Male sterility- New Frontiers in Cotton Breeding

B.M. Khadi, V.N. Kulkarni, I.S. Katageri and R.R. Soddi
Agricultural Research Station, Dharwad Farm-580008, India

ABSTRACT

Conventional hybrid cottonseed production is expensive and this has paved the way for intensification of research into male sterility systems in cotton. Histological, morphological differences, yield and fiber properties and changed restorer background were studied to establish facts on male sterility systems. Post meiotic obstruction in pollen development in GMS and pre-meiotic abnormalities in CGMS caused sterility in cotton. Morphologically fertile and sterile counterparts looked alike except for flower traits where significant reductions in ovary size, staminal column, style and anther filament length and anther number in CGMS. This was not apparent with GMS. Despite reports of reduction in yield with CGMS based hybrids compared to conventional hybrids of the same parents, some entirely new combinations of CGMS hybrids proved economically worthwhile. A comparison between two restorer lines, one based on G. hirsutum and the other on G. harknessii backgrounds, the latter proved superior for stable restoration. Among 64 lines converted, eight had a GOT above 40%, 33 had a seed index of 10 g or more and 11 had a halo length above 30 mm. A halo length of 28 mm, seed index up to 12 g and GOT up to 40% was observed in R lines. Hybrids of selected 12 lines and eight R lines exhibited heterosis for yield and boll features compared to the conventional checks. This emphasizes better performance of diversified A and R lines for hybrid production. The possibility of good CGMS lines in G aridum background is predicted.

Introduction

Existence of male sterility in cotton has created a new chapter in hybrid cotton breeding. India is the only country that has accepted conventional cotton hybrids on commercial scale in its Southern and Central regions. The fact that conventional hybrid cottonseed production involves tedious and costly process of hand emasculation has geared up intensive research on male sterility (MS) in cotton.

Material and Methods

The genetic male sterile (GMS) experimental material consisted of Gregg sterile and fertile lines in tetraploids. In the cytoplasmic male sterility (CMS) system, 12 A-lines (DMSA-1 to 12), 4 B-lines (DMSB-1 to 4) and 8 R-lines (DR-1 to 8) were used. Overall mean values of A and B lines were considered for comparison. 16 MS based hybrids (4 A x 4 R) in one set and 96 hybrids (12 A x 8 R) in another set were evaluated and 64 converted B-lines and 8R lines were studied for *per se* performance and hybrid vigour.

The histological basis of sterile and fertile plants were studied with light microscopy (Jensen, 1962). Mercuric bromophenol blue was used to stain the sections.

Results and Discussion

Histological basis of male sterility systems in cotton

a) Genetic male sterility system (GMS)

The process of microsporogenesis in genetic male sterile and fertile anthers was similar until shortly after meiosis when pollen development in sterile anthers began to diverge. The vacuolation of microspores was associated with crushing of chromatin material forming a convoluted nucleus coupled with shrinkage of microspore cytoplasm ultimately lead to the breakdown of deformed developing microspores, leading to sterility in the GMS line. Murthi and Weaver (1974) made similar observations.

b) Cytoplasmic male sterility (CMS)

The microsporogenesis in cytoplasm male sterile and fertile anthers was studied and conspicuous abnormal behaviour of the tapetum was noticed. Premature degeneration of the tapetum arrested the normal course of meiosis in sterile lines. These pre-meiotic abnormalities caused sterility in the CMS line, however the normal process of pollen development was observed in fertile anthers.

Influence of sterile cytoplasm/ nuclear MS genes on morphology of CMS/ GMS plants

Morphological traits did not differ significantly in GMS and CMS systems compared to their fertile versions (Richmond and Kohel, 1961). Sterile lines (GMS/CMS)

had significantly lower values for various flower-related traits except anther number compared to the fertile lines. However, there was no significant difference between GMS and fertile plants for characters like calyx area, ovary length and width or style length (Table 1). Shroff (1985) made similar observations. Non-significant differences were observed between sterile (GMS/CMS) and their respective fertile plants for yield and yield related traits (Table 1), indicating that sterile cytoplasm/nuclear MS genes do not affect the per se performance, but reduce flower size. Meyer (1973) made similar observations. Few A lines and their B-lines exhibited significant differences, except for 2.5 % span length and fiber strength (Table 1).

