6 | 90.35 | 9 |
| 10 | CMS-234A × RHA-43-5 | 22.64 | 3 | 50.40 | 5 | 88.36 | 9 |
| 11 | CMS-234A × PS-1070 | 18.43 | 2 | 42.18 | 4 | 83.47 | 9 |
| 12 | CMS-234A × ID-25 | 22.37 | 1 | 50.18 | 4 | 83.96 | 8 |
| 13 | CMS-17A × SCG-29 | 18.87 | 2 | 45.07 | 4 | 79.70 | 8 |
| 14 | CMS-17A × SCG-37 | 19.31 | 2 | 46.74 | 3 | 82.20 | 8 |
| 15 | CMS-17A × SCG-73 | 14.76 | 1 | 42.51 | 4 | 83.25 | 9 |
| 16 | CMS-17A × RES 834-1 | 17.76 | 2 | 41.51 | 5 | 79.54 | 8 |

The rate of development of disease (r) at different intervals also calculated by following formula given by Van der plank (1963).

$$r = \frac{\log 23. -\log}{t_2 - t_1} \quad \left[\frac{X_2}{1-X_2} \quad \frac{X_1}{1-X_1}\right]$$

Where

R - Apparent rate of infection or spread

$X_1$ - Per cent disease index at time $t_1$

$X_2$ - Per cent disease index at time $t_2$

$t_2$-$t_1$ - Time interval in days between the consecutive observations

Using the PDI obtained at fifteen days for each genotype the (AUPDC) Area Under Disease Progression Curve was also calculated using the formula given by Wilcoxson*et al.* (1975).

$$AUPDC = \sum_{i=1}^{k} 1/2\,(S_i + S_{i-1}) \times (T_i - T_{i-1})$$

Where

$S_i$ = severity at the end of time i

k = Number of successive evaluation

$T_i$-$T_{i-1}$ = Constant time interval (15 days)

## RESULTS AND DISCUSSION

The experimental material consisting of 68 entries including hybrids, parents and checks were evaluated for *Alternaria* leaf blight disease under natural epiphytotic conditions during *kharif* season. The weather condition during crop growth period was highly favourable for disease development. The disease appeared at very early stages and developed sufficiently during later stages of crop growth. The disease was scored using 0-9 scale at 15 days interval and results pertaining to study are presented below.

**Disease scoring of parents and their hybrids at different stages:**

The results of the scoring on *Alternaria* disease incidence at three stages of crop growth *viz.*, 45, 60 and 75 DAS (days after sowing) are given in Table 1.

**Disease scoring at 45 DAS**

Disease incidence of was found to be range between 1 and 2 grades for females and 1 to 3 grade for males. Lowest incidence was noticed in case of parents PS-1070 and RHA-43-5 in males, while CMS-234, CMS-17A, CMS-1030A and CMS-607A recorded with least grade of 1 among females. Among the

**Table 1: Cont...........................**

| Sl. No. | Genotypes | 45 days | 60 days | 75 days | | | |
|---|---|---|---|---|---|---|---|
| | | PDI | Score on 1-9 scale | PDI | Score on 1-9 scale | PDI | Score on 1-9 scale |
| 17 | CMS-17A × NDR-4 | 18.43 | 1 | 36.14 | 4 | 77.36 | 8 |
| 18 | CMS-17A × R-45 | 20.20 | 1 | 33.41 | 4 | 81.90 | 7 |
| 19 | CMS-17A × HRHA-10-3 | 20.20 | 2 | 32.19 | 4 | 80.08 | 8 |
| 20 | CMS-17A × RHA-298 | 19.76 | 1 | 39.74 | 4 | 79.92 | 7 |
| 21 | CMS-17A × RHA-334 | 16.87 | 2 | 33.36 | 4 | 83.95 | 7 |
| 22 | CMS-17A × RHA-43-5 | 17.54 | 2 | 33.97 | 5 | 75.15 | 7 |
| 23 | CMS-17A × PS-1070 | 12.88 | 1 | 29.13 | 3 | 70.65 | 6 |
| 24 | CMS-17A × ID-25 | 13.85 | 1 | 32.35 | 3 | 71.59 | 7 |
| 25 | CMS-607A × SCG-29 | 15.32 | 1 | 41.07 | 4 | 85.25 | 8 |
| 26 | CMS-607A × SCG-37 | 19.48 | 1 | 42.08 | 4 | 87.02 | 9 |
| 27 | CMS-607A × SCG-73 | 26.86 | 2 | 43.02 | 4 | 90.13 | 8 |
| 28 | CMS-607A × RES 834-1 | 20.42 | 2 | 39.74 | 4 | 89.69 | 9 |
| 29 | CMS-607A × NDR-4 | 18.53 | 1 | 42.96 | 4 | 87.08 | 9 |
| 30 | CMS-607A × R-45 | 14.28 | 1 | 42.99 | 4 | 83.92 | 9 |
| 31 | CMS-607A × HRHA-10-3 | 20.20 | 1 | 40.52 | 4 | 87.42 | 9 |
| 32 | CMS-607A × RHA-298 | 17.15 | 2 | 39.63 | 4 | 89.47 | 8 |
| 33 | CMS-607A × RHA-334 | 19.20 | 3 | 37.75 | 4 | 89.36 | 9 |
| 34 | CMS-60A × RHA-43-5 | 21.09 | 2 | 45.57 | 5 | 90.24 | 9 |
| 35 | CMS-607A × PS-1070 | 17.09 | 2 | 35.42 | 4 | 77.95 | 7 |
| 36 | CMS-607A × ID-25 | 21.98 | 2 | 36.52 | 5 | 79.21 | 7 |
| 37 | CMS-1030A × SCG-29 | 19.98 | 2 | 31.85 | 4 | 88.47 | 7 |
| 38 | CMS-1030A × SCG-37 | 20.42 | 2 | 38.13 | 4 | 77.65 | 7 |
| 39 | CMS-1030A × SCG-73 | 21.09 | 2 | 38.02 | 4 | 80.64 | 8 |
| 40 | CMS-1030A × RES 834-1 | 19.54 | 2 | 41.96 | 5 | 85.42 | 8 |
| 41 | CMS-1030A × NDR-4 | 22.87 | 3 | 41.74 | 4 | 91.24 | 8 |
| 42 | CMS-1030A × R-45 | 21.75 | 2 | 36.19 | 4 | 85.25 | 9 |
| 43 | CMS-1030A × HRHA-10-3 | 23.75 | 2 | 32.13 | 4 | 88.24 | 8 |
| 44 | CMS-1030A × RHA-298 | 22.42 | 3 | 42.85 | 5 | 89.58 | 9 |
| 45 | CMS-1030A × RHA-334 | 21.07 | 2 | 41.68 | 4 | 91.30 | 9 |
| 46 | CMS-1030A × RHA-43-5 | 19.31 | 1 | 41.57 | 5 | 88.97 | 8 |
| 47 | CMS-1030A × PS-1070 | 16.04 | 1 | 36.86 | 4 | 83.80 | 7 |
| 48 | CMS-1030A × ID-25 | 16.53 | 3 | 40.79 | 4 | 84.03 | 8 |
| | Checks | | | | | | |
| 1 | KBSH-44 | 20.65 | 3 | 46.62 | 5 | 81.25 | 8 |
| 2 | KBSH-53 | 20.98 | 3 | 44.63 | 5 | 90.25 | 8 |
| 3 | SB275 | 24.04 | 3 | 44.40 | 4 | 85.03 | 8 |
| 4 | KBSH-1 | 23.65 | 3 | 43.96 | 5 | 86.36 | 8 |

crosses, the disease ratings ranged from 1 to 3 and the one scoring lower grade is being noticed with one of the parents as resistant in the crosses.

