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# Effect of *G. harknessii* based cytoplasmic male sterility on seed cotton yield and fibre quality traits in upland cotton (*Gossypium hirsutum* L.)

**O. P. Tuteja, S. K. Verma and Mahendar Singh**

Central Institute for Cotton Research, Regional Station, Sirsa 125 055

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**Abstract**

**To study the effect of male sterile cytoplasm on seed cotton yield and fibre properties of hybrid cotton, five cytoplasmic male sterile lines (A) and their maintainers (B) were crossed with six restorer lines and two types of hybrids i.e. A x R and B x R were developed. The hybrids were evaluated for seed cotton yield, ginning out turn, 2.5% span length, uniformity ratio, micronaire value and tenacity. The results showed that, sterile cytoplasm has detrimental effect on yield of hybrid cotton. The hybrids produced by using restorers with *G. harknessii* cytoplasm as the female parent showed about 4.76 to 15.63 % reduction in yield However, no negative effect was observed for ginning out turn and other fibre quality traits. On the contrary, increased 2.5% span length was observed CMS based hybrids ranging from 0.36 to 15.63 per cent. The reduction in micronaire value was also observed in almost all the A x R hybrids except in one of the cross combinations F 505A x CIR 72. The highest reduction in micronaire value was up to 30 % in the hybrid combination Bikaneri Narma A x CIR 32 with sterile cytoplasm. Similarly, increase in tenacity value was noticed in CMS based hybrids, which was also reflected on strength/length ratio. The detrimental effect of sterile cytoplasm on yield could be overcome by using suitable restorer and stable CMS lines, attempting more number of cross combinations to find out the suitable hybrids with high yield potential and better fibre quality with CMS system.**

**Key words:** *Gossypium hirsutum* L., CMS, *Gossypium harknessii,* yield, fibre quality

## Introduction

Cotton is a world's leading fibre crop and second most important oil seed crop. In India, it is one of the important cash crops with area and production of 9.02 million hectares and 2.70 million bales, respectively [1]. A noticeable heterosis reported in cotton by many workers [2, 3]. Even though heterosis occurs in cotton, it has not been utilized widely in cotton as compared to maize and rice due to difficulties in producing cheap commercial $F_1$ hybrid seed production. For better exploitation of heterosis in cotton, development of hybrid seed production techniques that are simple and economically viable are essential. There are four approaches of seed production i.e. hand emasculation, chemical hybridizing agents, genic male sterility and cytoplasmic male sterility (CMS). Use of chemical hybridizing agent is not feasible in cotton due to long flowering period. Most of hybrid seed production in major hybrid cotton growing countries like India and China is done using hand emasculation and pollination approach due to low labour cost. However, seed production using this approach is economically not viable especially in countries where labour cost is high. Thus, hybrid seed in cotton can only be effectively and economically produced using either the genetic male sterility (GMS) or cytoplasmic male sterility (CMS) approach. The economics and ease of hybrid seed production are important considerations in the utilization of hybrid vigor in crop plants. In view of economic importance of cotton in the world and to meet the increasing demand of cotton, the use of CMS and GMS line approach may prove the best method of hybrid seed production in cotton as this system can reduce the cost of hybrid seed production considerably less almost half [4].

Availability of stable CMS lines and restorers with high restorability are the basic requirements for the development of hybrids from CMS sources i.e. *G. arboreum, G. anamolum, G. harknessii* and *G. trilobum.* Only *G. harknessii* based cytoplasmic male sterility has been widely used in hybrid cotton across the world, which was developed by Meyer [4, 5]. A diploid (2n = 26 *G. harknessii* Brandagee (D2-2) was used as female by Meyer [6] to transfer *G, hirsutum* genome in the cytoplasm of *G. harknessii.* However, the use of this CGMS source is limited for want of potential restorers. In case of cytoplasmic male sterility system the abnormality of disintegration before pollen mother cell undergoes meiosis has been reported by Khadi *et al.* [7]. Whereas in case of genetic male sterility system the abnormality is post meiotic.

Earlier studies indicated that *G. harknessii* cytoplasm has detrimental effect on yield [8-11] but this effect could be overcome by using better CMS lines, restorers with high restorability by synthesizing more number of cross combinations and selecting desirable combinations. Thus, the breeder should pay more attention on breeding better fertility restorers to produce higher viable pollen %, higher boll setting %, reduced number of aborted seeds per boll, to increase the yield of the hybrids. On the other hand, Davis [12] studied A x R and B x R combinations to determine the effect of *G. harknessii* cytoplasm on the performance of hybrids but found no obvious differences between them. Since, cotton is the most important source of natural fiber in the world, hybrid cotton is an alternate option to meet the increasing demand of cotton fibre. The present investigation was undertaken to study the effect of *G. harknessii* based cytoplasmic male sterility on the cotton yield and fibre quality traits in hybrid cotton.

