RESEARCH ARTICLES

Wild *Gossypium anomalum*: a unique source of fibre fineness and strength

Subhash S. Mehetre
Directorate of Research, Mahatma Phule Krishi Vidyapeeth, Rahuri 413 722, India

The improvement in textile spinning machinery has an important impact upon the entire cotton fibre business, particularly in the demand for high quality cotton fibre. Genetic improvement of fibre quality traits, viz. length, strength, fineness, maturity and uniformity is vital to meeting the challenge of the textile industry. Amongst wild *Gossypium* L. species, the African *Gossypium anomalum* Waw. & Peyr. \((2n = 2x = 26; \text{B}_1\text{B}_2)\) produces cotton with good fibre strength and fineness coupled with resistance to pest and diseases. The seed hairs of *Gossypium anomalum* are short and non-convoluted and are fully thickened with secondary cellulose deposition, and possess low fibre weight due to thinness of wall. X-ray crystallography and crystallinity index studies showed that *Gossypium anomalum* has highest fibre strength with highest crystallinity index due to maximum cellulose deposition. Either inter se mating among selected BC$_1$F$_1$ plants or a second backcross of the elite plants to the cultivated parent was found effective in improving the recovery of desirable segregants. Inter crossing of plants selected in F$_2$ or BC$_3$ from large populations result in enhancement of variability and rapid accumulation of favourable genes for the improvement of biochemical traits, disease resistance and for developing germplasm pools. Examination of single plant for fibre weight and swollen hair diameter and pursuing selection for fineness with economic attributes is necessary to avoid loss of fibre strength and fineness during subsequent generations. Intermating of several synthetic hexaploids increases the variability, fertility and recombination potential. Utilization of *Gossypium anomalum* to impart fineness (low fibre weight) with high maturity to *Gossypium arboreum* L. yielded commendable results. If *Bt* gene is incorporated into this hybrid, it can be an excellent source of bollworm tolerance coupled with superior fibre properties and yield.

**Keywords:** Amphidiploidy, cellulose deposition, *Gossypium anomalum*, haploidy, fibre convolutions, lumen.

COTTON fibre is an important raw material for the textile industry. Upland cottons (*Gossypium hirsutum* L.) account for over 90% of lint production because of their high productivity and it is the cornerstone of textile industries worldwide. The demand for improved fibre quality by textile industry will continue to improve their processes. Currently, spinning machinery used by the textile processing industry sets the standards for fibre quality and these are mostly based on the physical properties of fibre such as greater cotton fibre quality, especially strength. Strong fibres survive the rigours of ginning, opening, cleaning, carding, combing and drafting. Therefore, an important breeding objective has been to introduce fibre strength genes from other *Gossypium* species or strains while maintaining the cotton fibre (lint) yield. Accordingly, cotton breeding has to be re-oriented for developing cotton genotypes for higher spinning potential.

**Wild *Gossypium anomalum* Waw. & Peyr.: a source to introgress desirable genes**

Hybridization between species secures genes or gene combinations that are normally not available within the limits of species. Further improvement in certain characters through transgressive breeding is also possible. Amongst wild *Gossypium* L. species, the African wild *Gossypium anomalum* Waw. & Peyr. \((2n = 2x = 26; \text{B}_1\text{B}_2)\) possesses desirable characters, viz. resistance to jassids, mites, bollworm, rust and bacterial blight, high fibre length, fineness, strength and maturity, a source of male sterility through cytoplasm, narrow bracts and hairiness of leaf, high convolutions in fibre and oil content, hence found useful in providing cotton with good fibre length and fineness coupled with resistance to pest and diseases. In addition to the genes responsible for fineness and lint strength enhancing its spinning potential, it has non-convoluted, non-spinnable brown and short (0.80 mm) lint. According to earlier reports, seed hairs of *Gossypium anomalum* are strong and extremely short (0.27 mm) brown, scanty and strongly adhering lint to seed coat and thus it is of no economic value as a source of lint length or ginning percentage genes but it may be useful as a source of fineness and strength of lint. Further, its fibres are also non-convoluted and are fully thickened, with secondary cellulose deposition, and thinnest (diameter is hardly 8–10) due to which their mature fibre weight is lowest (0.59 g/cm) compared to fibres of ‘Coconadas’ and ‘Karunganni’ (1.90 and 2.21 g/cm).
respectively) belonging to *Gossypium arboreum* cottons. Low fibre weight is inherited as a dominant character\(^{15,46}\). Highest percentage (from 99% (ref. 46) to 100% (ref. 19)) of fine\(^{42}\) mature fibres is the most important feature of *Gossypium anomalum* fibre. Swollen hair diameter, an appropriate method to determine fineness of short fibres of *Gossypium anomalum* where it is hard to get two ends is recommended\(^{46}\). Minimum, maximum and average diameter of its fibre is 3.7, 8.3 and 6.9 microns respectively, while lumen width is 0.8 micron. Further, more than 60% of the fibres examined had almost no lumen. The diameter value is little a more than half of the diameter value observed for normal cotton. It therefore indicates that the linear density of these fibres would be of about 1/4th to 1/3rd of the normal fibres. The length of the fibres is very short\(^{50}\).

*Gossypium anomalum* has a potential\(^{18,19,44,49}\) for transferring desired characters\(^{10-43}\) (Figure 1) including narrow bracts which reduce trash in harvest\(^{18}\) and hence recommended transfer of lint fineness\(^{12,25}\) and strength and fineness\(^{19,44,46,49}\) from *Gossypium anomalum* to deshi cotton.