**Disease scoring at 60 DAS**

Incidence of disease appeared to be severe as could be seen from some of the male parents recording grade 5. The lowest incidence was recorded in case of male parents SCG-29, SCG-37, NPR-4, HRHA-10-3, RHA-334, PS-1070 and ID-25 with grade 4. Among females, CMS-234A and CMS-17A recorded least grade of 4. Among the crosses, disease ratings were between 3 and 7. The crosses have shown differential response to disease incidence and majority of the hybrids recorded 4 grade falling under moderately resistant category. And CMS-17A based hybrids CMS-17A ´PS-1070 and CMS-17A ´ ID-25 recorded the least grade of 3. The hybrids exhibiting lesser incidence at this stage fell in line with earlier screening in most of the cases.

**Disease scoring at 75 DAS**

At 75 DAS, most of the parents, experimental hybrids and the commercial checks appeared to be highly susceptible scoring grade more than 7 and in some crosses as high as grade 9. However, only one hybrid CMS-17A ´PS-1070 shown relatively lesser incidence with 6 grade. The respective PDI values calculated at all the three stages are listed in Table 1.

Overall, it was observed that among lines, CMS-17A and testers SCG-29, HRHA-10-3, RHA-298, RHA-334 and PS-1070 had susceptible reaction with grade of 7 or 8 and remaining parents have shown highly susceptible reaction with grade of 9. Among the hybrids, the cross combination CMS-17A ´ PS-1070 recorded moderately resistant reaction (grade 6), although CMS-17A and PS-1070 were found to show susceptible reaction. Since moderately resistance is seen in $F_1$, one can not conclude that it is non-additive, it can be due to varying dosages of alleles acting additively.

Out of 68 genotypes screened, none of them were found to be immune or resistant to *Alternaria* leaf blight. These are grouped into six categories based on reaction to disease as presented in Table 3.

**Apparent rate of infection (r) and area under disease progress curve (AUDPC) of *Alternaria* leaf blight**

**Table 2: Apparent rate of infection "r" value**

| Sl. No. | Genotypes | 45 to 60 days 'r' | 60 to 75 days 'r' | Average 'r' | AUDPC |
|---|---|---|---|---|---|
| | Female parents | | | | |
| 1 | CMS-234 A | 0.05 | 0.22 | 0.14 | 1798.18 |
| 2 | CMS-17 A | 0.08 | 0.13 | 0.11 | 1476.03 |
| 3 | CMS-607 A | 0.05 | 0.25 | 0.15 | 1870.05 |
| 4 | CMS-1030 A | 0.06 | 0.14 | 0.10 | 1669.69 |
| | Male parents | | | | |
| 1 | SCG-29 | 0.06 | 0.17 | 0.12 | 1725.04 |
| 2 | SCG-37 | 0.08 | 0.21 | 0.14 | 1598.35 |
| 3 | SCG-73 | 0.08 | 0.15 | 0.11 | 1789.68 |
| 4 | RES-834-1 | 0.08 | 0.21 | 0.15 | 1836.08 |
| 5 | NDR-4 | 0.02 | 0.27 | 0.14 | 1548.52 |
| 6 | R-45 | 0.07 | 0.15 | 0.11 | 1764.44 |
| 7 | HRHA-10-3 | 0.05 | 0.17 | 0.11 | 1692.60 |
| 8 | RHA-298 | 0.09 | 0.16 | 0.12 | 1829.91 |
| 9 | RHA-334 | 0.05 | 0.21 | 0.13 | 1707.88 |
| 10 | RHA-43-5 | 0.11 | 0.33 | 0.22 | 1668.38 |
| 11 | PS-1070 | 0.09 | 0.15 | 0.12 | 1531.90 |
| 12 | ID-25 | 0.09 | 0.13 | 0.11 | 1556.93 |
| | Crosses | | | | |
| 1 | CMS-234A × SCG-29 | 0.06 | 0.16 | 0.11 | 1804.61 |
| 2 | CMS-234A × SCG-37 | 0.07 | 0.12 | 0.09 | 1630.98 |
| 3 | CMS-234A × SCG-73 | 0.07 | 0.14 | 0.10 | 1796.19 |
| 4 | CMS-234A × RES 834-1 | 0.09 | 0.12 | 0.11 | 1757.85 |
| 5 | CMS-234A × NDR-4 | 0.07 | 0.18 | 0.13 | 1812.05 |
| 6 | CMS-234A × R-45 | 0.08 | 0.12 | 0.10 | 1768.02 |
| 7 | CMS-234A × HRHA-10-3 | 0.09 | 0.11 | 0.10 | 1820.28 |
| 8 | CMS-234A × RHA-298 | 0.07 | 0.20 | 0.14 | 1852.18 |
| 9 | CMS-234A × RHA-334 | 0.08 | 0.16 | 0.12 | 1649.33 |
| 10 | CMS-234A × RHA-43-5 | 0.08 | 0.13 | 0.11 | 1758.31 |
| 11 | CMS-234A × PS-1070 | 0.08 | 0.13 | 0.10 | 1535.16 |
| 12 | CMS-234A × ID-25 | 0.09 | 0.11 | 0.10 | 1717.84 |
| 13 | CMS-17A × SCG-29 | 0.08 | 0.10 | 0.09 | 1556.85 |
| 14 | CMS-17A × SCG-37 | 0.09 | 0.11 | 0.10 | 1607.26 |
| 15 | CMS-17A × SCG-73 | 0.10 | 0.13 | 0.11 | 1483.42 |
| 16 | CMS-17A × RES 834-1 | 0.08 | 0.11 | 0.10 | 1485.65 |

The apparent rate of *Alternaria* leaf blight infection per unit per day (r) was calculated from PDI by using formula of Vander Plank (1963) and presented in Table 2.

The cultivars with slow disease development are becoming popular nowadays in many crops. Slow blighting is known as the slow rate of development of *Alternaria* blight disease, slow blighters are traitized by a lower 'r' value and AUDPC when compared to susceptible varieties under the same conditions. This type of tolerance is preferred since these slow blighting varieties allow certain amount of disease to develop, which results in reduced selection pressure on pathogen to aquire virulence for its survival in nature (Hooker, 1967).

The rate of apparent infection in hybrids revealed a wide variation among the different hybrids and parents at different intervals. Among the hybrids tested, the highest average 'r' value was observed in the hybrid CMS-234A ´ RHA-298 (0.14) followed by CMS-234A ´ NDR-4 (0.13) and CMS-607A ´ RHA-298 (0.12). The least average 'r' value was recorded by hybrids CMS-17A ´ RHA-43-5 (0.08) followed by most of the hybrids with 0.09. The crosses involving line CMS-17A recorded lower 'r' value.

Among the male parents, the highest average 'r' value recorded in RHA-43-5 (0.2) and many parents with 0.1 average 'r' value. Among checks, KBSH-53 recorded highest average 'r' value, while KBSH-44 recorded lowest (0.09) average 'r' value.

Of the 48 hybrids tested for disease development by assessing per cent leaf area affected at different intervals starting from 45 days after sowing to 75 days after sowing, six hybrids *viz.*, CMS-234A ´ HRHA-10-3, CMS-234A ´ ID-25, CMS-17A ´ SCG-73, CMS-17A ´ SCG-37, CMS-607A ´ SCG-29 and CMS-607A ´ R-45 exhibited early onset of disease with more initial disease incidence and ended up with terminal disease severity compared with hybrids CMS-234A ´ NDR-4, CMS-234A ´ RHA-298, CMS-234A ´ RHA-334, CMS-607A ´ RHA-298, CMS-607A ´ RHA-334, CMS-607A ´ 43-5, CMS-1030A ´ RHA-334 and CMS-1030A ´ RHA-43-5 exhibited early onset of disease with more initial disease incidence and ended up with maximum terminal disease severity. While CMS-234A ´SCG-37, CMS-17A ´ SCG-29, CMS-17A ´ NDR-4, CMS-17A ´ HRHA-10-3, CMS-17A ´ RHA-298, CMS-17A ´ RHA-43-5, CMS-17A ´ PS-1070, CMS-17A ´ ID-25, CMS-607A ´ ID-25 and CMS-1030A ´SCG-37 showed lower initial diseases though on set of disease was in the same week.