## Materials and methods

The cytoplasmic genic male sterile (CGMS) lines were developed by using IH 76 carrying *G. harknessii* cytoplasm as donor by back cross breeding. The material for the present study comprised 5 cytoplasmic male sterile lines and their maintainers (LRA 5166 B, SH 2379 B, Jhorar B, Bikaneri Narma B and F 505 B) and six restorers (CIR 23A, CIR 26, CIR 28A, CIR 32, CIR 28A, CIR 70 and CIR 72). The restorer lines (R) were crossed with A and B to produce two types of hybrid combinations. Thus, 60 $F_1$ hybrids were generated and tested with conventional check hybrid CSHH 198. The material was grown in RBD with three replications during *kharif* 2004-2005. In the experiment, the row to row and plant to plant distances were maintained 1.0 m and 0.45m, respectively. All the recommended cultural practices were followed before and after sowing . Seed cotton yield was measured on per plot basis and converted in to kg/hectare. After ginning, the lint was tested for 2.5% span length, uniformity ratio, Micronaire value and tenacity (g/tex) on high volume instrument (HVI) as per usual method [13].

To study the effect of cytoplasmic male sterility on yield and fibre quality traits, Chi-square test for goodness of fit was applied for comparing the A x R and Bx R hybrids. In order to record the seed fertility percentage, 10 flowers in each plant were selfed. The bolls developed through selfed flowers were examined for number of seeds/boll. Similarly, 10 opened bolls in each plant were also examined for number of seeds. The ratio between closed (selfed seed set) and open seed set was expressed as seed fertility percentage [11].

$$\text{Fertility restoration (\%)} = \frac{\text{Number of seeds in selfed bolls}}{\text{Number of seeds in pollinated bolls}} \times 100$$

## Results and discussion

The mean performance of hybrids having sterile cytoplasm (A x R) was compared with hybrids having normal cytoplasm with respect to yield and fibre quality traits, by applying the Chi-square ($\chi^2$) test for goodness of fit (Table 1). The mean seed cotton yield of B x R hybrids was significantly higher than the A x R hybrids in almost all the combinations except in Jhorar A x CIR 72. The results of present study indicated that hybrids with sterile cytoplasm performed poorely in yield as compared to B x R hybrids with normal cytoplasm. The hybrids produced by using restorers with *G. harknessii* cytoplasm as the female parent showed about 4.76 to 15.63 % reduction in yield in SH 2379A x CIR 23A and Bikaneri Narma A x CIR 213A, respectively (Table 2). Weaver [8] also reported that the hybrids produced by using restorer with *G. hirsutum* cytoplasm as the female parent showed about 8 % reduction in seed cotton yield. The hybrids using cultivars as the female parent with normal cytoplasm consistently produced the highest seed cotton yield. Similarly, Zhu *et al.* [14] also observed detrimental effects of sterile cytoplasm on yield and its contributing traits in cotton. Thus results of present study are in close agreement with that of earlier reports of [8, 10, 11].

However, for ginning out turn there was no effect of *G. harknessii* cytoplasm and the mean ginning out turn of hybrids with sterile cytoplasm and with normal cytoplasm were found to be at par. For fibre quality traits *viz.*, 2.5% span length, uniformity ratio, micronaire value and tenacity, no significant differences were observed between A x R and B x R hybrids. On the contrary, increased 2.5% span length was observed in 26 CMS based hybrids ranging from 0.36 to 15.63 per cent. The reduction in micronaire value was also observed in almost all the A x R hybrids except in one of the cross