**Role of Gossypium anomalum in improvement of cultivated diploid (African) cottons**

An attempt of the deliberate utilization of *Gossypium anomalum* to improve the fineness of *Gossypium arboreum* cotton cultivar (cv) ‘Jubilee’ was first made by Afzal et al.\(^{12}\) who derived four strains, viz. DC 93, DC 94, DC 95 and DC 96 from BC\(_{2}\)F\(_{3}\) of *Gossypium arboreum × Gossypium anomalum* crosses. Fully fertile and fine linted plants with optimum mature fibre weight and 1.50 × 10\(^{-6}\)g/cm, good mean fibre length of 0.90" and above with swollen hair diameter of 20.0 \(\mu\) was secured from F\(_{2}\) and F\(_{3}\) of BC\(_{1}\) and BC\(_{2}\) of ‘Karunganni’ (Gossypium arboreum) cotton × *Gossypium anomalum* crosses\(^{44}\), hence transfer of lint fineness from *Gossypium anomalum* to deshi cotton is recommended\(^{41}\). Commandable improvement of fibre qualities of backcross progenies of diploid cottons\(^{21,32}\) in Punjab\(^{17}\) and in Tamil Nadu\(^{44}\) have been secured. Two lines in the second generation of backcrossing to *Gossypium arboreum*, with better mean values for all economic characters than *Gossypium arboreum* and eight plants having fine fibres with swollen hair diameters less than 22.4 \(\mu\) were derived from an intermediate cross between *Gossypium arboreum × Gossypium anomalum*\(^{25}\). Besides fineness, *Gossypium anomalum* also possesses strength as pressly strength index (PSI) as high as 9.82 lb/mg and fineness of 0.093 millionth of an ounce per inch was recorded in the progeny of hybrid BC\(_{2}\)F\(_{2}\) of 68174 × *Gossypium anomalum*. In addition, derived lines numerically out-yielded the *Gossypium arboreum* check varieties\(^{39}\).

Out of interspecific hybrids derived from crosses of four and six geographical races of *Gossypium herbaceum* and six of *Gossypium arboreum* respectively, with *Gossypium anomalum*. *Gossypium arboreum* race sinense × *Gossypium anomalum* had good bundle strength\(^{25,44}\) while swollen hair diameter was found to have high and low correlation with fibre maturity and halo length including ginning percentage respectively\(^{25}\). During transfer of lint fineness\(^{18,25}\) and fineness (low fibre weight) with high maturity\(^{15,45,46}\) from *Gossypium anomalum* to the cultivated *Gossypium arboreum*, the undesirable features of the *Gossypium anomalum*, viz. late habit, small bolls, short staple and brown lint were eliminated while agronomic base of *Gossypium arboreum* was restored after exercising vigorous selection pressure\(^{49}\). Individual examination of single plant for fibre weight and swollen hair diameter and pursuing selection for fineness with economic attrib-

---

**Figure 1.** Morphological features of the African wild *Gossypium anomalum* Waw. & Peyr. (*Gossypium anomalum*) (2n = 2x = 26; B, B\(_{1}\)). a, Branch at flowering; b, branch at boll maturity; c, pink flower with dark red petal spot; d, mature burst boll; e, narrow bracts; f, seeds with brown fuzz; g, matured boll with narrow bracts, and h, brown, scanty lint strongly adhered to seed coat.
utes is suggested\textsuperscript{49}. While selecting derivatives combining the economic traits, fibre characteristics and stabilizing them so as to get desired uniform cultures very close observations and extensive testing of individual plant are necessary\textsuperscript{23}. Attention should be given to ginning percentage (GP) and yield only after transference of fineness and strength is achieved\textsuperscript{50}.

In Asiatic \texttimes Gossypium anomalum hybrids, sufficient number of bolls was not set due to high sterility, hence fibre characters could not be assessed because of non-availability of adequate lint. The \(F_1\) fibre was brown with a mean halo length of 16 mm while in the induced amphiploids the fibres were deep brown to dull white, but silky. The ginning percentage was low in all amphiploids ranging from 21.0 to 24.0 with lint indices being 1.5 to 2.1 g (ref. 34).

Plants with white lint and fibre fineness\textsuperscript{24} were recovered from segregants of \textit{Gossypium arboreum \times F_2 (Gossypium herbaceum \times Gossypium anomalum)}\textsuperscript{24,45}. Second backcross generation of \textit{Gossypium arboreum} with \textit{(Gossypium arboreum \times Gossypium anomalum)} \(F_1\) showed an increase in the mean fertility over the first backcross generation. Combinations of fine white lint, high seed weight, a large number of seeds/boll, bolls and good fertility from \(BC_2\) of \textit{(Gossypium arboreum \times Gossypium anomalum)} were found. Female parent used for hybridization had an influence on the time taken for seed germination\textsuperscript{74}. Back cross derivatives of 10 hybrids in the combination of \textit{Gossypium arboreum \times F_1 (Gossypium herbaceum \times Gossypium anomalum)}, four \(F_1\) (\textit{Gossypium arboreum \times Gossypium anomalum}) \times \textit{Gossypium herbaceum} and eight \(F_1\) (\textit{Gossypium arboreum \times Gossypium anomalum}) showed improvement in fertility and fibre characters such as length, fineness and number of convolutions\textsuperscript{74}. Even though the mean halo length was also poor \((14.0-23.1\, \text{mm})\), the fineness \((60-151\, \text{millitex})\) and bundle strength \((13.4-8.3\, \text{lb/m})\) of lint was high. Such values are rarely met within existing cultivated diploid or tetraploid cottons. The extreme fineness value and higher bundle strength were recorded by amphiploids involving race \textit{bengalensis} and \textit{sinense} respectively. However, the fibres possessed deep to high brown tinge inherited from \textit{Gossypium anomalum}\textsuperscript{34}. The undesirable characters of \textit{Gossypium anomalum} were not evidenced during incorporating fibre fineness from \textit{Gossypium anomalum}\textsuperscript{50}. The crosses of \textit{Gossypium anomalum} are more successful with \textit{Gossypium herbaceum} than with the \textit{Gossypium arboreum}, because of the modifier complex of \textit{Gossypium anomalum} being nearer to the \textit{Gossypium herbaceum} than that of \textit{Gossypium arboreum}. In addition, the chromosomes of \textit{Gossypium anomalum} (\(B_1\)) and \textit{Gossypium herbaceum} (\(A_1\)) are structurally similar \textit{Gossypium arboreum} (\(A_2\)) differs from both by one translocation\textsuperscript{55}. The differences between \(A_1\) and \(B_1\) may be the result of gene mutations and introgression\textsuperscript{56}.