Vander Plank (1963) suggested to measure the disease severity by several means from the beginning to the end of epidemic to assess slow blighting tolerance in compound interest disease like *Alternaria* leaf blight. Based on disease severity, CMS-

**Table 2: Cont.........................................**

| Sl. No. | Genotypes | 45 to 60 days 'r' | 60 to 75 days 'r' | Average 'r' | AUDPC |
|---|---|---|---|---|---|
| 17 | CMS-17A × NDR-4 | 0.06 | 0.12 | 0.09 | 1398.66 |
| 18 | CMS-17A × R-45 | 0.05 | 0.15 | 0.10 | 1418.41 |
| 19 | CMS-17A × HRHA-10-3 | 0.04 | 0.14 | 0.09 | 1386.56 |
| 20 | CMS-17A × RHA-298 | 0.07 | 0.12 | 0.09 | 1491.91 |
| 21 | CMS-17A × RHA-334 | 0.06 | 0.16 | 0.11 | 1383.02 |
| 22 | CMS-17A × RHA-43-5 | 0.06 | 0.12 | 0.09 | 1336.26 |
| 23 | CMS-17A × PS-1070 | 0.07 | 0.12 | 0.09 | 1160.02 |
| 24 | CMS-17A × ID-25 | 0.07 | 0.11 | 0.09 | 1230.09 |
| 25 | CMS-607A × SCG-29 | 0.09 | 0.14 | 0.12 | 1485.21 |
| 26 | CMS-607A × SCG-37 | 0.07 | 0.15 | 0.11 | 1576.06 |
| 27 | CMS-607A × SCG-73 | 0.05 | 0.17 | 0.11 | 1724.23 |
| 28 | CMS-607A × RES 834-1 | 0.06 | 0.17 | 0.12 | 1625.11 |
| 29 | CMS-607A × NDR-4 | 0.08 | 0.15 | 0.11 | 1575.43 |
| 30 | CMS-607A × R-45 | 0.10 | 0.13 | 0.12 | 1488.33 |
| 31 | CMS-607A × HRHA-10-3 | 0.07 | 0.15 | 0.11 | 1566.40 |
| 32 | CMS-607A × RHA-298 | 0.08 | 0.17 | 0.12 | 1522.61 |
| 33 | CMS-607A × RHA-334 | 0.06 | 0.18 | 0.12 | 1524.33 |
| 34 | CMS-60A × RHA-43-5 | 0.08 | 0.16 | 0.12 | 1676.69 |
| 35 | CMS-607A × PS-1070 | 0.07 | 0.12 | 0.10 | 1372.27 |
| 36 | CMS-607A × ID-25 | 0.05 | 0.13 | 0.09 | 1471.52 |
| 37 | CMS-1030A × SCG-29 | 0.04 | 0.19 | 0.11 | 1441.06 |
| 38 | CMS-1030A × SCG-37 | 0.06 | 0.12 | 0.09 | 1460.69 |
| 39 | CMS-1030A × SCG-73 | 0.06 | 0.14 | 0.10 | 1509.42 |
| 40 | CMS-1030A × RES 834-1 | 0.07 | 0.14 | 0.11 | 1563.11 |
| 41 | CMS-1030A × NDR-4 | 0.06 | 0.18 | 0.12 | 1653.39 |
| 42 | CMS-1030A × R-45 | 0.05 | 0.15 | 0.10 | 1508.31 |
| 43 | CMS-1030A × HRHA-10-3 | 0.03 | 0.19 | 0.11 | 1500.08 |
| 44 | CMS-1030A × RHA-298 | 0.06 | 0.16 | 0.11 | 1650.93 |
| 45 | CMS-1030A × RHA-334 | 0.07 | 0.18 | 0.12 | 1625.99 |
| 46 | CMS-1030A × RHA-43-5 | 0.07 | 0.16 | 0.12 | 1580.52 |
| 47 | CMS-1030A × PS-1070 | 0.07 | 0.15 | 0.11 | 1421.93 |
| 48 | CMS-1030A × ID-25 | 0.08 | 0.14 | 0.11 | 1490.11 |
| | Checks | | | | |
| 1 | KBSH-44 | 0.08 | 0.11 | 0.09 | 1618.45 |
| 2 | KBSH-53 | 0.07 | 0.17 | 0.12 | 1660.94 |
| 3 | SB-275 | 0.06 | 0.13 | 0.10 | 1664.40 |
| 4 | KBSH-1 | 0.06 | 0.14 | 0.10 | 1661.82 |

**Table 4: list of hybrids with their fertility status**

| Inbred lines | CMS 234A | CMS 17A | CMS 607 A | CMS 1030A |
|---|---|---|---|---|
| SCG -29 | Restorer | Restorer | Restorer | Restorer |
| SCG -37 | Restorer | Partial Restorer | Restorer | Partial Restorer |
| SCG -73 | Restorer | Restorer | Partial Restorer | Restorer |
| RES 834-1 | Restorer | Restorer | Maintainer | Restorer |
| NDR-4 | Partial Restorer | Restorer | Maintainer | Partial Restorer |
| R-45 | Partial Restorer | Restorer | Maintainer | Partial Restorer |
| HRHA-10-3 | Restorer | Restorer | Maintainer | Restorer |
| RHA-298 | Restorer | Restorer | Restorer | Restorer |
| RHA-334 | Partial Restorer | Maintainer | Restorer | Partial Restorer |
| RHA-43-5 | Partial Restorer | Partial Restorer | Partial Restorer | Partial Restorer |
| PS-1070 | Partial Restorer | Restorer | Maintainer | Partial Restorer |
| ID-25 | Restorer | Restorer | Restorer | Restorer |

17A´PS-1070, CMS-17A ´ ID-25 can be considered as slow blighters, whereas hybrids obtained from CMS-17A as female parent, CMS-607A ´ PS-1070, CMS-607A ´ ID-25, CMS-1030A ´ SCG-29, CMS-1030A ´ SCG-31 and CMS-1030A ´ PS-1070 could be termed as intermediate blighters while remaining all hybrids can be considered as fast blighters.

Among parents, CMS-234A, NDR-4 and RHA-334 showed less initial disease severity ended up with more incidence while CMS-1030A, CMS-607A, SCG-29, SCG-37, SCG-73, RES-834-1, RHA-298 and RHA-43-5 showed high initial and terminal disease severity. And CMS-17A, PS-1070 and ID-25 showed initial more disease severity ended up with less incidence compared with other parents. All checks recorded low disease severity could be considered as slow blighters.