**Table 1.** Effect of sterile cytoplasm on seed cotton yield, ginning out turn and fibre quality traits

| Sr.No. | CMS hybrids | Seed cotton yield (kg/ha) | | | GOT (%) | | | 2.5 span length (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Conv. | CMS | $\chi^2$ | Conv. | CMS | $\chi^2$ | Conv. | CMS | $\chi^2$ |
| 1 | LRA 5166 x CIR 23 A | 1865 | 1768 | 5.32* | 3S..2 | 34.4 | 0.02 | 27.7 | 29.7 | 0.13 |
| 2 | LRA 5166 x CIR 26 | 1561 | 1465 | 6.29* | 35.6 | 36.0 | 0.00 | 26.7 | 28.1 | 0.07 |
| 3 | LRA 5166 x CIR 28A | 1970 | 1816 | 13.06** | 34.2 | 34.2 | 0.00 | 26.5 | 28.6 | 0.15 |
| 4 | LRA 5166 x CIR 32 | 1909 | 1667 | 35.13** | 32.8 | 32.6 | 0.00 | 25.3 | 27.1 | 0.12 |
| 5 | LRA 5166 x CIR 70 | 1859 | 1663 | 23.10** | 35.2 | 36.0 | 0.02 | 27.0 | 28.0 | 0.04 |
| 6 | LRA 5166 x CIR 72 | 1515 | 1364 | 16.72** | 35.2 | 35.4 | 0.00 | 28.4 | 27.9 | 0.01 |
| | **Total** | - | - | 99.62** | - | - | 0.04 | - | - | 0.52 |
| 7 | SH 2379 x CIR 23 A | 2121 | 2020 | 5.05* | 37.8 | 36.6 | 0.04 | 28.0 | 27.6 | 0.01 |
| 8 | SH 2379 x CIR 26 | 2020 | 1818 | 22.44** | 36.2 | 35.8 | 0.00 | 26.2 | 28.4 | 0.17 |
| 9 | SH 23 79 x CIR 28 A | 2475 | 2166 | 44.08** | 34.8 | 35.6 | 0.02 | 25.8 | 27.6 | 0.12 |
| 10 | SH 2379 x CIR 32 | 1566 | 1391 | 22.02** | 35.2 | 36.0 | 0.02 | 25.6 | 28.9 | 0.38 |
| 11 | SH 2379 x CIR 70 | 1866 | 1750 | 7.69** | 36.7 | 37.8 | 0.03 | 25.8 | 27.9 | 0.16 |
| 12 | SH 2379 x CIR 72 | 1869 | 1666 | 24.74** | 36.4 | 36.8 | 0.00 | 26.3 | 26.8 | 0.01 |
| | **Total** | - | - | 126.02** | - | - | 0.12 | - | - | 0.84 |
| 13 | Jhorar x CIR 23 A | 2374 | 2010 | 65.92** | 36.6 | 35.7 | 0.02 | 26.3 | 27.3 | 0.04 |
| 14 | Jhorar x CIR 26 | 2020 | 1814 | 23.39** | 33.8 | 33.8 | 0.00 | 26.7 | 28.1 | 0.07 |
| 15 | Jhorar x CIR 28 A | 2172 | 1909 | 36.23** | 35.2 | 34.9 | 0.00 | 27.3 | 27.5 | 0.00 |
| 16 | Jhorar x CIR 32 | 1818 | 1707 | 7.22** | 33.0 | 33.0 | 0.00 | 25.1 | 28.0 | 0.30 |
| 17 | Jhorar x CIR 70 | 1616 | 1465 | 15.56** | 36.0 | 35.4 | 0.01 | 24.6 | 27.4 | 0.29 |
| 18 | Jhorar x CIR 72 | 1750 | 1566 | 21.62** | 36.2 | 34.6 | 0.07 | 27.7 | 27.8 | 0.00 |
| | **Total** | - | - | 169.95** | - | - | 0.11 | - | - | 0.69 |
| 19 | B.N. x CIR 23 A | 2323 | 1960 | 67.23** | 36.7 | 37.6 | 0.02 | 26.1 | 27.2 | 0.04 |
| 20 | B.N. x CIR 26 | 2380 | 2273 | 5.04* | 35.0 | 34.7 | 0.00 | 25.6 | 26.8 | 0.05 |
| 21 | B.N. x CIR 28 A | 2020 | 1950 | 2.51 | 34.2 | 33.8 | 0.00 | 24.6 | 26.0 | 0.08 |
| 22 | B.N. x CIR 32 | 1515 | 1412 | 7.51** | 34.7 | 35.2 | 0.01 | 25.2 | 26.8 | 0.10 |
| 23 | B.N. x CIR 70 | 1768 | 1614 | 14.69** | 37.2 | 36.5 | 0.01 | 25.6 | 25.4 | 0.00 |
| 24 | B.N. x CIR 72 | 2626 | 2222 | 73.45** | 36.2 | 36.0 | 0.00 | 26.8 | 27.0 | 0.00 |
| | **Total** | 2105 | 1905 | 170.44** | 35.1 | 35.6 | 0.05 | 25.7 | 26.5 | 0.27 |
| 25 | F 505 x CIR 23 A | 1768 | 1555 | 29.18** | 35.6 | 35.6 | 0.00 | 27.2 | 28.6 | 0.07 |
| 26 | F 505 x CIR 26 | 2323 | 2017 | 46.42** | 34.2 | 33.9 | 0.00 | 28.3 | 27.3 | 0.04 |
| 27 | F 505 x CIR 28 A | 2525 | 2231 | 38.74** | 34.4 | 33.8 | 0.01 | 25.7 | 27.1 | 0.07 |
| 28 | F 505 x CIR 32 | 1813 | 1615 | 24.27** | 33.4 | 33.7 | 0.00 | 26.6 | 28.5 | 0.13 |
| 29 | F 505 x CIR 70 | 2222 | 1914 | 49.56** | 36.0 | 36.2 | 0.00 | 26.2 | 28.2 | 0.14 |
| 30 | F 505 x CIR 72 | 2020 | 1717 | 53.47** | 38.0 | 37.8 | 0.00 | 26.3 | 28.5 | 0.17 |
| | **Total** | - | - | 241.65** | - | - | 0.02 | - | - | 0.62 |