### Role of Gossypium anomalum in improvement of cultivated tetraploid cottons

\textit{Induced/synthesized polyploidy}: Fertility restoration was observed in \textit{Gossypium arboreum \times Gossypium anomalum} synthesized allopolyploids\textsuperscript{27,61} and in spontaneous polyploids\textsuperscript{52}. Tetraploid plant with good fibre properties and jassid resistance from \textit{Gossypium hirsutum \times Gossypium anomalum} hexaploid\textsuperscript{38} and 6x (\textit{Gossypium herbaceum \times Gossypium anomalum \times Gossypium hirsutum})\textsuperscript{91}, and from crosses involving either \textit{Gossypium harknessii \times Gossypium longicalyx} with \textit{Gossypium hirsutum}\textsuperscript{86} were obtained. After repeated efforts to transfer fineness and strength from \textit{Gossypium anomalum} to \textit{Gossypium hirsutum} and Indo-American strains, some promising cultures, viz. ‘Co-ano’ having finer fibre (fibre weight of 0.102 to 10.6 oz) and microspinning test of 2169 lbs on 40s were obtained besides extra long staple (1.18")\textsuperscript{53}. Hexaploid of \textit{Gossypium hirsutum \times Gossypium anomalum} was synthesized and from its \(BC_2\) generation, few plants with 28.5 mm halo length and others with 46.8 ginning percentage were obtained\textsuperscript{4} that indicated immense possibilities of transferring useful interspecific gene transfer to cultivated American (\textit{Gossypium hirsutum}) cottons\textsuperscript{18,61}.

Strains, viz. H.H.8 and H.H.25 derived from crosses between induced hexaploid by doubling chromosomes of \(F_1\) hybrid (Co.2 \texttimes Gossypium anomalum). ‘Co-ano’ cultures obtained from a synthetic pentaploid were further backcrossed to Indo-American strain B.C.68 for its improvement. While selecting for yield, the fineness and strength could not be retained\textsuperscript{62}. Fertile slow growing but vigorous and healthy hexaploids, those having very strong, silky fibre but proportion of seed was low and fibres remained matted round the seed. During transfer of \textit{Gossypium anomalum} characters to cultivated tetraploids\textsuperscript{37}, the allopolyploids of either \textit{Gossypium arboreum} or \textit{Gossypium herbaceum \times Gossypium anomalum} almost bred true but they have characters, viz. short, brown, scanty and strongly adhering lint to seed, etc. of \textit{Gossypium anomalum}, hence no economic value\textsuperscript{57}. Poor boll setting in the later generations of the tetraploids of \textit{Gossypium herbaceum \times Gossypium anomalum} and many undesirable characters like slow growth, late maturity, coloured lint and difficult ginning, etc. are met within these tetraploids\textsuperscript{65}. Valuable plants with highly desirable fibre properties were derived from 6x (\textit{Gossypium hirsutum \times Gossypium anomalum}) backcrossed to \textit{Gossypium hirsutum}\textsuperscript{15,66}.

While selecting plants for improved yield and other characters from \(5 \times 5\) back crosses of doubled (\textit{Gossypium hirsutum Co.2 \times Gossypium anomalum}) \times Co.2 as well as from the outcrosses of the \textit{Gossypium hirsutum} and \textit{Gossypium barbadense} types, fibre fineness and strength derived from the wild species have undergone gradual reduction. A number of promising cultures for ginning outturn and other fibre technological properties were obtained from intercroses where perennial American types.
and *Gossypium anomalum* were utilized as parents as well as in hybridization of *inter se* derivatives of crosses between Asiatic and American varieties × *Gossypium anomalum*.

Backcross progeny of F₁ (amphiploid × *Gossypium barbadense* and *Gossypium hirsutum*) was highly sterile either on selfing or on dusting pollen from the cultivated tetraploid parents. However, few bolls were obtained with good fibre properties where *Gossypium hirsutum* varieties were used as the female parent and the F₁ (amphiploid of *Gossypium arborum* race *burmanicum* × *Gossypium anomalum*) × *Gossypium hirsutum*, as pollen parent. The lint was almost white and fine to feel.

Asiatic × *Gossypium anomalum* combinations were produced, doubled and crossed with tetraploid cottons for interspecific gene transfer. Amphidiploids of hybrids between geographical races of the Asiatic cottons and *Gossypium anomalum* were produced and backcrossed with either amphiploids or their progenies for introgression of genes to the cultivated *Gossypium hirsutum* or *Gossypium barbadense* as the female parent. Segregants combining the long-willed white fibre types without loss of other attributes besides eudicous bracts, vigour and hardiness were recovered. Thus successful transfer of one or two attributes of *Gossypium anomalum* on the tetraploid background has been achieved. Based on an earlier review, it appeared that comparative study of *Gossypium anomalum* with each race of Asiatic cotton will prove to be of great value and hence it is suggested to assess the genetic potentials of different geographical races of *Gossypium arborum*.

Earlier literature is replete to draw a conclusion that successful incorporation of desired traits from wild germplasm into cultivated varieties is met with difficulties because of the finely tuned genetic system controlling lint quality, strength and texture, hybrid breakdown, high negative correlation between yield and fibre strength, and reduced chasmas. However, recovered transgressive segregants in wide crosses afford vast opportunities in selecting plants with desired attributes from segregating populations and introgression of genes from wild to commercial cultivars; it is possible because of formation of at least some chiasmata between the chromosomes of any two genome groups of *Gossypium*. Because nature of introgressive breeding is a long range, clear-cut criteria and screening procedures are therefore, essential while handling the material. Success depends on the strategies determined for achieving the goals under a specific situation and more often blending of conventional and unconventional techniques. In interspecific hybrids of *Gossypium*, a greater proportion of female gametes than male gametes is usually functional with few exceptions, hence backcross breeding should be exploited.

In *Gossypium*, the colehicine technique is effective in induction of polyploidy/amphidiploidy, which is often needed in interspecific gene transfer. In new tetraploids such as *Gossypium davidsonii* × *Gossypium anomalum*, spontaneous tetraploids are recovered during interspecific hybridization. Occurrence of new spontaneous tetraploid plants during crossing of the triploid hybrid with allotetraploid is attributed to the functioning of unreduced gametes during species crosses. Compared to allohexaploid combinations involving wild species with tetraploid cultivated species, the allotetraploid of *Gossypium arborum* × *Gossypium anomalum* offered less difficulty in securing sufficient number of progenies in successive generations. However, in its fourth filial generation there was reversion to diplody and appearance of wild parental and recombinant types. In the F₂ generation of the synthetic amphiploid hexaploids *Gossypium hirsutum* × *Gossypium anomalum*, availability of very less population for study is the main constraint.

**Backcross breeding:** Investigations of comparative merits and demerits of back crossing of the induced allo-tetraploids and allohexaploids with both *Gossypium hirsutum* and *Gossypium barbadense* as well as by utilizing the selected progenies of induced amphidiploids in successive generations alone for backcrossing with *Gossypium hirsutum* and *Gossypium barbadense*, and review of backcrossing with special reference to cotton improvement revealed that during repeated backcrossing one set of chromosomes was retained as a going concern with genes balanced. This technique has been used successfully in crosses of *Gossypium* species. Backcross breeding is the most desirable for achieving practical breeding objectives. Seventy six new germplasm lines through various methods, viz. hybridization, in vitro culture, selection, identification and multiplication were created from *Gossypium hirsutum* and *Gossypium arborum*, four wild species including *Gossypium anomalum*, and a semi-wild *Gossypium mexicanum*. These lines had span length of 33.4–37.7 mm, high lint percentage (45–48.7%) and very early maturity with growth period of 100–115 days.