**Table 5a: Heterosis for *Alternaria* per cent disease index at 45 days**

| Sl. No. | Crosses | Heterosis (%) for *Alternaria* per cent disease index at 45 days | | | | |
|---|---|---|---|---|---|---|
| | | Mid parent | Better parent | KBSH-44 | KBSH-53 | SB-275 |
| 1 | CMS-234A × SCG-29 | 5.13 | -0.81 | 32.26** | 30.15** | 13.57 |
| 2 | CMS-234A × SCG-37 | 0 | -17.74* | 9.68 | 7.93 | -5.82 |
| 3 | CMS-234A × SCG-73 | -1.19 | -8.87 | 21.51* | 19.57 | 4.34 |
| 4 | CMS-234A × RES 834-1 | -14.04 | -20.97* | 5.38 | 3.7 | -9.51 |
| 5 | CMS-234A × NDR-4 | -7.17 | -11.29 | 18.28 | 16.4 | 1.57 |
| 6 | CMS-234A × R-45 | -8.74 | -14.5 | 14 | 12.18 | -2.11 |
| 7 | CMS-234A × HRHA-10-3 | -12.34 | -16.13* | 11.83 | 10.05 | -3.97 |
| 8 | CMS-234A × RHA-298 | -0.1 | -8.42 | 22.11* | 20.16 | 4.85 |
| 9 | CMS-234A × RHA-334 | -26.74** | -29.84** | -6.45 | -7.94 | -19.67* |
| 10 | CMS-234A × RHA-43-5 | 7.38 | -17.73* | 9.69 | 7.94 | -5.81 |
| 11 | CMS-234A × PS-1070 | -16.07 | -33.06** | -10.75 | -12.17 | -23.36* |
| 12 | CMS-234A × ID-25 | 1.77 | -18.75* | 8.33 | 6.61 | -6.97 |
| 13 | CMS-17A × SCG-29 | -7.99 | -22.73* | -8.6 | -10.06 | -21.52* |
| 14 | CMS-17A × SCG-37 | 12.43 | 8.75 | -6.45 | -7.94 | -19.67* |
| 15 | CMS-17A × SCG-73 | -25.92** | -36.52** | -28.52** | -29.66** | -38.62** |
| 16 | CMS-17A × RES 834-1 | -10.5 | -23.08* | -13.98 | -15.35 | -26.13** |
| 17 | CMS-17A × NDR-4 | -11.58 | -26.54** | -10.75 | -12.17 | -23.36* |
| 18 | CMS-17A × R-45 | -0.6 | -16 | -2.15 | -3.71 | -15.98 |
| 19 | CMS-17A × HRHA-10-3 | -3.21 | -19.66* | -2.15 | -3.71 | -15.98 |
| 20 | CMS-17A × RHA-298 | -0.05 | -13.87 | -4.3 | -5.82 | -17.82 |
| 21 | CMS-17A × RHA-334 | -19.27* | -33.05** | -18.28 | -19.58 | -29.83** |
| 22 | CMS-17A × RHA-43-5 | 12.25 | 5.68 | -15.05 | -16.41 | -27.06** |
| 23 | CMS-17A × PS-1070 | -21.91 | -22.42 | -37.63** | -38.63** | -46.45** |
| 24 | CMS-17A × ID-25 | -16.1 | -16.52 | -32.90** | -33.97** | -42.38** |
| 25 | CMS-607A × SCG-29 | -43.57** | -48.72** | -25.81* | -26.99* | -36.29** |
| 26 | CMS-607A × SCG-37 | -18.20* | -34.79** | -5.64 | -7.14 | -18.97* |
| 27 | CMS-607A × SCG-73 | 1.13 | -10.08 | 30.11** | 28.04** | 11.72 |
| 28 | CMS-607A × RES 834-1 | -22.88** | -31.63** | -1.08 | -2.65 | -15.05 |
| 29 | CMS-607A × NDR-4 | -32.55** | -37.96** | -10.23 | -11.66 | -22.91* |
| 30 | CMS-607A × R-45 | -47.06** | -52.22** | -30.86** | -31.96** | -40.63** |
| 31 | CMS-607A × HRHA-10-3 | -26.56** | -32.38** | -2.15 | -3.71 | -15.98 |
| 32 | CMS-607A × RHA-298 | -35.06** | -42.60** | -16.94 | -18.26 | -28.68** |
| 33 | CMS-607A × RHA-334 | -30.29** | -35.74** | -7.01 | -8.49 | -20.15* |
| 34 | CMS-60A × RHA-43-5 | -5.27 | -29.40** | 2.15 | 0.52 | -12.28 |
| 35 | CMS-607A × PS-1070 | -26.09** | -42.78** | -17.2 | -18.52 | -28.90** |
| 36 | CMS-607A × ID-25 | -5.07 | -26.43** | 6.45 | 4.76 | -8.59 |
| 37 | CMS-1030A × SCG-29 | -17.05* | -18.18* | -3.23 | -4.77 | -16.9 |
| 38 | CMS-1030A × SCG-37 | -1.6 | -14.02 | -1.08 | -2.65 | -15.05 |
| 39 | CMS-1030A × SCG-73 | -10.26 | -11.21 | 2.15 | 0.52 | -12.28 |
| 40 | CMS-1030A × RES 834-1 | -16.59* | -17.76 | -5.38 | -6.88 | -18.75* |
| 41 | CMS-1030A × NDR-4 | -6.36 | -8.84 | 10.75 | 8.99 | -4.9 |
| 42 | CMS-1030A × R-45 | -9.02 | -9.58 | 5.32 | 3.65 | -9.56 |
| 43 | CMS-1030A × HRHA-10-3 | -2.85 | -5.54 | 15.05 | 13.22 | -1.2 |
| 44 | CMS-1030A × RHA-298 | -3.96 | -5.61 | 8.6 | 6.87 | -6.74 |
| 45 | CMS-1030A × RHA-334 | -13.92 | -16.4 | 2.05 | 0.43 | -12.37 |
| 46 | CMS-1030A × RHA-43-5 | 0.58 | -18.69* | -6.45 | -7.94 | -19.67* |
| 47 | CMS-1030A × PS-1070 | -20.08* | -32.48** | -22.32* | -23.56* | -33.29** |
| 48 | CMS-1030A × ID-25 | -17.7 | -30.39** | -19.92 | -21.19* | -31.23** |

* - Significant at 5%; ** - Significant at 1%

The 'r' values varied and at times they did not remain constant for a given genotype and also did not show a particular trend in general. This observation is in agreement with that of Wilcoxson*et al.* (1975) and Nargund (1989) who have pointed out that 'r' values are not useful criteria as AUDPC values in studying the disease development. It was suggested that computed 'r' values influenced to the extent of new foliage growth that occurred during the epidemic for all the genotypes, but it was more prevailing in the tolerant genotypes, hence the present investigation revealed that 'r' values are of less reliability in identifying slow blighting tolerance.

The AUDPC was calculated for each of genotypes by using the PDI recorded and presented in Table 2. Area Under Disease Progress Curve (AUDPC) values which are summation of values calculated at several intervals during disease progress has been used by Wilcoxson*et al.* (1975) for comparison of rate of development of stem rust in different wheat varieties. AUDPC values were used for comparing slow rusting ability. It was concluded that AUDPC values in the genotypes were distinct and consistent from trait to trait. In the present investigation also, genotypes differed distinctly for AUDPC values.