| Sr. No. | CMS hybrids | Uniformity ratio(%) | | | Micronaire value | | | Tenacity(g/tex) | | | Strength/length ratio | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conv. | CMS | $\chi^2$ | Conv. | CMS | $\chi^2$ | Conv. | CMS | $\chi^2$ | Conv. | CMS |
| 1 | LRA5166 x CIR23 A | 43.0 | 42.0 | 0.02 | 4.6 | 4.1 | 0.06 | 19.6 | 21.7 | 0.06 | 0.71 | 0.73 |
| 2 | LRA5166 x CIR26 | 46.0 | 44.0 | 0.09 | 4.3 | 4.1 | 0.01 | 20.6 | 23.5 | 0.01 | 0.77 | 0.84 |
| 3 | LRA5166 x CIR28A | 47.0 | 44.0 | 0.20 | 4.9 | 4.3 | 0.08 | 21.0 | 23.1 | 0.08 | 0.79 | 0.81 |
| 4 | LRA5166 x CIR32 | 49.0 | 45.0 | 0.36 | 4.8 | 4.2 | 0.09 | 20.7 | 22.1 | 0.09 | 0.82 | 0.82 |
| 5 | LRA5166 x CIR70 | 43.0 | 45.0 | 0.09 | 4.6 | 4.4 | 0.01 | 20.5 | 20.2 | 0.01 | 0.76 | 0.72 |
| 6 | LRA5166 x CIR72 | 45.0 | 43.0 | 0.09 | 4.4 | 4.4 | 0.00 | 22.0 | 22.2 | 0.00 | 0.77 | 0.80 |
| | **Total** | - | - | 0.86 | - | - | 0.25 | - | - | 0.25 | - | - |
| 7 | SH 2379 x CIR 23 A | 44.0 | 45.0 | 0.02 | 4.6 | 4.4 | 0.01 | 19.5 | 20.4 | 0.01 | 0.70 | 0.74 |
| 8 | SH 2379 x CIR 26 | 42.0 | 44.0 | 0.09 | 4.7 | 3.8 | 0.21 | 19.6 | 21.5 | 0.21 | 0.75 | 0.76 |
| 9 | SH 2379 x CIR 28 A | 43.0 | 46.0 | 0.20 | 4.5 | 4.0 | 0.06 | 19.6 | 21.5 | 0.06 | 0.76 | 0.78 |
| 10 | SH 23 79 x CIR 32 | 43.0 | 43.0 | 0.00 | 4.4 | 3.9 | 0.06 | 19.3 | 21.9 | 0.06 | 0.75 | 0.76 |
| 11 | SH 23 79 x CIR 70 | 42.0 | 42.0 | 0.00 | 4.7 | 4.0 | 0.12 | 18.4 | 20.9 | 0.12 | 0.71 | 0.75 |
| 12 | SH 2379 x CIR 72 | 44.0 | 45.0 | 0.02 | 4.8 | 4.2 | 0.09 | 19.5 | 22.3 | 0.09 | 0.74 | 0.83 |
| | **Total** | - | - | 0.33 | - | - | 0.56 | - | - | 0.56 | - | - |
| 13 | Jhorar x CIR 23 A | 47.0 | 41.0 | 0.88 | 5.2 | 4.3 | 0.19 | 21.3 | 19.5 | 0.19 | 0.81 | 0.71 |
| 14 | Jhorarx CIR 26 | 44.0 | 41.0 | 0.22 | 4.7 | 4.1 | 0.09 | 21.3 | 21.3 | 0.09 | 0.80 | 0.76 |