Recurrent backcrossing and 2–3 backcrosses are enough to achieve success, whereas two backcrosses were found enough to preserve genes for fibre quality. Each backcross of the B × D hybrid to *Gossypium hirsutum* gives a 30% chance for each *Gossypium anomalum* chromosome to get integrated into a gamete, besides increased fertility. Elimination of association of undesirable linked factors can be achieved by making additional generations of backcrossers and selfing and growing large populations.

Release of locked up variability and better recombination are achieved by intermating of several synthetic hexaploids to increase the variability, fertility and recombination potential. *Inter se* crossing among selected BC₁F₁ plants and a second backcross of the elite plants to
the cultivated parent is effective in improving the recovery of desirable segregants\textsuperscript{100}. Interbreeding in plants selected in F\textsubscript{2} or BC\textsubscript{2} from large populations may be quite effective in bringing about enhancement in variability and rapid accumulation of favourable constellation of genes. Thus enlarged spectrum of variability is obtained by selfing and intermating for improvement of biochemical traits, disease resistance and for developing germplasm pools for selection\textsuperscript{103}. When genes of a cultivated species are transferred to the cytoplasmic background of certain wild species, especially from *Gossypium harknessii* and *Gossypium anomalum* besides *Gossypium arboreum*, male sterility was observed\textsuperscript{56,80}.

**Successful pre-breeding efforts at Mahatma Phule Krishi Vidyapeeth**

**SDS–PAGE and RAPD of wild species of Gossypium**

Considering the potential of *Gossypium anomalum* in introgression of desirable genes into cultivated cotton, a systematic programme was planned. Variability for flower\textsuperscript{104} and leaf\textsuperscript{105} characters as well as SDS–PAGE and RAPD\textsuperscript{106} analysis in cultivated and wild species of *Gossypium*, belonging to B\textsubscript{1}, B\textsubscript{2}, B\textsubscript{3} and B\textsubscript{6}, D\textsubscript{1}, D\textsubscript{2–4}, D\textsubscript{5}, D\textsubscript{6}, D\textsubscript{7}, E\textsubscript{1}, F\textsubscript{1} and G\textsubscript{5} perennial cottons, and races of *Gossypium hirsutum* L., *Gossypium barbadense* L. and *Gossypium arboreum* L. were studied and critical inter and intra-genomic variation for floral\textsuperscript{104} and foliar\textsuperscript{105} characters, divergence by SDS–PAGE and RAPD\textsuperscript{106} was ascertained.

**Overcoming cross incompatibility**

Application of 30% sugar + GA\textsubscript{3} 50 ppm + NAA 100 ppm to stigma before pollination to overcome cross incompatibility of cross *Gossypium hirsutum* CMS 76H × *Gossypium anomalum* as well as improve boll setting in the backcross was suggested\textsuperscript{107}.

**Effective propagation of wild species and sterile interspecific hybrids**

Air layering was found effective in propagating wild species and sterile interspecific hybrids including *Gossypium hirsutum × Gossypium anomalum*\textsuperscript{108}.

**Alternative short-cut methods of interspecific hybridization**

**Utilization of (poly) haploids of tetraploid cottons:** An interspecific hybrid A\textsubscript{6}D\textsubscript{6}B\textsubscript{1} between *Gossypium hirsutum* haploid (2n = 2x = 26; A\textsubscript{6}D\textsubscript{6}) × *Gossypium anomalum* (2n = 2x = 26; B\textsubscript{1}B\textsubscript{1}) was obtained and studied for its detailed cytomorphology\textsuperscript{109}. The detailed data on meiotic chromosome pairing in this hybrid in comparison with its parents was indicated on an average of 7.2\textsuperscript{2} + 0.03\textsuperscript{3} that indicated homology between A/D and B chromosomes and the bivalent formation was specific rather than random\textsuperscript{107}. It was indicated that an amphidiploid (2n = 2x = 26; A\textsubscript{6}D\textsubscript{6}B\textsubscript{1}B\textsubscript{1}) if induced will be an excellent source for securing combinations for disease and insect pest resistance and also combined with desired fibre quality parameters\textsuperscript{109}. Crossing haploids (2n = 2x = 26) of tetraploid (2n = 4x = 52) cottons with wild species was found to be an alternative short-cut method of crossing cultivated allotetraploid species, viz., *Gossypium hirsutum* and *Gossypium barbadense* with *Gossypium anomalum*. A routine method on this line has been reported by several workers and it is mostly on the hybridization between tetraploid (2n = 4x = 52) × diploid (2n = 2x = 26) species. Such transfer is possible with difficulties and the breeding programme is comparatively lengthy because most F\textsubscript{1}S being triploid are sterile. Only after doubling its chromosome complement it can be backcrossed to cultivated tetraploids to obtain plants with 2n = 4x = 52 chromosome having desired character combinations\textsuperscript{103}.

**Utilization of cytoplasmic male sterile lines:** An interspecific F\textsubscript{1} hybrid between *Gossypium arboreum* ‘Petaloid A-47’ (cytoplasmic male sterile) × *Gossypium anomalum* was obtained with an intention to introgress the desired genes into *Gossypium arboreum* cotton and male fertility restorer genes in *Gossypium arboreum* cotton\textsuperscript{111} and reported comparative observations on chromosome behaviour during meiosis of the hybrid and its parents\textsuperscript{112}.