**Table 5b: Heterosis (%)for *Alternaria* per cent disease index at 60 days**

| Sl. No. | Crosses | Heterosis (%) for *Alternaria* per cent disease index at 60 days | | | | |
|---|---|---|---|---|---|---|
| | | Mid parent | Better parent | KBSH-44 | KBSH-53 | SB-275 |
| 1 | CMS-234A × SCG-29 | 6.41 | 6.01 | 1.97 | 6.54 | 7.07 |
| 2 | CMS-234A × SCG-37 | 4.41 | 1.01 | -3.57 | 0.75 | 1.25 |
| 3 | CMS-234A × SCG-73 | 5.56 | -1.08 | 8.03 | 12.87* | 13.43* |
| 4 | CMS-234A × RES 834-1 | 7.9 | 0.5 | 11.19* | 16.17** | 16.75** |
| 5 | CMS-234A × NDR-4 | 32.52** | 11.54* | 6.48 | 11.25* | 11.81* |
| 6 | CMS-234A × R-45 | 10.17* | 5.74 | 9.77 | 14.69** | 15.26** |
| 7 | CMS-234A × HRHA-10-3 | 26.48** | 23.70** | 18.09** | 23.38** | 24.00** |
| 8 | CMS-234A × RHA-298 | 3.8 | -4.53 | 8.57 | 13.43* | 14.00* |
| 9 | CMS-234A × RHA-334 | 5.54 | 2.15 | -2.49 | 1.88 | 2.39 |
| 10 | CMS-234A × RHA-43-5 | 9.14* | 5.33 | 8.09 | 12.93* | 13.50* |
| 11 | CMS-234A × PS-1070 | -2.42 | -5.22 | -9.52 | -5.47 | -5 |
| 12 | CMS-234A × ID-25 | 12.30* | 11.88* | 7.62 | 12.44* | 13.00* |
| 13 | CMS-17A × SCG-29 | 5.6 | 0.49 | -3.33 | 1 | 1.5 |
| 14 | CMS-17A × SCG-37 | 13.82** | 12.31* | 0.24 | 4.73 | 5.26 |
| 15 | CMS-17A × SCG-73 | -7.01 | -16.51** | -8.82 | -4.74 | -4.26 |
| 16 | CMS-17A × RES 834-1 | -9.85* | -19.52** | -10.96* | -6.97 | -6.51 |
| 17 | CMS-17A × NDR-4 | 1.89 | -10.8 | -22.49** | -19.02** | -18.62** |
| 18 | CMS-17A × R-45 | -24.85** | -30.98** | -28.35** | -25.14** | -24.76** |
| 19 | CMS-17A × HRHA-10-3 | -22.49** | -24.35** | -30.95** | -27.86** | -27.50** |
| 20 | CMS-17A × RHA-298 | -15.02** | -25.04** | -14.76** | -10.94* | -10.5 |
| 21 | CMS-17A × RHA-334 | -18.80** | -19.91** | -28.46** | -25.26** | -24.88** |
| 22 | CMS-17A × RHA-43-5 | -23.11** | -29.01** | -27.14** | -23.88** | -23.50** |
| 23 | CMS-17A × PS-1070 | -29.35** | -30.56** | -37.51** | -34.72** | -34.39** |
| 24 | CMS-17A × ID-25 | -24.20** | -27.86** | -30.61** | -27.50** | -27.14** |
| 25 | CMS-607A × SCG-29 | -9.87* | -11.27* | -11.91* | -7.96 | -7.5 |
| 26 | CMS-607A × SCG-37 | -4.27 | -9.1 | -9.76 | -5.71 | -5.24 |
| 27 | CMS-607A × SCG-73 | -11.49** | -15.51** | -7.73 | -3.6 | -3.12 |
| 28 | CMS-607A × RES 834-1 | -18.79** | -22.96** | -14.76** | -10.94* | -10.5 |
| 29 | CMS-607A × NDR-4 | 12.00* | -7.2 | -7.87 | -3.74 | -3.26 |
| 30 | CMS-607A × R-45 | -9.20* | -11.18* | -7.8 | -3.67 | -3.19 |
| 31 | CMS-607A × HRHA-10-3 | -8.79 | -12.47* | -13.10* | -9.21 | -8.75 |
| 32 | CMS-607A × RHA-298 | -20.20** | -25.27** | -15.01** | -11.21* | -10.76 |
| 33 | CMS-607A × RHA-334 | -14.15** | -18.46** | -19.04** | -15.42** | -14.99** |
| 34 | CMS-60A × RHA-43-5 | -3.19 | -4.77 | -2.27 | 2.11 | 2.62 |
| 35 | CMS-607A × PS-1070 | -19.73** | -23.49** | -24.04** | -20.64** | -20.24** |
| 36 | CMS-607A × ID-25 | -19.86** | -21.11** | -21.68** | -18.17** | -17.76** |
| 37 | CMS-1030A × SCG-29 | -28.78** | -28.98** | -31.68** | -28.62** | -28.26** |
| 38 | CMS-1030A × SCG-37 | -11.54* | -14.50** | -18.21** | -14.55** | -14.12* |
| 39 | CMS-1030A × SCG-73 | -20.38** | -25.32** | -18.45** | -14.79** | -14.37* |
| 40 | CMS-1030A × RES 834-1 | -12.75** | -18.65** | -10 | -5.97 | -5.5 |
| 41 | CMS-1030A × NDR-4 | 11.27* | -6.42 | -10.48* | -6.47 | -6 |
| 42 | CMS-1030A × R-45 | -22.19** | -25.24** | -22.39** | -18.91** | -18.51** |
| 43 | CMS-1030A × HRHA-10-3 | -26.27** | -27.96** | -31.08** | -28.00** | -27.64** |
| 44 | CMS-1030A × RHA-298 | -11.75** | -18.76** | -7.61 | -3.47 | -2.99 |
| 45 | CMS-1030A × RHA-334 | -3.31 | -6.51 | -10.57* | -6.56 | -6.1 |
| 46 | CMS-1030A × RHA-43-5 | -10.07* | -13.12* | -10.84* | -6.85 | -6.38 |
| 47 | CMS-1030A × PS-1070 | -14.84** | -17.37** | -20.95** | -17.41** | -17.00** |

* - Significant at 5%;** - Significant at 1%

The hybrids CMS-234A ´ SCG-29, CMS-234A ´ SCG-7, CMS-A ´ RES-834-1, CMS-234A ´ NDR-4, CMS-234A ´ R-45, CMS-234A ´ HRHA-10-3, CMS-234A ´ RHA-298, CMS-234A ´ RHA-43-5 and CMS-607A ´ SCG-73 recorded high AUDPC values for disease hence, these hybrids were considered as fast blighters. The lowest AUDPC values for *Alternaria* leaf blight were recorded in hybrids like CMS-17A ´ PS-1070 (1160.02), CMS-17A ´ ID-25 (1230.09), CMS-17A ´ HRHA-10-3 (1386.56), CMS-17A ´ RHA-334 (1388.02), CMS-17A ´ RHA-43-5 (1336.26) can be considered as slow blighters as compared to checks KBSH-44, KBSH-53 and SB-275.

Among parents, CMS-17A (1476.03) and PS-1070 (1531.90) recorded lowest AUDPC values and CMS-607A (1870.05) and RES-834-1 (1836.08) recorded highest AUDPC value. While, check KBSH-53 recorded AUDPC value lowest (1660.94).

The present study indicates that it is possible to synthesize hybrids with reasonable degree of tolerance by involving disease tolerant parents. The extent of resistance however can be enhanced when allelic differences exist between parents and by subjecting above crosses to recurrent selection (Ravikumar*et al.*, 1995 and Shobarani, 2003). The work carried out so far in detection of *Alternaria* resistance is quite meager sunflower in view of lack of resistance in the entire world