| 15 | Jhorar x CIR 28 A | 46.0 | 45.0 | 0.02 | 4.5 | 3.8 | 0.13 | 20.6 | 21.8 | 0.13 | 0.75 | 0.79 |
| 16 | Jhorar x CIR 32 | 45.0 | 47.0 | 0.09 | 5.0 | 4.1 | 0.20 | 19.8 | 22.0 | 0.20 | 0.79 | 0.79 |
| 17 | Jhorar x CIR 70 | 47.0 | 44.0 | 0.20 | 4.8 | 4.0 | 0.16 | 19.6 | 21.2 | 0.16 | 0.80 | 0.77 |
| 18 | Jhorar x CIR 72 | 43.0 | 47.0 | 0.34 | 4.6 | 3.9 | 0.13 | 21.3 | 22.9 | 0.13 | 0.77 | 0.82 |
| | **Total** | - | - | 1.75 | - | - | 0.89 | - | - | 0.89 | - | - |
| 19 | B.N. x CIR 23 A | 46.0 | 42.0 | 0.38 | 4.8 | 3.9 | 0.21 | 20.4 | 22.0 | 0.21 | 0.78 | 0.81 |
| 20 | B.N. x CIR 26 | 43.0 | 46.0 | 0.20 | 4.4 | 3.8 | 0.09 | 21.5 | 22.8 | 0.09 | 0.84 | 0.85 |
| 21 | B.N. x CIR 28 A | 48.0 | 45.0 | 0.20 | 5.2 | 3.7 | 0.61 | 21.3 | 20.3 | 0.61 | 0.87 | 0.78 |
| 22 | B.N. x CIR 32 | 45.0 | 52.0 | 0.94 | 5.0 | 3.5 | 0.64 | 19.0 | 22.5 | 0.64 | 0.75 | 0.84 |
| 23 | B.N. x CIR 70 | 42.0 | 45.0 | 0.20 | 4.7 | 3.3 | 0.59 | 20.2 | 22.5 | 0.59 | 0.79 | 0.89 |
| 24 | B.N. x CIR 72 | 47.0 | 47.0 | 0.00 | 4.5 | 4.0 | 0.06 | 21.4 | 22.5 | 0.06 | 0.80 | 0.83 |
| | **Total** | - | - | 1.92 | - | - | 2.21 | - | - | 2.21 | - | - |
| 25 | F 505 x CIR 23 A | 45.0 | 47.0 | 0.09 | 4.6 | 4.3 | 0.02 | 20.8 | 22.0 | 0.02 | 0.76 | 0.77 |
| 26 | F 505 x CIR 26 | 51.0 | 44.0 | 1.11 | 4.8 | 3.8 | 0.26 | 21.3 | 22.0 | 0.26 | 0.75 | 0.81 |
| 27 | F 505 x CIR 28 A | 46.0 | 48.0 | 0.08 | 4.6 | 4.4 | 0.01 | 21.8 | 21.7 | 0.01 | 0.85 | 0.80 |
| 28 | F 505 x CIR 32 | 45.0 | 45.0 | 0.00 | 4.8 | 4.4 | 0.04 | 21.4 | 21.6 | 0.04 | 0.80 | 0.76 |
| 29 | F 505 x CIR 70 | 48.0 | 47.0 | 0.02 | 4.8 | 4.3 | 0.06 | 20.5 | 20.7 | 0.06 | 0.78 | 0.73 |
| 30 | F 505 x CIR 72 | 48.0 | 45.0 | 0.20 | 4.5 | 4.9 | 0.03 | 20.0 | 21.1 | 0.03 | 0.76 | 0.74 |
| | **Total** | - | - | 1.50 | - | - | 0.42 | - | - | 0.42 | - | - |