**Confirmation of hybridity**

Hybrids between *Gossypium davidsonii* × *Gossypium anomalum*\textsuperscript{113} and *Gossypium herbaceum* var. ‘Jaywant’ and *Gossypium anomalum*\textsuperscript{114} were produced and their hybridity was confirmed on the basis of cytomorphological observations\textsuperscript{111,112}. Hybridity of *Gossypium davidsonii* × *Gossypium anomalum*\textsuperscript{111} and *Gossypium hirsutum* CMS 76H × *Gossypium anomalum*\textsuperscript{115} was confirmed by random amplification of polymorphic DNA (RAPD). Plant bearing ‘petaloid’ anthers in its flowers in F\textsubscript{2} generation of a cross between *Gossypium arboreum* var. MPKV-GMS × *Gossypium anomalum* was observed\textsuperscript{116}. Cytomorphology and mechanism of ‘petaloidy’ formation was described\textsuperscript{114}. Cytomorphological and RAPD analysis of the F\textsubscript{1}, F\textsubscript{2} and BC\textsubscript{1} generations of *Gossypium arboreum* var. ‘Y-1’ × *Gossypium anomalum* and plants with sufficient degree of fertility and desired fibre and economic traits were identified\textsuperscript{117,118}. RAPD and cytagenetic study in F\textsubscript{1} and F\textsubscript{2} of interspecific cross between *Gossypium*
Arboreum var. MPKv-GMS × Gossypium anomalum helped in confirmation of hybrid status as well as selection and plants with increased bivalent formation and fertility coupled with improved fibre quality parameters and yield attributes comparable to Gossypium arboreum were selected from F2 segregants; those plants were selfed and backcrossed to the cultivated parent119,120.

**Behaviour of filials**

F1, F2 and BC1 of interspecific cross between Gossypium arboreum var. MPKv-GMS × Gossypium anomalum were studied along with their parents during 2001–2003 (ref. 121). Cytological studies in all the five generations indicated that irregular chromosome behaviour in the F1, F2 and BC1 progenies led to pollen sterility. Based on fibre properties, pollen fertility, bivalent frequency and yield contributing characters in the best nine and seven plants were selected from F2 and BC1 respectively, on the basis of boll set/plant, boll diameter, improved fibre quality parameters, yield, pollen fertility and bivalent frequency and were analysed by RAPD. Totally 15 decamer primers were tested, out of which eight primers, viz. OPC-19, OPA-11, OPB-01, OPB-07, OPD-04, OPC-20, OPD-05 and OPA-12 showed polymorphism, OPC-19 showed 86.36% polymorphism121.

Interspecific F1 hybrids, Gossypium arboreum var. ‘G-27’ × Gossypium anomalum and Gossypium capitatis- viridis and their five generations (P1, P2, F1, F2 and F3) were studied during 2001–2003. Compact arrangement of cellular layers, accompanied with shorter mesophyll layers, presence of palisade layer on abaxial surface and longer distance to phloem from abaxial epidermis are desirable characters in developing co-resistance to more than one/more sucking pests in cotton (Figure 2). The nature of inheritance and gene action involved for the control of different morpho-physiological traits, anatomical and biochemical parameters responsible for tolerance/resistance to sucking pest complex and bollworms were estimated using ‘generation mean analysis’. Both additive and dominant gene actions were found significant in the inheritance of these traits. Duplicate epistasis for all morphophysiological characters and complementary epistasis for chlorophyll and sugar content was predominant. Correlation studies indicated significant negative association of anatomical and biochemical traits with sucking pest complex except jassids. Four F1 progenies of the cross were promising for seed cotton yield, improved fibre properties and tolerance to sucking pest complex and bollworms. Cytological studies in the progenies indicated almost normal meiotic behaviour and pollen formation119–123.

**Induced polyploids and their utilization**

The morphology, meiotic chromosome behaviour and fertility of first (C1) and second (C2) generations of induced amphidiploid Gossypium arboreum var. ‘Y-1’ × Gossypium anomalum in comparison with F1 and its parents and crossability of C1 and C2 plants with Gossypium hirsutum varieties were studied during 2000–2001 (ref. 124). Reduced fertility and boll set, internodal length, petal length, boll diameter, boll weight, lint weight, seed weight, seeds/boll as compared to Gossypium arboreum var. ‘Y-1’ parent and F1 was observed in C1 (Figure 3). Values for these traits were higher in C2 than C1 plants. However, in comparison with F1 hybrid, increase in average boll diameter, boll weight, lint weight and seeds/boll except bolls/plant in C2 than C1 generation was evidenced. Increased bivalent frequency with comparatively regular pairing and unequal separation was observed that resulted in increase in pollen fertility, germination and size over F1 hybrid. Since fair degree of crossability with Gossypium hirsutum and fibre fineness of Gossypium anomalum was evidenced in C1 and C2, these materials are thought to be an excellent source for transmitting exceptionally high fibre strength to cultivated tetraploids125,126.

**Unusual fibre properties observed in synthesized amphidiploid (C1)**

We127 synthesized amphidiploid (C1) which had mean fibre length 21.1 mm (tested by Baer Sorter method); equivalent fibre length at 2.5% S. L. (22.9 mm); uniformity (87%), micronaire value 3.3 (tested by gravimetric method (fibre weight) and tenacity 3.2 mm (g/t) 35.1). A tenacity of 35.1 g/t even though the 2.5% span length was
only 22.9 mm, appeared to be a very good and unusual outcome.

**In ovulo embryo culture for transfer of unusual fibre properties**

Basu (Cotton Corporation of India Ltd) advised us to use this ‘an excellent source’ in our breeding programme for development of high strength tetraploid cotton (pers. commun.). Hence, efforts were initiated for transferring high fibre strength of *Gossypium anomalum* and sucking pest tolerance of *Gossypium arboresum* to cultivated tetraploid *Gossypium hirsutum*, a high yielding species and *Gossypium barbadense* that is known for quality cottons. Few germinable seeds were obtained from the amphidiploid and a population of nine plants was raised. These nine plants were crossed with *Gossypium hirsutum* cvs. JLIH-168, LRA-5166 and a bollworm resistant germplasm line ‘BWR’. After effecting large number of crosses a few bolls were set without any seeds. Hence, in ovulo embryo culture of the ovules excised 3, 5, 7 and 10 days pollination (DAP) was tried. The ovules of a cross amphidiploid × BWR excised after 72 DAP were germinated after 72–77 days after planting. Thus post fertilization barriers were successfully overcome. We could establish five adult plants and hybrid nature of these plants was confirmed by cytological studies of interspecific hybrid, its synthesized amphidiploid (A1) and its progeny (A2) were reported.

**Investigations of trispecific F₁ (Gossypium arboresum × Gossypium anomalum) doubled × Gossypium barbadense**

**Cytomorphological and molecular studies.** The parents, trispecific F₁ (Gossypium arboresum × Gossypium anomalum) doubled × Gossypium barbadense hybrid and its F₂ segregants of 34 plants were studied during 2004–2006 (ref. 129). The irregular chromosome behaviour in the F₁ hybrid and F₂ segregating generation, led to decrease in pollen size, pollen sterility, pollen germination and pollen fertility. RAPD revealed that out of 26 decamer primers tested, 12 showed distinct polymorphism. The primer OPC-19 generated an additional fragment of approximately 850 bp in the segregants with high-fibre strength whereas it was missing in the low-fibre strength segregants. It was suggested that OPC-19 marker might be closely linked to fibre strength.