The varied performance between sterile and fertile lines might be the result of differential behaviour of the same genome in the sterile and fertile cytoplasms (Meyer, 1973), or sterile cytoplasm provides an unstable substrate(s) for the paternal genes. In addition, the presence of cytoplasmic factors per se may influence the expression of the phenotype (Rhyne, 1965).

Performance of male sterile based intra *hirsutum* hybrids

A total of 16 hybrids and four A and R lines were studied for yield and fiber characteristics in comparison with conventional hybrids, in a line x tester design under rainfed conditions. The abstracted data on parents, hybrids and checks is presented in Table 2.

a) MS based intra hirsutum hybrids compared with their parents

Male sterile and restorer performance was compared with hybrids. Hybrids exhibited significantly superior seed cotton yield compared to parents. The higher range of parents, 18.0 q/ha was the lower range of hybrids and similar observations were made with lint yield. Characters like number of monopodia and sympodia, boll weight, seeds per boll and seed index were found to be transmitted from the male parents since means and range values of these characters were similar in hybrids.

b) Comparison between MS based hybrids with conventional intra hirsutum hybrids

Mean and range of different characters of the 16 hybrids under experimentation were compared with conventional hybrids like DHH-11 (State check) and NHH-44. (National check).

The data indicate the possibility of producing a successful MS based hybrid that is comparable to high yielding conventional checks. Mean or range values of different characters of MS hybrids were on par with the checks DHH 11 and NHH-44. The performance of the top yielding MS based hybrid, DMSHH-4, was on par with both the checks for almost all the characters. These observations were in agreement with Bhale and Bhat (1990).

Conversion of male sterility, diversification of restorers and hybrid vigour

The experience of breeders in India is that if the parents of high yielding conventional hybrids are converted into CMS lines, the hybrid will be lower yielding than the original conventional hybrid. It was thought necessary to convert large numbers of elite lines into A and R lines and then evaluate hybrids made from the converted lines for heterosis. In the respect, a total of 64 identical superior genotypes were converted into male sterile lines with *G. harknessii* cytoplasm and evaluated for yield, yield related and fiber traits. They were compared with the parents possessing good combining ability of superior conventional hybrids. Simultaneously, restorer genes were transferred to eight superior lines. The per se performance of converted A and R lines is given Table 3. The results indicate the possibility of producing male sterile and restorer lines comparable to the parents of the best conventional hybrids.

A set of 96 new hybrids produced from 12 selected A lines and eight restorers was evaluated for seed cotton yield and boll weight under a water stress situation (Table 4). Heterosis up to 40.5 per cent was observed over the National Check NHH-44. However, no significant heterosis for seed cotton yield was observed over DHH 11. Similarly, 51 hybrids out of ninety six were found on par with NHH 44 and 14 hybrids with DHH 11 (Table 4). Significant improvement for boll weight was observed. Some of the highs yielding male sterile based hybrids were DMSHH Nos. 53, 49, 55, 73 and 52. Male sterile lines DMSA-1, 28 and 11 and restorers DR-5 and DR-7 were found to produce good hybrids suited for commercial utilization. The reduction in flower size and morphology never affected the production of MS based hybrids which were on par or superior to conventional hybrids. The objective of breeders in India is to produce MS based hybrids at least on par with conventional checks that will enable the farmer to get cheaper hybrid seed.

Acknowledgements

Our thanks to are due to Rajesh Meti, AAO for helping in the evaluation of MS hybrids.

References

Bhale, N.L. and M.G. Bhat. (1990): Investigations on exploitation of heterosis in cotton (*Gossypium hirsutum*) using male sterility. Indian J. Genet. 50:37-44.

Jensen, W.A. (1962): Botanical histochemistry: Principles and Practices. W.H. Freeman and Co. San Francisco.

Mazia, D., P.A. Brewar and M. Albert (1953): The cytological staining and measurement of proteins

with murcuric bromophenal blue – Bio.Bull., 104:57-67.