*,**Significant at 5% and 1% level, respectively; Conv. = Conventional

**Table 2.** Percent decrease/increase of seed cotton yield, ginning out turn and fibre quality traits of A x R hybrids over B x R hybrids

| Sr.No. | CMS hybrids | Seed cotton yield (kg/ha) | | | GOT (%) | | | 2.5 span length (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Conv. | CMS | % decr/ incr. | Conv. | CMS | % decr/ incr. | Conv. | CMS | % decr/ incr. |
| 1 | LRA5166 x CIR23 A | 1865 | 1768 | –5.20 | 35.2 | 34.4 | 2.27 | 27.7 | 29.7 | 7.22 |
| 2 | LRA5166 x CIR26 | 1561 | 1465 | –6.15 | 35.6 | 36.0 | –1.12 | 26.7 | 28.1 | 5.24 |
| 3 | LRA5166 x CIR28A | 1970 | 1816 | –7.82 | 34.2 | 34.2 | 0.00 | 26.5 | 28.6 | 7.92 |
| 4 | LRA5166 x CIR32 | 1909 | 1667 | –12.68 | 32.8 | 32.6 | 0.61 | 25.3 | 27.1 | 7.11 |
| 5 | LRA5166 x CIR70 | 1859 | 1663 | –10.54 | 35.2 | 36.0 | –2.27 | 27.0 | 28.0 | 3.70 |
| 6 | LRA5166 x CIR72 | 1515 | 1364 | –9.97 | 35.2 | 35.4 | –0.57 | 28.4 | 27.9 | –1.76 |
| 7 | SH 2379 x CIR 23 A | 2121 | 2020 | –4.76 | 37.8 | 36.6 | 3.17 | 28.0 | 27.6 | –1.43 |
| 8 | SH 2379 x CIR 26 | 2020 | 1818 | –10.00 | 36.2 | 35.8 | 1.10 | 26.2 | 28.4 | 8.40 |
| 9 | SH 2379 x CIR 28 A | 2475 | 2166 | –12.48 | 34.8 | 35.6 | –2.30 | 25.8 | 27.6 | 6.98 |
| 10 | SH 2379 x CIR 32 | 1566 | 1391 | –11.17 | 35.2 | 36.0 | –2.27 | 25.6 | 28.9 | 12.89 |
| 11 | SH 2379 x CIR 70 | 1866 | 1750 | –6.22 | 36.7 | 37.8 | –3.00 | 25.8 | 27.9 | 8.14 |
| 12 | SH 2379 x CIR 72 | 1869- | 1666 | –10.86 | 36.4 | 36.8 | –1.10 | 26.3 | 26.8 | 1.90 |
| 13 | Jhorar x CIR 23 A | 2374 | 2010 | –15.33 | 36.6 | 35.7 | 2.46 | 26.3 | 27.3 | 3.80 |
| 14 | Jhorar x CIR 26 | 2020 | 1814 | –10.20 | 33.8 | 33.8 | 0.00 | 26.7 | 28.1 | 5.24 |
| 15 | Jhorar x CIR 28 A | 2172 | 1909 | –12.11 | 35.2 | 34.9 | 0.85 | 27.3 | 27.5 | 0.73 |
| 16 | Jhorar x CIR 32 | 1818 | 1707 | –6.11 | 33.0 | 33.0 | 0.00 | 25.1 | 28.0 | 11.55 |
| 17 | Jhorar x CIR 70 | 1616 | 1465 | –9.34 | 36.0 | 35.4 | 1.67 | 24.6 | 27.4 | 11.38 |
| 18 | Jhorar x CIR 72 | 1750 | 1566 | –10.51 | 36.2 | 34.6 | 4.42 | 27.7 | 27.8 | 0.36 |
| 19 | B.N. x CIR 23 A | 2323 | 1960 | –15.63 | 36.7 | 37.6 | –2.45 | 26.1 | 27.2 | 4.21 |
| 20 | B.N. x CIR 26 | 2380 | 2273 | –4.50 | 35.0 | 34.7 | 0.86 | 25.6 | 26.8 | 4.69 |
| 21 | B.N. x CIR 28 A | 2020 | 1950 | –3.47 | 34.2 | 33.8 | 1.17 | 24.6 | 26.0 | 5.69 |
| 22 | B.N. x CIR 32 | 1515 | 1412 | –6.80 | 34.7 | 35.2 | –1.44 | 25.2 | 26.8 | 6.35 |
| 23 | B.N. x CIR 70 | 1768 | 1614 | –8.71 | 37.2 | 36.5 | 1.88 | 25.6 | 25.4 | –0.78 |
| 24 | B.N. x CIR 72 | 2626 | 2222 | –15.38 | 36.2 | 36.0 | 0.55 | 26.8 | 27.0 | 0.75 |
| 25 | F 505 x CIR 23 A | 1768 | 1555 | –12.05 | 35.6 | 35.6 | 0.00 | 27.2 | 28.6 | 5.15 |
| 26 | F 505 x CIR 26 | 2323 | 2017 | –13.17 | 34.2 | 33.9 | 0.88 | 28.3 | 27.3 | –3.53 |
| 27 | F 505 x CIR 28 A | 2525 | 2231 | –11.64 | 34.4 | 33.8 | 1.74 | 25.7 | 27.1 | 5.45 |
| 28 | F 505 x CIR 32 | 1813 | 1615 | –10.92 | 33.4 | 33.7 | –0.90 | 26.6 | 28.5 | 7.14 |
| 29 | F 505 x CIR 70 | 2222 | 1914 | –13.86 | 36.0 | 36.2 | –0.56 | 26.2 | 28.2 | 7.63 |
| 30 | F 505 x CIR 72 | 2020 | 1717 | –15.00 | 38.0 | 37.8 | 0.53 | 26.3 | 28.5 | 8.37 |