**Evaluation of fibre properties:** The fibre properties, viz. fibre length (2.5% S. L. mm), uniformity percentage, micronaire and tenacity (g/t) of F₂ population of 34 plants were compared with *Gossypium arboresum* variety ‘Y-1’ and inter- and intra-specific hybrids, ‘Phule-388’ and ‘Phule-492’ respectively. Fibre length (2.5% S. L. mm) ranged from 27.9 to 35.7, uniformity 43–50%, micronaire value 2.4–5.1 and tenacity (g/t) from 17.6 to 29.6.

**X-ray diffraction scanning analysis of fibre properties:** The X-ray diffraction (XRD) scanning report indicated distinct variation in the cellulose deposition pattern amongst segregating plants as compared to parents (Figure 3). Denser cellulose deposition was found in F₁ interspecific hybrid doubled (Gossypium arboresum × Gossypium anomalum) and F₂ segregating population, whereas it was less in the *Gossypium barbadense*. In addition, the number of wrinkles and its distribution varied in parents, F₁ and F₂ generation. The profuse wrinkling surface had been seen in doubled F₁ hybrid (Gossypium arboresum × Gossypium anomalum), and some of the F₂ plants. The cellulose microfibrils observed among the parents, F₁ hybrid and F₅s were quite different in appearance. Large variations were observed in the dimensions of microfibrillar structure of cellulose (Figure 4). The data on the X-ray crystallography and crystallinity index showed that the parental material *Gossypium anomalum* had highest fibre strength with highest crystallinity index.

**Figure 3.** Morphological features of the A. Cultivated diploid desi *Gossypium arboresum* (2n = 20, A1A1); B. F₁ hybrid between *Gossypium arboresum* and *Gossypium anomalum*; and C. Doubled F₁ hybrid (Gossypium arboresum × Gossypium anomalum). a. Leaf shape and size at flowering; b. Flowers with variation in colour and basal petal spot; c. Bract shape and size, and d. Mature/burst boll.
Table 1. X-ray diffraction radial scan analysis of the parents F₁ hybrid and selected F₂ plants

<table>
<thead>
<tr>
<th>Plant identity</th>
<th>2.5% span length (mm)</th>
<th>Fibre strength (g/t)</th>
<th>Uniformity (%)</th>
<th>Micronaire value</th>
<th>Crystallinity index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gossypium anomalum</td>
<td>14.8</td>
<td>27.2</td>
<td>44</td>
<td>3.0</td>
<td>80.08</td>
</tr>
<tr>
<td>Gossypium arboreum</td>
<td>25.8</td>
<td>17.0</td>
<td>50</td>
<td>5.1</td>
<td>73.76</td>
</tr>
<tr>
<td>Gossypium arboreum × Gossypium anomalum 2</td>
<td>22.0</td>
<td>21.2</td>
<td>46</td>
<td>2.8</td>
<td>74.23</td>
</tr>
<tr>
<td>Gossypium barbadense F₁ hybrid</td>
<td>31.1</td>
<td>24.5</td>
<td>46</td>
<td>4.0</td>
<td>73.70</td>
</tr>
<tr>
<td>F₁ plant (8T/5)</td>
<td>33.8</td>
<td>25.2</td>
<td>46</td>
<td>2.5</td>
<td>70.62</td>
</tr>
<tr>
<td>F₁ plant (1T/3)</td>
<td>27.5</td>
<td>25.6</td>
<td>48</td>
<td>2.8</td>
<td>71.76</td>
</tr>
</tbody>
</table>

F₂ generation: One hundred and thirty two F₂ segregating plants of a trispecific cross (Gossypium arboreum × Gossypium anomalum) × Gossypium barbadense were evaluated during 2004–2006 (ref. 132) for various characters including reactions for sucking pests and bollworm complex and molecular marker analysis indicated substantial variability amongst these materials. Out of these 132, twenty three plants were selected to grow F₃ progenies based on seed cotton yield, resistance to sucking pests, locule and green boll damage by boll worm and fibre quality parameters. Amongst these seven, F₃ segregants were superior in all the fibre quality attributes than the standard/released intra- and inter-specific cotton hybrids. The highest (24.5) percentage of oil was recorded in plant number 103/2. Amongst F₃ progenies, no. 36 was superior in many aspects.³²

F₃ fibre length (2.5% S. L. mm) ranged from 21.9 to 35.2, uniformity 45–52%, micronaire value 2.4–5.6, tenacity (g/t) from 17.7 to 26.8 and extensibility 5.1–7.0%.

F₂, F₃ and F₄ generations: These materials (F₄ generations) were further evaluated during 2005–2007 (ref. 133) for the reaction to sucking pests and bollworm complex, fibre quality parameters and, detection of transgressive segregants for quantitative characters including de novo recombinants for qualitative characters (Figure 5) and compared with earlier F₂ (refs 129, 130) and F₃ (ref. 132) results.

A wide range of variability was also noticed for different characters in F₂, F₃ and F₄ generations for reaction to

which may be due to the maximum cellulose deposition (Table 1)²⁹,¹³⁰

While doubled F₁ (Gossypium arboreum × Gossypium anomalum) recorded crystallinity index of 76.11 followed by plant number 1T/3 (75.22), Gossypium arboreum × Gossypium anomalum (74.23), Gossypium arboreum, Gossypium barbadense, F₂ plant number 8 T/5 (71.76) and F₁ interspecific hybrid. The microfibrils were denser in the high-fibre strength than low-fibre strength segregants. The present material showed increased wrinkling surfaces with distinct differences among them. Such increased wrinkling surfaces might be associated with improved ginning characteristics. These variations observed may be due to the induced changes in the convolution of mature dried fibres. The convolutions have a striking correlation with the X-ray angle; the more convoluted varieties showing higher X-ray angle³¹. The convolutions play a crucial role in the extension of the fibre. The fibrils in the cotton are helically deposited in the cell wall. A measure of this inclination is the ‘X-ray angle’ which is the half width (in degrees) of the azimuthal X-ray intensity distribution of the (002) diffraction are. Higher the X-ray angle, the lesser orientation fibrils are with respect to the fibre axis. A low X-ray angle would lead to high-fibre strength and vice versa. Based on fibre properties, pollen fertility and bivalent frequency and yield contributing characters, the 12 best F₂ plants combined with desired fibre quality parameters coupled with yield were selected for further evaluation in F₃ (refs 129, 130).