Meyer, V.G. (1971): Some effects of *G.harkenessi* cytoplasm on the number and fertility of cotton anthers – Agronomy Abstracts, 12:28-32.

Meyer, V.G. (1973): A study of reciprocal hybrids between upland cotton and experimental lines with cytoplasms from seven other species – Crop Sci. 13:439-444.

Murthi, A.N. and J.B. Weaver, Jr. (1974): Histological studies on five male sterile strains of upland cotton – Crop Science. 14:658-663.

Rhyne, C.L. (1965): Cytoplasmic inheritance of reduced androecium in cotton –The Journal of Heredity. 61:67-70.

Richmond, T.R. and R.J Kohel. (1961): Analysis of a completely male-sterile character in American upland cotton. Crop Science 1:397-401.

Table 1. Comparison between male sterile and respective maintainers for different traits in cotton.

Traits	Mean of		t/Z/CD value	Overall mean of		t/z/CD value
	GMS Sterile	GMS Fertile		4 CGMS 'A' lines	4 Fertile 'B'lines	
Morphological traits			**t value**			**t value**
Plant height (cm)	85.6	84.9	0.3132	87.97	88.07	0.0369
Stem diameter (cm)	0.88	0.79	1.0060	0.86	0.82	0.8878
Leaf area (cm^2)	27.57	24.71	1.2570	44.3	39.6	1.0599
Flower traits			**Z value**			**Z value**
Pedicel length (cm)	1.06	1.17	1.9920*	0.87	1.35	5.2266**
Calyx area ((cm^2)	1.89	1.97	1.6700	1.61	2.13	8.0229**
Bract area (cm^2)	3.44	3.77	2.9340**	3.09	3.79	3.3596*
Corolla area (cm^2)	8.44	8.98	2.1930*	4.87	8.21	9.2803*
Ovary length (cm)	0.57	0.59	0.9520	0.60	0.81	1.8144**
Ovary width (cm)	0.61	0.66	0.1490	0.57	0.68	6.5142**
Staminal column length (cm)	1.60	2.25	23.4780**	1.53	2.05	0.9810**
Style length (cm)	1.78	1.85	1.9480	1.57	1.89	6.4417**
Filament length (cm)	0.33	0.59	21.3220**	0.29	0.54	13.775**
Anther number	92.6	80.1	9.0330**	92.07	84.3	4.2384**
Yield related traits.			**CD at 5%**			**CD at 5%**
Monopodia	1.93	1.87	0.13	1.7-1.9	1.7-1.9	NS
Sympodia	9.73	10.0	0.81	8.6-10.4	8.5-10.5	0.81
Fruiting points	95.4	96.0	15.50	83.9-114.8	84.3-112.7	15.5
Boll wt(g)	4.85	4.63	0.65	2.8-5.2	3.1-5.4	0.65
GOT (%)	43.5	44.3	7.46	33.1-43.6	35.9-44.5	7.5
Seed index(G)	8.82	8.92	0.27	7.7-10.1	7.8-10.2	0.3
Lint index (g)	6.67	7.20	2.28	3.8-7.7	4.3-7.6	2.3
Bolls/plant	17.0	18.2	3.25	14.5-19.9	12.3-19.5	3.2
Yield/plant(g)	78.2	80.2	16.7	49.6-85.6	51.9-88.8	16.7
Fiber related traits						**CD at 5%**
2.5% Span length (mm)	-	-	-	27.8-33.6	26.4-30.8	1.55
Micronaire	-	-	-	3.6-4.3	3.4-3.9	0.47
Maturity Co-efficient	-	-	-	0.66-0.74	0.68-0.72	NS
Uniformity Ratio %	-	-	-	48.6-52.3	50.3-52.0	NS
Strength (g/tex)3.2mm gauge	-	-	-	18.8-27.7	19.3-22.3	1.02

Table 2. Performance of male sterile intra hirsutum hybrids compared with their parents and conventional commercial checks for yield and fiber properties.