| Sr.No. | CMS hybrids | Uniformity ratio(%) | | | Micronaire value | | | Tenacity(g/tex) | | | Strength/length ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conv. | CMS | % decr/ incr. | Conv. | CMS | % decr/ incr. | Conv. | CMS | % decr/ incr. | Conv. | CMS | % decr/ incr. |
| 1 | LRA5166 x CIR23 A | 43.0 | 42.0 | –2.38 | 4.6 | 4.1 | –10.87 | 19.6 | 21.7 | 10.71 | 0.71 | 0.73 | 2.53 |
| 2 | LRA5166 x CIR26 | 46.0 | 44.0 | –4.55 | 4.3 | 4.1 | –4.65 | 20.6 | 23.5 | 14.08 | 0.77 | 0.84 | 0.00 |
| 3 | LRA5166 x CIR28A | 47.0 | 44.0 | –6.82 | 4.9 | 4.3 | –12.24 | 21.0 | 23.1 | 10.00 | 0.79 | 0.81 | –5.26 |
| 4 | LRA5166 x CIR32 | 49.0 | 45.0 | –8.89 | 4.8 | 4.2 | –12.50 | 20.7 | 22.1 | 6.76 | 0.82 | 0.82 | 3.90 |
| 5 | LRA5166 x CIR70 | 43.0 | 45.0 | 4.44 | 4.6 | 4.4 | –4.35 | 20.5 | 20.2 | –1.46 | 0.76 | 0.72 | 1.30 |
| 6 | LRA5166 x CIR72 | 45.0 | 43.0 | –4.65 | 4.4 | 4.4 | 0.00 | 22.0 | 22.2 | 0.91 | 0.77 | 0.80 | 5.71 |
| 7 | SH 2379 x CIR 23 A | 44.0 | 45.0 | 2.22 | 4.6 | 4.4 | –4.35 | 19.5 | 20.4 | 4.62 | 0.70 | 0.74 | 2.63 |
| 8 | SH 2379 x CIR 26 | 42.0 | 44.0 | 4.55 | 4.7 | 3.8 | –19.15 | 19.6 | 21.5 | 9.69 | 0.75 | 0.76 | 1.33 |
| 9 | SH 2379 x CIR 28 A | 43.0 | 46.0 | 6.52 | 4.5 | 4.0 | –11.11 | 19.6 | 21.5 | 9.69 | 0.76 | 0.78 | 5.63 |
| 10 | SH 2379 x CIR 32 | 43.0 | 43.0 | 0.00 | 4.4 | 3.9 | –11.36 | 19.3 | 21.9 | 13.47 | 0.75 | 0.76 | 12.16 |
| 11 | SH 2379 x CIR 70 | 42.0 | 42.0 | 0.00 | 4.7 | 4.0 | –14.89 | 18.4 | 20.9 | 13.59 | 0.71 | 0.75 | 4.05 |
| 12 | SH 2379 x CIR 72 | 44.0 | 45.0 | 2.22 | 4.8 | 4.2 | –12.50 | 19.5 | 22.3 | 14.36 | 0.74 | 0.83 | –12.35 |
| 13 | Jhorar x CIR 23 A | 47.0 | 41.0 | 14.63 | 5.2 | 4.3 | –17.31 | 21.3 | 19.5 | –8.45 | 0.81 | 0.71 | 5.33 |
| 14 | Jhorar x CIR 26 | 44.0 | 41.0 | –7.32 | 4.7 | 4.1 | –12.77 | 21.3 | 21.3 | 5.83 | 0.80 | 0.76 | 0.00 |
| 15 | Jhorar x CIR 28 A | 46.0 | 45.0 | –2.22 | 4.5 | 3.8 | –15.56 | 20.6 | 21.8 | 11.11 | 0.75 | 0.79 | –3.75 |
| 16 | Jhorar x CIR 32 | 45.0 | 47.0 | 4.26 | 5.0 | 4.1 | –18.00 | 19.8 | 22.0 | 8.16 | 0.79 | 0.79 | 6.49 |
| 17 | Jhorar x CIR 70 | 47.0 | 44.0 | –6.82 | 4.8 | 4.0 | –16.67 | 19.6 | 21.2 | 7.51 | 0.80 | 0.77 | –2.53 |
| 18 | Jhorar x CIR 72 | 43.0 | 47.0 | 8.51 | 4.6 | 3.9 | –15.22 | 21.3 | 22.9 | 3.86 | 0.77 | 0.82 | 3.85 |
| 19 | B.N. x CIR 23 A | 46.0 | 42.0 | –9.52 | 4.8 | 3.9 | –18.75 | 20.4 | 22.0 | 6.05 | 0.78 | 0.81 | –10.34 |
| 20 | B.N. x CIR 26 | 43.0 | 46.0 | 6.52 | 4.4 | 3.8 | –13.64 | 21.5 | 22.8 | –4.69 | 0.84 | 0.85 | 12.00 |
| 21 | B.N. x CIR 28 A | 48.0 | 45.0 | –6.67 | 5.2 | 3.7 | –28.85 | 21.3 | 20.3 | 18.42 | 0.87 | 0.78 | 12.66 |
| 22 | B.N. x CIR 32 | 45.0 | 52.0 | 13.46 | 5.0 | 3.5 | –30.00 | 19.0 | 22.5 | 11.39 | 0.75 | 0.84 | 3.75 |
| 23 | B.N. x CIR 70 | 42.0 | 45.0 | 6.67 | 4.7 | 3.3 | –29.79 | 20.2 | 22.5 | 5.14 | 0.79 | 0.89 | 3.75 |
| 24 | B.N. x CIR 72 | 47.0 | 47.0 | 0.00 | 4.5 | 4.0 | –11.11 | 21.4 | 22.5 | 7.28 | 0.80 | 0.83 | 1.32 |
| 25 | F 505 x CIR 23 A | 45.0 | 47.0 | 4.26 | 4.6 | 4.3 | –6.52 | 20.8 | 22.0 | 3.29 | 0.76 | 0.77 | –5.88 |
| 26 | F 505 x CIR 26 | 51.0 | 44.0 | –15.91 | 4.8 | 3.8 | –20.83 | 21.3 | 22.0 | 0.46 | 0.75 | 0.81 | –5.00 |
| 27 | F 505 x CIR 28 A | 46.0 | 48.0 | 4.17 | 4.6 | 4.4 | –4.35 | 21.8 | 21.7 | 0.93 | 0.85 | 0.80 | –6.41 |
| 28 | F 505 x CIR 32 | 45.0 | 45.0 | 0.00 | 4.8 | 4.4 | –8.33 | 21.4 | 21.6 | 0.98 | 0.80 | 0.76 | –2.63 |
| 29 | F 505 x CIR 70 | 48.0 | 47.0 | –2.13 | 4.8 | 4.3 | –10.42 | 20.5 | 20.7 | 5.50 | 0.78 | 0.73 | –2.53 |
| 30 | F 505 x CIR 72 | 48.0 | 45.0 | –6.67 | 4.5 | 4.9 | 8.89 | 20.0 | 21.1 | 2.38 | 0.76 | 0.74 | |