Figure 4. X-ray crystallography of parents, F₁ interspecific hybrid and its selected F₂ plants with X-ray diffraction radial scanning. Internal cotton fibre structure showing cellulose deposition and microfibrils. a, Fibre sample of Gossypium anomalum, b, Fibre sample of 2 (Gossypium arboreum × Gossypium anomalum). c, Fibre sample of Gossypium barbadense RHB 001. d, Fibre sample of F₁ interspecific hybrid of triscross 2 (Gossypium arboreum × Gossypium anomalum) × Gossypium barbadense.
sucking pests, viz. jassids, thrips, white flies and aphids. Comparatively lower incidence of sucking pests and boll worms (locule damage basis) was observed in F₄ generation. Desirable transgressive segregants for all the nine characters studied were identified. The proportion of transgressive segregation was highest (89.56%) for seed cotton yield. Seed cotton yield of better parent was transgressed simultaneously with transgression of one or more other characters, viz. seed cotton yield (g/plant), plant height (cm), number of sympodia, number of monopodia, days to flower, number of bolls per plant, boll weight (g), seed index and ginning percentage. The seven promising transgressive segregants were observed in F₃ generation. Selection of plants can be helpful in the introgression of the desirable characters from wild to cultivated species. Few abnormal and sterile plants were observed in F₄ generation.

Evaluation of F₂, F₃ and F₄ generations for resistance to sucking pests and bollworm complex: Negative association of chlorophyll content with jassids, thrips, white fly and aphids and significant negative association of hair density with jassid were evidenced. From correlation and transgressive segregation studies, it was inferred that number of bolls per plant, boll weight and number of sympodia per plant are important components of seed cotton yield and there was simultaneous transgression for one or more of these components with seed cotton yield. On the basis of yield contributing characters, fibre properties, reaction to sucking pest and boll worm complex, the best 13 F₃ families were selected for further evaluation.

Evaluation of F₄ and F₅ generations for yield, yield contributing characters and fibre properties: The F₄ and F₅ generations were studied during 2007–2009 (ref. 134) and showed substantial variability for all the characters studied. The incidence of sucking pests and bollworm complex was low in F₅ generation as compared to F₄ generation. F₅ fibre length (2.5% S. L. mm) ranged from 22.1 to 33.5, uniformity 42–53%, micronaire value 2.4–5.2 and tenacity (g/t) from 17.6 to 24.4 and extensibility 5.6–7.0%.

The genetic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were of high magnitude for lint weight, seed cotton yield, bolls per plant, sympodia per plant and monopodia per plant, whereas high heritability along with high genetic advance as a percentage of mean was recorded in seed cotton yield, ginning percentage, lint weight, sympodia per plant and bolls per plant indicating, the role of additive gene effect and selection will be effective for these characters.

Molecular analysis: The genomic DNAs of three parents, viz. Gossypium arboreum, Gossypium anomalum and Gossypium barbadense and their 30 progenies comprising 11 low, 14 medium and five high-fibre strength were subjected to PCR amplification using 40 random deamer primers. It was revealed that 36 primers exhibited polymorphism. A total of 541 amplicons were
Table 2. Fibre properties of the individual selected plant and range from different generations of F₁ hybrid between *Gossypium arboreum* × *Gossypium anomalum* and first to fifth generation of doubled (*Gossypium arboreum* × *Gossypium anomalum*) × *Gossypium barbadense* cross