**Table 5c: Heterosis for *Alternaria* per cent disease index at 75 days**

| Sl. No. | Crosses | Heterosis (%) for *Alternaria* per cent disease index at 75 days | | | | |
|---|---|---|---|---|---|---|
| | | Mid parent | Better parent | KBSH-44 | KBSH-53 | SB-275 |
| 1 | CMS-234A × SCG-29 | -2.84 | -4.98* | 11.89** | 0.74 | 6.92** |
| 2 | CMS-234A × SCG-37 | -13.44** | -14.03** | 1.23 | -8.86** | -3.26 |
| 3 | CMS-234A × SCG-73 | -4.74* | -7.42** | 9.02** | -1.84 | 4.18 |
| 4 | CMS-234A × RES 834-1 | -9.06** | -9.16** | 6.97** | -3.69 | 2.22 |
| 5 | CMS-234A × NDR-4 | -2.2 | -2.31 | 15.04** | 3.57 | 9.93** |
| 6 | CMS-234A × R-45 | -7.22** | -9.80** | 6.22* | -4.37 | 1.5 |
| 7 | CMS-234A × HRHA-10-3 | -7.07** | -9.69** | 6.35* | -4.25 | 1.63 |
| 8 | CMS-234A × RHA-298 | 1.52 | -0.4 | 17.28** | 5.60* | 12.08** |
| 9 | CMS-234A × RHA-334 | -4.74* | -5.57* | 11.20** | 0.12 | 6.27* |
| 10 | CMS-234A × RHA-43-5 | -8.50** | -9.33** | 8.74** | -2.09 | 3.92 |
| 11 | CMS-234A × PS-1070 | -8.91** | -12.77** | 2.73 | -7.51** | -1.83 |
| 12 | CMS-234A × ID-25 | -7.08** | -12.25** | 3.33 | -6.97** | -1.25 |
| 13 | CMS-17A × SCG-29 | -8.42** | -12.86** | -1.91 | -11.69** | -6.27* |
| 14 | CMS-17A × SCG-37 | -7.09** | -12.89** | 1.16 | -8.92** | -3.33 |
| 15 | CMS-17A × SCG-73 | -3.69 | -7.80** | 2.46 | -7.75** | -2.09 |
| 16 | CMS-17A × RES 834-1 | -10.65** | -16.68** | -2.11 | -11.86** | -6.45** |
| 17 | CMS-17A × NDR-4 | -13.10** | -18.96** | -4.79 | -14.28** | -9.01** |
| 18 | CMS-17A × R-45 | -5.28* | -9.36** | 0.8 | -9.25** | -3.68 |
| 19 | CMS-17A × HRHA-10-3 | -7.34** | -11.29** | -1.44 | -11.26** | -5.81* |
| 20 | CMS-17A × RHA-298 | -8.48** | -13.19** | -1.64 | -11.44** | -6.01* |
| 21 | CMS-17A × RHA-334 | -4.93* | -10.71** | 3.32 | -6.98** | -1.27 |
| 22 | CMS-17A × RHA-43-5 | -16.51** | -22.88** | -7.51** | -16.72** | -11.61** |
| 23 | CMS-17A × PS-1070 | -16.96** | -19.33** | -13.05** | -21.71** | -16.91** |
| 24 | CMS-17A × ID-25 | -14.58** | -15.81** | -11.89** | -20.67** | -15.80** |
| 25 | CMS-607A × SCG-29 | -9.54** | -12.13** | 4.92 | -5.54* | 0.26 |
| 26 | CMS-607A × SCG-37 | -9.05** | -10.30** | 7.10** | -3.57 | 2.35 |
| 27 | CMS-607A × SCG-73 | -3.76 | -7.09** | 10.93** | -0.13 | 6.01* |
| 28 | CMS-607A × RES 834-1 | -6.81** | -7.55** | 10.38** | -0.62 | 5.48* |
| 29 | CMS-607A × NDR-4 | -9.52** | -10.24** | 7.17** | -3.51 | 2.41 |
| 30 | CMS-607A × R-45 | -10.43** | -13.50** | 3.28 | -7.01** | -1.31 |
| 31 | CMS-607A × HRHA-10-3 | -6.65** | -9.89** | 7.59** | -3.14 | 2.81 |
| 32 | CMS-607A × RHA-298 | -5.37** | -7.78** | 10.11** | -0.86 | 5.22* |
| 33 | CMS-607A × RHA-334 | -6.45** | -7.89** | 9.97** | -0.99 | 5.09* |
| 34 | CMS-60A × RHA-43-5 | -7.19** | -7.39** | 11.07** | 0 | 6.14* |
| 35 | CMS-607A × PS-1070 | -15.55** | -19.65** | -4.07 | -13.63** | -8.32** |
| 36 | CMS-607A × ID-25 | -12.98** | -18.35** | -2.51 | -12.23** | -6.84** |
| 37 | CMS-1030A × SCG-29 | -0.24 | -3.27 | 8.89** | -1.97 | 4.05 |
| 38 | CMS-1030A × SCG-37 | -13.86** | -17.71** | -4.44 | -13.96** | -8.68** |
| 39 | CMS-1030A × SCG-73 | -5.63** | -7.91** | 2.33 | -7.87** | -2.22 |
| 40 | CMS-1030A × RES 834-1 | -5.81** | -10.52** | 5.13* | -5.35* | 0.46 |
| 41 | CMS-1030A × NDR-4 | 0.61 | -4.42* | 12.29** | 1.1 | 7.31** |
| 42 | CMS-1030A × R-45 | -3.27 | -5.65* | 4.92 | -5.54* | 0.26 |
| 43 | CMS-1030A × HRHA-10-3 | 0.16 | -2.26 | 8.60** | -2.22 | 3.78 |
| 44 | CMS-1030A × RHA-298 | 0.66 | -2.7 | 10.25** | -0.74 | 5.36* |
| 45 | CMS-1030A × RHA-334 | 1.48 | -2.89 | 12.37** | 1.17 | 7.38** |
| 46 | CMS-1030A × RHA-43-5 | -2.96 | -8.70** | 9.50** | -1.41 | 4.64 |
| 47 | CMS-1030A × PS-1070 | -3.39 | -4.31 | 3.14 | -7.14** | -1.44 |
| 48 | CMS-1030A × ID-25 | -1.69 | -2.2 | 3.41 | -6.89** | -1.18 |

* - Significant at 5%; ** - Significant at 1%

collections. Further, resistance to *Alternaria* is reported to exhibit differential reactions with the environment (Nagarajuet *al.*, 1992). Therefore, in absence of high level of resistance in *Alternaria*, there is no option but to involve tolerant parents in hybrid combinations as has been evidential in some of tolerant hybrids to maintain moderate level resistance in the present study.

**Heterosis and combining studies for percent disease index (PDI) at 45,60 and 75 DAS**

In the present investigation, we also studied the heterosis and combining studies for *Alternaria* disease incidence based on percent disease index (PDI) values at 45,60 and 75 days after sowing. But among 48 hybrids, 27 hybrids were completely fertile, thus analysis of variance for combining ability for disease incidence was for 18 hybrids in a Line (3)×Tester (6) design (Table 4).

Heterosis for *Alternaria* disease incidence , among 48 hybrids tested, CMS-17A´PS-1070 and CMS-17A´ ID-25 recorded significant negative heterosis over mid parent, better parent and commercial checks at 45, 60 and 75 days of sowing. Among female parents CMS-17A based hybrids recorded significant negative heterosis over mid parent and better parents.