Characters	Overall mean and range of				Top MS Hybrid	Commercial checks		CD	CV%
	8 Parents	4 Females	4 Restorers	16 Hybrids	DMSH H-4	DHH-11	NHH-44		
Yield Related									
Monopodia/ plant	2.26 1.3-2.9	2.5 2.1-2.9	1.8 1.3-2.1	1.8 1.4-2	1.5	2.6	1.3	0.4	13.2
Sympodia/ plant	20.9 17.1-28.1	22.5 20.3-28.1	19.4 17.1-20.8	20.3 18.2-23.3	20.1	23.6	23.1	3.9	11.8
Bolls/Plant	11.3 8.5-16.4	13 10.2-16.4	9.6 8.5-7.10	13.4 10.5-18.7	13.3	14.5	12.5	3.4	16.8
Boll/Wt.(g)	6.1 3.1-7.6	5.3 3.1-7	6.8 6.1-7.6	6.8 5.4-7.8	7.1	6.7	5.9	0.7	7.1
Seeds/Boll	33.5 27.1-40.0	30.2 27.1-36.8	36.8 33.1-40	35.8 33.0-38.6	37.1	35.3	38.4	4.0	7.1
Seed Index (g)	11.3 7.3-12.6	10.5 7.3-12.6	12.1 11.5-12.3	11.6 9.5-13.5	11.6	10.9	9.8	1.4	7.8
Lint Index (g)	6.7 4.3-8.4	6.8 4.3-8.4	6.5 6.2-6.9	7.5 6.1-8.4	7.5	7.9	5.8	1.0	8.9
Seed Cotton yield(q/ha)	15.2 11.6-18	15 11.6-18	15.4 14.5-16.3	20.1 18.1-22.9	22.9	23	18.8	4.1	13.7
GOT (%)	37.1 33.6-44.4	39.2 37.0-44.4	35 33.6-37.5	39.4 37.6-42.3	39.2	42.1	37.3	3.0	5.0
Lint yield (kg/ha)	5.6 4.3-6.7	5.9 4.3-6.7	5.4 4.8-6.1	8.0 7.1-9.0	9.0	9.7	7.0	1.7	14.7
Fiber Properties									
Fiber length (mm)	28.3 26.6-31.7	29.2 27.4-31.7	27.4 26.6-29	29 27.4-30.6	27.4	28.9	28.7	1.5	2.4
Uniformity Ratio	44.9 41.7-47	43.4 41.7-45.7	46.3 44.7-47	46 44.3-47.7	47.7	45	45.3	2.2	2.2
Micronaire	3.6 3.0-4.10	3.9 3.7-4.10	3.3 3.0-3.7	3.7 3.5-4.1	3.9	4.0	3.7	0.3	4.0
Maturity Co-efficient	0.68 0.61-0.73	0.71 0.70-.73	0.64 0.61-0.70	0.70 0.68-0.74	0.72	0.73	0.70	0.2	1.9
Strength (g/ tex) “0"gauge	40.2 34.6-45.4	43.5 39.1-45.4	37 34.6-39.1	37.7 35.7-41.2	38.9	40.6	38.9	3.0	4.0

Table 3. Characteristics of new B and R lines.

Character	Mean and range of 64 B lines	No. of B lines superior to check (parent)	Range of 8 R lines	No. of R lines superior to check (parent)
Ginning Out Turn %	36.2 (32-43.0)	8 (>40%)	32-40	1 (>40%)
Seed Index (g)	9.7 (7.0-12.0)	33 (>10g)	9.0-12.0	6 (>10 g)
Lint Index (g)	5.4 (3.3-7.3)	18 (>6.0g)	5.1-8.5	5 (>6.0)
Halo length (mm)	26.3 (21.0-32.3)	17 (>28.0)	23.0-28.7	1 (>28)

Table 4. Heterosis of New CMS based intra hirsutum hybrids (96) involving drought conditions.

	Range of heterosis over NHH-44	Range of heterosis over DHH-11	CD	CV %
Seed Cotton yield	-58.2 to 40.5 (51)	-69.2 to 3.4 (14)	26.0	18.3

Boll weight (g)	-25.5 to 36.2 (a11)	-33.9 to 20.7 (88)	8.0	16.1

Figures in the parentheses indicate no. of CMS hybrids showing on par yield with checks.