Conv. = Conventional; decr. = decrease; incr. = increase

combinations F 505A x CIR 72. The highest reduction in micronaire value was up to 30% Bikaneri Narma A x CIR 32 hybrid with sterile cytoplasm. Similarly, 27 CMS based hybrid combinations showed increase in tenacity value as compared to hybrids produced with normal cytoplasm of *G. hirsutum*, which also reflected better strength/length ratio, a desirable character from modern textile spinning point of view. However, for uniformity ratio, no definite trend was observed between A x R and B x R hybrids (Table 2).

For understanding the reasons of low yield in hybrids with sterile cytoplasm (A x R) as compared to hybrids with normal cytoplasm (B x R) the effect of restorer lines on *G. harknessii* cytoplasm was studied by, the bolls developed from selfed flowers and open

**Table 3.** Estimation of fertility restoration percentage in CGMS based intraspecific hybrids of G. *hirsutum*

| CMS lines | Restorer lines | | | | | |
|---|---|---|---|---|---|---|
| | CIR23A | CIR26 | CIR28A | CIR32 | CIR70 | CIR72 |
| LRA 5166 A | 84.0 | 81.5 | 86.4 | 100 | 83.3 | 81.8 |
| SH 2379 A | 91.7 | 95.0 | 84.0 | 87.0 | 95.2 | 85.7 |
| Jhorar A | 82.6 | 80.8 | 88.7 | 75.0 | 84.0 | 83.3 |
| Bikaneri Narma A | 87.0 | 91.7 | 89.7 | 84.0 | 88.5 | 88.5 |
| F 505 A | 86.4 | 95.8 | 95.5 | 96.2 | 84.6 | 84.0 |
| Mean | 86.3 | 89.0 | 88.7 | 88.8 | 87.12 | 84.7 |

**Table 4.** Top cross combinations on the basis of mean performance and heterosis for seed cotton yield and fibre quality traits

| S.No. | Hybrids | Seed cotton yield (kg/ha) | Hete-rosis | GOT (%) | Hete-rosis | 2.5% span length (mm) | Hete-rosis | U.R. (%) | Hete-rosis | Mic. value | Hete-rosis | Tena-city (g/tex) | Hete-rosis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | F 505 B x CIR 28 A | 2525 | 20.24 | 34.4 | 2.99 | 25.7 | -5.86 | 46.0 | 0.00 | 4.6 | -9.80 | 21.8 | -8.40 |
| 2 | SH2379B x CIR28A | 2475 | 17.86 | 33.8 | 1.20 | 25.8 | -5.49 | 43.0 | -6.52 | 4.5 | -11.76 | 19.6 | -17.65 |
| 3 | JhorarB x CIR23A | 2374 | 15.05 | 36.6 | 9.58 | 26.3 | -3.66 | 47.0 | 2.17 | 5.2 | 1.96 | 21.3 | -10.50 |
| 4 | B.N.B x CIR23A | 2323 | 10.62 | 35.2 | 5.39 | 26.1 | -4.40 | 46.0 | 0.00 | 4.8 | -5.88 | 20.4 | -14.29 |
| 5 | F505B x CIR26 | 2323 | 10.62 | 34.2 | 2.40 | 28.3 | 3.66 | 51.0 | 10.87 | 4.8 | -5.88 | 21.3 | -10.50 |
| 6 | CSHH 198 (LC) | 2100 | - | 33.4 | - | 27.3 | - | 46.0 | - | 5.1 | - | 23.8 | - |

pollinated flowers examining the number of seeds/boll. The data on seed setting percentage presented in Table 3, envisaged that the mean selfed seed percentage in the intra *hirsutum* crosses with a particular restorer line ranged from 84.7 to 89.0 percent. The CMS based cross combination LRA 5166 A x CIR 32, showed 100 percent seed set upon selfing. Based on fertility restoring capacity, almost all the hybrids with sterile cytoplasm recorded more than 80 per cent seed set in selfing except in Jhorar x CIR 32 (75.0 %) and BN x CIR 23A (78.0%). This indicated that fertility restoration is complex phenomenon in cotton crop [11,15]. It was also observed that the number of seeds in case of selfed bolls of all the CMS based hybrids were found significantly less as compared to open pollinated bolls, which indicated that aborted seed percentage might be higher in case with sterile cytoplasm as female and consequently the low seed cotton yield in these hybrids. Wang *et al*. [16] and Yu and Wang [17] studied the performance of hybrids with DES-HAF 277 fertility restorer and concluded that, lower restorability of DES-HAF 277 was the major reason of lower yield in CMS based hybrids.

Based on seed cotton yield and other contributing characters only five $F_1$ hybrids, out of 60, were considered for analysing magnitude of hererosis. The hybrid F 505 B x CIR 28A produced highest seed cotton yield (2525 kg/ha) which accounts for 20.24 % superiority over the conventional check hybrid CSHH 198. Other crosses having significantly high seed cotton yield were SH 2379B x CIR 28A, Jhorar B x CIR 23A, Bikaneri Narma B x CIR 23A and F 505B x CIR 26, having 17.86, 15.05 and 10.62 heterosis over best check hybrid respectively. These hybrids were also superior for ginning outturn per cent and micronaire value. In conclusion, although male sterile cytoplasm has some negative effect on seed cotton yield, but has positive effect on ginning out turn and fibre quality traits. However, by using restorers with high restorability and stable CMS lines, synthesis of more number of cross combinations it might be possible to find out hybrids with high heterotic potential as discussed in preceding paragraph. Some of these hybrids (Table 4) can be released for commercial cultivation after confirmation of their performance in multilocation trials. Secondly, good restorers like CIR 28A and CIR 23A showed desirable restorability, should be used to solve the problem of poor fertility restoration in hybrids especially CMS based hybrids.

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