**Table 5d: Heterosis (%) for seed yield (kg/ha)**

| Sl. No. | Crosses | Heterosis (%) for seed yield (kg/ha) | | | | |
|---|---|---|---|---|---|---|
| | | Mid parent | Better parent | KBSH-44 | KBSH-53 | SB-275 |
| 1 | CMS-234A × SCG-29 | 173.74** | 81.35** | 6.33 | -0.25 | 50.08** |
| 2 | CMS-234A × SCG-37 | 393.00** | 322.21** | 12.86 | 5.87 | 59.29** |
| 3 | CMS-234A × SCG-73 | 291.53** | 200.44** | 7.07 | 0.44 | 51.12** |
| 4 | CMS-234A × RES 834-1 | 315.76** | 253.69** | -32.61** | -36.78** | -4.88 |
| 5 | CMS-234A × NDR-4 | 151.97** | 71.73** | -9.89 | -15.47 | 27.19* |
| 6 | CMS-234A × R-45 | 367.82** | 273.87** | 19.06* | 11.69 | 68.04** |
| 7 | CMS-234A × HRHA-10-3 | 159.47** | 82.51** | -14.52 | -19.81* | 20.65 |
| 8 | CMS-234A × RHA-298 | 233.96** | 162.82** | -12.76 | -18.16* | 23.14 |
| 9 | CMS-234A × RHA-334 | 333.68** | 312.40** | -12.87 | -18.26* | 22.98 |
| 10 | CMS-234A × RHA-43-5 | 513.98** | 330.00** | -18.07 | -23.14* | 15.64 |
| 11 | CMS-234A × PS-1070 | 223.86** | 138.54** | -3.92 | -9.87 | 35.61** |
| 12 | CMS-234A × ID-25 | 261.88** | 183.33** | -4.6 | -10.51 | 34.65* |
| 13 | CMS-17A × SCG-29 | 99.64** | 53.89** | -9.77 | -15.36 | 27.35* |
| 14 | CMS-17A × SCG-37 | 189.24** | 166.34** | -15.42 | -20.65* | 19.38 |
| 15 | CMS-17A × SCG-73 | 201.81** | 185.39** | 1.7 | -4.59 | 43.55** |
| 16 | CMS-17A × RES 834-1 | 439.50** | 283.27** | 21.72* | 14.18 | 71.80** |
| 17 | CMS-17A × NDR-4 | 210.28** | 149.04** | 30.67** | 22.59* | 84.44** |
| 18 | CMS-17A × R-45 | 167.69** | 167.33** | -14.87 | -20.14* | 20.16 |
| 19 | CMS-17A × HRHA-10-3 | 198.95** | 150.83** | 17.48 | 10.21 | 65.81** |
| 20 | CMS-17A × RHA-298 | 250.05** | 242.48** | 13.68 | 6.65 | 60.46** |
| 21 | CMS-17A × RHA-334 | 434.76** | 345.26** | 41.40** | 32.65** | 99.58** |
| 22 | CMS-17A × RHA-43-5 | 523.81** | 286.89** | 22.87* | 15.26 | 73.42** |
| 23 | CMS-17A × PS-1070 | 210.25** | 177.44** | 11.74 | 4.83 | 57.72** |
| 24 | CMS-17A × ID-25 | 319.45** | 307.54** | 37.22** | 28.72** | 93.67** |
| 25 | CMS-607A × SCG-29 | 76.78** | 8.95 | -36.12** | -40.08** | -9.84 |
| 26 | CMS-607A × SCG-37 | 421.41** | 293.69** | 5.23 | -1.28 | 48.53** |
| 27 | CMS-607A × SCG-73 | 401.98** | 247.02** | 23.67* | 16.01 | 74.55** |
| 28 | CMS-607A × RES 834-1 | 321.66** | 317.48** | -43.08** | -46.60** | -19.66 |
| 29 | CMS-607A × NDR-4 | 133.21** | 46.91* | -22.92* | -27.69** | 8.8 |
| 30 | CMS-607A × R-45 | 542.33** | 358.67** | 46.06** | 37.02** | 106.16** |
| 31 | CMS-607A × HRHA-10-3 | 146.99** | 59.45** | -25.32** | -29.94** | 5.41 |
| 32 | CMS-607A × RHA-298 | 161.13** | 84.20** | -38.86** | -42.64** | -13.7 |
| 33 | CMS-607A × RHA-334 | 231.54** | 172.75** | -42.38** | -45.94** | -18.67 |
| 34 | CMS-607A × RHA-43-5 | 897.67** | 678.17** | 6.1 | -0.47 | 49.76** |
| 35 | CMS-607A × PS-1070 | 349.12** | 200.58** | 21.07* | 13.57 | 70.88** |
| 36 | CMS-607A × ID-25 | 290.17** | 174.09** | -7.72 | -13.43 | 30.25* |
| 37 | CMS-1030A × SCG-29 | 46.44** | 23.11 | -27.82** | -32.28** | 1.88 |
| 38 | CMS-1030A × SCG-37 | 159.70** | 116.72** | -13.41 | -18.77* | 22.21 |
| 39 | CMS-1030A × SCG-73 | 127.84** | 115.53** | -13.89 | -19.22* | 21.54 |
| 40 | CMS-1030A × RES 834-1 | 220.15** | 113.62** | -14.65 | -19.93* | 20.47 |
| 41 | CMS-1030A × NDR-4 | 139.64** | 111.06** | 10.75 | 3.89 | 56.31** |
| 42 | CMS-1030A × R-45 | 94.70** | 74.94** | -30.10** | -34.43** | -1.34 |
| 43 | CMS-1030A × HRHA-10-3 | 110.49** | 95.03** | -8.66 | -14.31 | 28.93* |
| 44 | CMS-1030A × RHA-298 | 175.03** | 151.77** | 0.59 | -5.63 | 41.98** |
| 45 | CMS-1030A × RHA-334 | 246.72** | 165.03** | 5.89 | -0.66 | 49.46** |
| 46 | CMS-1030A × RHA-43-5 | 192.70** | 74.32** | -30.35** | -34.66** | -1.7 |
| 47 | CMS-1030A × PS-1070 | 256.79** | 255.36** | 43.13** | 34.27** | 102.02** |
| 48 | CMS-1030A × ID-25 | 247.57** | 220.24** | 27.95** | 20.03* | 80.59** |

* - Significant at 5%;** - Significant at 1%

Among male parents, PS-1070 and ID-25 based hybrids recorded significant negative heterosis (Table . 5a,5b and 5c). For seed yield per hectare, all hybrids expressed significant positive heterosis over mid parent and better parent and the hybrids CMS 17A× ID-25 and CMS-1030 A × ID-25 recorded positive standard heterosis (Table5d). The results are in agreement with Gangappa*et al.*, (1993), Radhika*et al.*. (2001) and Longanathan and Gopalan (2006).

From the analysis of variance for combining ability (Table 6), it was quite evident that significant differences existed among lines for percent disease index at 45, 60 and 75 DAS and mean sum of squares due to testers were significant for per cent disease index at 45 DAS and 75 DAS. The crosses between the lines and testers differed significantly for both percent disease incidence and seed yield per hectare indicating that lines and testers complement each other for combining ability. The variance due to interaction between females and males was significant for seed yield per hectare and disease incidence at 60 and 75 DAS suggesting significant contribution of sca effects towards variation among the crosses. The estimates of SCA variances were high for seed yield per hectare indicating predominance of non-additive gene action for this trait, which

**Table 6: Analysis of variance for combining ability for different traits in sunflower**

| Source | d.f | Seed yield (kg/ha) | PDI at 45 DAS | PDI at 60 DAS | PDI at 75 DAS |
|---|---|---|---|---|---|
| Replications | 1 | 88943.08 | 27.09 | 36.57* | 49.17** |
| Crosses | 17 | 184158.80** | 25.85** | 108.91** | 58.59** |
| Line effect | 2 | 461002.80 | 131.07** | 627.48** | 307.99** |
| Tester effect | 5 | 185225.80 | 22.24* | 26.65 | 47.49* |
| Line ´ Tester effect. | 10 | 128256.50** | 6.62 | 46.33** | 14.253** |
| Error | 17 | 23016.08 | 7.17 | 6.29 | 2.65 |
| s² GCA | | 43301.73 | 15.56 | 62.39 | 36.33 |
| s² SCA | | 55333.03 | 0.55 | 20.43 | 5.46 |
| s² GCA/ var SCA | | 0.78 | 28.42 | 3.05 | 6.65 |
| Contribution % of | | | | | |
| Line | | 29.45 | 59.64 | 67.78 | 61.85 |
| Tester | | 29.58 | 25.30 | 7.20 | 23.84 |
| Line ´ Tester | | 40.97 | 15.06 | 25.02 | 14.31 |

* - Significant at 5%;** - Significant at 1

**Table 7: General combining ability effects (gca) of parents for different traits in sunflower**

| Sl. No | Source | Seed yield (kg/ha) | PDI at 45 DAS | PDI at 60 DAS | PDI at 75 DAS |
|---|---|---|---|---|---|
| 1 | CMS-234A | -132.22** | 3.39* | 8.33** | 3.95** |
| 2 | CMS-17A | 225.19 | -3.21** | -3.70** | -5.71** |
| 3 | CMS- 1030A | -92.96** | -0.19** | -4.63** | 1.75* |
| | SE for lines | 38.29 | 0.68 | 0.67 | 0.53 |
| | CD @ 5% | 80.78 | 1.43 | 1.42 | 1.11 |
| | CD @ 1% | 110.96 | 1.97 | 1.95 | 1.53 |
| 1 | SCG-29 | -162.89** | 1.31 | -1.11** | 1.64 |
| 2 | SCG-73 | -22.52** | -0.43** | 1.03 | 0.27 |
| 3 | RES-834-1 | -132.21** | -1.06** | 2.50 | -0.77** |
| 4 | HRHA-10-3 | -25.66** | 1.61 | -2.81** | 0.19 |
| 5 | RHA-298 | 13.11 | 1.72 | 1.88 | 3.54* |
| 6 | ID-25 | 330.16 | -3.16** | -1.49** | -4.86** |
| | SE for tester | 54.15 | 0.96 | 0.95 | 0.75 |
| | CD @ 5% | 114.24 | 2.02 | 2.01 | 1.57 |
| | CD @ 1% | 156.93 | 2.78 | 2.76 | 2.16 |

* - Significant at 5%;** - Significant at 1%

**Table 8: Specific combining ability (sca) effects for different traits in sunflower**

| | Source | Seed yield (kg/ha) | PDI at 45 DAS | PDI at 60 DAS | PDI at 75 DAS |
|---|---|---|---|---|---|
| 1 | CMS-234A × SCG-29 | 402.06** | 1.86 | -2.28 | 0.60 |
| 2 | CMS-234A × SCG-73 | 273.54** | 1.38 | -1.60 | -0.37 |
| 3 | CMS-234A × RES 834-1 | -255.93* | -1.32 | -1.60 | -1.00 |
| 4 | CMS-234A × HRHA-10-3 | -71.08 | -2.66 | 6.93** | -2.46 |
| 5 | CMS-234A × RHA-298 | -81.44 | -0.65 | -2.19 | 3.08* |
| 6 | CMS-234A × ID-25 | -267.14* | 1.39 | 0.74 | 0.15 |
| 7 | CMS-17A × SCG-29 | -214.75* | 0.03 | 7.28** | -0.95 |
| 8 | CMS-17A × SCG-73 | -170.27 | -2.35 | 2.58 | 3.97** |
| 9 | CMS-17A × RES 834-1 | 261.81* | 1.28 | 0.11 | 1.29 |
| 10 | CMS-17A × HRHA-10-3 | 86.96 | 1.06 | -3.89* | 0.88 |
| 11 | CMS-17A × RHA-298 | -12.90 | 0.50 | -1.03 | -2.64 |
| 12 | CMS-17A × ID-25 | 49.15 | -0.52 | -5.05** | -2.56 |
| 13 | CMS-1030A × SCG-29 | -187.30 | -1.88 | -5.01** | 0.36 |
| 14 | CMS-1030A × SCG-73 | -103.27 | 0.97 | -0.98 | -3.60* |
| 15 | CMS-1030A × RES 834-1 | -5.89 | 0.04 | 1.49 | -0.29 |
| 16 | CMS-1030A × HRHA-10-3 | -15.89 | 1.59 | -3.03 | 1.57 |
| 17 | CMS-1030A × RHA-298 | 94.35 | 0.15 | 3.23 | -0.44 |
| 18 | CMS-1030A × ID-25 | 217.99* | -0.86 | 4.31* | 2.41 |
| | SE for crosses | 93.78 | 1.66 | 1.65 | 1.29 |
| | CD @ 5% | 197.86 | 3.51 | 3.49 | 2.72 |
| | CD @ 1% | 271.81 | 4.82 | 4.79 | 3.74 |

* - Significant at 5%; ** - Significant at 1%

**Table 9: Top three crosses exhibiting maximum sca effects, their mean performance and gca status of parents with respect to nine characters in sunflower**

| Character | Crosses | SCA | Mean | GCA status | |
|---|---|---|---|---|---|
| | | | | Female | Male |
| Seed yield(kg/ha) | CMS-234A × SCG-29 | 402.06 | 1712.95 | Low | Low |
| | CMS-234A × SCG-73 | 273.54 | 1724.80 | Low | High |
| | CMS-17A × RES-834-1 | 261.81 | 1960.80 | High | Low |
| PDI at 45 days | CMS-234A × HRHA-10-3 | -2.66 | 23.09 | Low | Low |
| | CMS-17A × SCG-73 | -2.35 | 14.76 | High | Low |
| | CMS-1030A × SCG-29 | -1.88 | 19.98 | High | Low |
| PDI at 60 days | CMS-17A × ID-25 | -5.05 | 32.36 | High | High |
| | CMS-1030A × SCG-29 | -5.01 | 31.86 | High | High |
| | CMS-17A × HRHA-10-3 | -3.90 | 32.19 | High | High |
| PDI at 75 days | CMS-1030A × SCG-73 | -3.60 | 83.14 | Low | Low |
| | CMS-17A × RHA298 | -2.64 | 79.92 | High | Low |
| | CMS-17A × ID-25 | -2.56 | 71.59 | High | High |

was also evident from the study of heterosis. Based on PDI values in the present study, it could be seen that gca variance was more suggesting that additive gene action was more prevalent in governing *Alternaria*resistance.

Total variances due to crosses can be partitioned into variances due to lines, testers and their interaction effects. The contributions of lines as compared to testers was more for per cent disease index at 60 and 75 DAS. Whereas, testers contributed a greater extent with respect to seed yield per hectare and PDI at 45 DAS. The female and male interaction was higher than their parents for seed yield per ha, PDI at 45 DAS indicating that interaction of genes in hybrid combinations played a major role in the expression of these traits.

Among the lines, CMS-17A line was the best general combiner for seed yield per hectare and *Alternaria*disease incidence. Among testers, ID-25 and RHA-298 had positive gca effects for seed yield and ID-25 recorded resistant reaction for *Alternaria* disease at 45, 60 and 75 days after sowing (Table 7). Out of 18 hybrids, three hybrids (CMS-17A ´ HRHA-10-3, CMS-17A ´ ID-25 and CMS-1030A ´ SCG-29) recorded significant negative sca effect thus they were good specific combiners for *Alternaria* disease resistance at 60 DAS and one hybrid (CMS-1030A ´ SCG-73) recorded significantly negative sca effect indicating that good specific combiner for this important biotic stress resistance at 75 DAS. In the present study, all the four types of parental combinations were observed in the crosses. However, majority of the crosses exhibited high sca effects as a result of either high ´high or high ´ low gca parents indicating a genetic interaction of additive ´additive or additive ´dominance interaction.

For disease incidence except, seed yield per ha, the high highgca combination of parents were observed to be the potential heterotic cross combinations, indicating the predominance of additive gene action and low ´lowgca combination of parents were heterotic cross combination for disease incidence at 60 and 75 DAS and seed yield per hectare indicating the predominance of non-additive gene action (Table 9).

From the foregoing discussion, it may be concluded that the crosses CMS-1030A× ID-25, CMS-17A× ID-25 and CMS-17A× NDR-4 were rated as the best crosses for exploitation of heterosis in commercial scale for both seed yield per plant and *Alternaria* disease incidence and the partial fertile hybrid with moderate resistance against *Alternaria* disease and better seed yield per hectare like CMS-1030A× PS-1070 were used in conversion programme to convert in to fertile hybrid.

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