<table>
<thead>
<tr>
<th>Generation</th>
<th>2.5% S. L. (mm)</th>
<th>Uniformity (%)</th>
<th>Micronaire value</th>
<th>Tenacity (g/t)</th>
<th>Extensibility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₁</td>
<td>19.3 (18.3)*</td>
<td>65</td>
<td>1.6</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>A₁</td>
<td>22.9 (21.1)*</td>
<td>87</td>
<td>3.3</td>
<td>35.1</td>
<td>–</td>
</tr>
<tr>
<td>F₂ bulk</td>
<td>18.5 (17.5)*</td>
<td>70</td>
<td>2.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>A₂</td>
<td>27.9–35.7</td>
<td>43–50</td>
<td>2.4–5.1</td>
<td>17.6–29.6</td>
<td>–</td>
</tr>
<tr>
<td>A₂-3</td>
<td>30.8</td>
<td>50</td>
<td>2.7</td>
<td>28.4</td>
<td>–</td>
</tr>
<tr>
<td>A₂-5</td>
<td>35.7</td>
<td>48</td>
<td>2.6</td>
<td>28.8</td>
<td>–</td>
</tr>
<tr>
<td>A₂-26</td>
<td>28.4</td>
<td>52</td>
<td>3.3</td>
<td>29.5</td>
<td>–</td>
</tr>
<tr>
<td>A₃</td>
<td>22.1–33.5</td>
<td>42–53</td>
<td>2.4–5.2</td>
<td>17.6–24.4</td>
<td>5.6–7.0</td>
</tr>
<tr>
<td>A₃-11</td>
<td>34.4</td>
<td>48</td>
<td>3.2</td>
<td>24.2</td>
<td>6.4</td>
</tr>
<tr>
<td>A₃-23</td>
<td>29.8</td>
<td>48</td>
<td>2.8</td>
<td>24.6</td>
<td>5.9</td>
</tr>
<tr>
<td>A₃-39</td>
<td>26.3</td>
<td>52</td>
<td>3.3</td>
<td>25.6</td>
<td>5.6</td>
</tr>
<tr>
<td>A₃-31</td>
<td>30.9</td>
<td>48</td>
<td>3.2</td>
<td>24.0</td>
<td>6.0</td>
</tr>
<tr>
<td>A₃-39</td>
<td>28.7</td>
<td>48</td>
<td>3.4</td>
<td>25.0</td>
<td>5.9</td>
</tr>
<tr>
<td>A₃-42</td>
<td>36.9</td>
<td>47</td>
<td>3.1</td>
<td>29.7</td>
<td>6.1</td>
</tr>
<tr>
<td>A₄</td>
<td>21.9–35.2</td>
<td>45–52</td>
<td>2.4–5.6</td>
<td>17.7–26.8</td>
<td>5.1–7.0</td>
</tr>
<tr>
<td>A₄-49</td>
<td>28.1</td>
<td>48</td>
<td>2.8</td>
<td>25.0</td>
<td>6.3</td>
</tr>
<tr>
<td>A₄-33</td>
<td>35.2</td>
<td>48</td>
<td>3.2</td>
<td>26.6</td>
<td>5.9</td>
</tr>
<tr>
<td>A₄-24</td>
<td>33.4</td>
<td>47</td>
<td>3.1</td>
<td>26.8</td>
<td>6.3</td>
</tr>
<tr>
<td>A₄-26</td>
<td>30.7</td>
<td>49</td>
<td>3.2</td>
<td>27.2</td>
<td>6.0</td>
</tr>
<tr>
<td>A₄-28</td>
<td>32.5</td>
<td>47</td>
<td>3.3</td>
<td>26.0</td>
<td>6.2</td>
</tr>
<tr>
<td>A₄-42</td>
<td>30.9</td>
<td>48</td>
<td>3.3</td>
<td>25.7</td>
<td>5.7</td>
</tr>
<tr>
<td>A₄-45</td>
<td>30.1</td>
<td>49</td>
<td>3.6</td>
<td>24.4</td>
<td>5.9</td>
</tr>
<tr>
<td>A₄</td>
<td>30.1</td>
<td>45</td>
<td>2.8</td>
<td>25.7</td>
<td>5.7</td>
</tr>
<tr>
<td>A₅</td>
<td>24.2–32.8</td>
<td>46–55</td>
<td>2.5–6.0</td>
<td>17.9–26.7</td>
<td>5.5–6.4</td>
</tr>
<tr>
<td>A₅-3</td>
<td>30.7</td>
<td>47</td>
<td>3.0</td>
<td>25.7</td>
<td>5.5 (8.9)**</td>
</tr>
<tr>
<td>A₅-18</td>
<td>29.9</td>
<td>49</td>
<td>3.8</td>
<td>24.1</td>
<td>5.5 (5.7)**</td>
</tr>
<tr>
<td>A₅-43</td>
<td>32.2</td>
<td>48</td>
<td>3.2</td>
<td>25.5</td>
<td>5.5 (5.1)**</td>
</tr>
<tr>
<td>A₅-47</td>
<td>29.2</td>
<td>49</td>
<td>3.8</td>
<td>24.2</td>
<td>5.5 (6.8)**</td>
</tr>
<tr>
<td>A₅-43</td>
<td>29.1</td>
<td>47</td>
<td>3.7</td>
<td>24.3</td>
<td>5.5 (8.6)**</td>
</tr>
<tr>
<td>A₅-32</td>
<td>30.8</td>
<td>48</td>
<td>3.7</td>
<td>24.3</td>
<td>5.5 (6.1)**</td>
</tr>
<tr>
<td>A₅-100</td>
<td>30.8</td>
<td>48</td>
<td>3.6</td>
<td>25.4</td>
<td>5.5 (6.0)**</td>
</tr>
<tr>
<td>A₅-107</td>
<td>31.1</td>
<td>52</td>
<td>4.0</td>
<td>24.4</td>
<td>5.5 (4.7)**</td>
</tr>
<tr>
<td>A₅-110</td>
<td>33.0</td>
<td>47</td>
<td>3.9</td>
<td>24.9</td>
<td>5.5 (4.9)**</td>
</tr>
<tr>
<td>A₅-171</td>
<td>32.3</td>
<td>48</td>
<td>3.9</td>
<td>25.0</td>
<td>5.5 (5.8)**</td>
</tr>
<tr>
<td>A₅-180</td>
<td>32.8</td>
<td>49</td>
<td>3.1</td>
<td>26.7</td>
<td>5.5 (3.9)**</td>
</tr>
</tbody>
</table>

*Mean length (mm); **Short fibre (%); –, not estimated because of nonavailability of sufficient lint sample.
F₁ = hybrid between *Gossypium arboreum* × *Gossypium anomalum.*
F₂ = second filial generation of hybrid *Gossypium arboreum* × *Gossypium anomalum.*
A₁ to A₅ = First to fifth generation of doubled (*Gossypium arboreum* × *Gossypium anomalum*) × *Gossypium barbadense.*

Numbers A₁ to A₅ indicate the plant number for which the fibre properties are mentioned.

generated, out of which 444 were polymorphic and 97 were unique bands with an average of 82.83% polymorphism.

RAPD revealed that amplicons generated in *Gossypium anomalum* were also observed in segregating mapping populations by random operon primers by OPB-11 (729 bp and 1029 bp) and OPB-15 (200 bp). Similarly, amplicons generated in *Gossypium barbadense* were also observed in segregating mapping populations by random operon primers OPB-04 (525 bp), OPB-07 (411 and 612 bp), OPB-08 (1151 bp), OPB-12 (610 and 754 bp), OPB-15 (380 bp) and OPB-18 (537 bp). Thus, these bands could be associated with fibre length. RAPD revealed the confirmation of introgression of particular traits from *Gossypium anomalum* and *Gossypium barbadense* into segregating mapping populations. On the basis of fibre properties and yield contributing characters, 12 F₄ progenies were found to be superior and they are under evaluation. F₅ fibre length (2.5% S. L. mm) ranged from 24.2 to 32.8, uniformity 46–55%, micronaire value 2.5–6.0 and tenacity (g/t) from 17.9 to 26.7 and extensibility 5.5–6.4%. Plants with desirable combinations were selected for further evaluation.

Fibre properties of F₁ and F₂ of (Gossypium arbor-

*reum × Gossypium anomalum) and A₁ to A₅ generations of
doubled (Gossypium arborum × Gossypium anom-
alum) × Gossypium barbadense: Fibre properties of F₁ (hybrid between Gossypium arborum × Gossypium anomalum); F₂ (second filial generation of hybrid Gossypium arborum × Gossypium anomalum) and A₁ to A₅ (first to fifth generation of doubled (Gossypium arborum × Gossypium anomalum) × Gossypium barba-

CURRENT SCIENCE, VOL. 99, NO. 1, 10 JULY 2010
dense) given in Table 2 indicate appreciable improvement in either single or more than one fibre quality parameters.

Recovery of cytologically and morphologically distinct plants: During hybridization of (doubled *Gossypium arboreum × Gossypium anomalum*) × *Gossypium hirsutum var. J.l.H-168) × *Gossypium hirsutum var. J.H-I-168*, some plants were conspicuous because of their distinct morphological features. Cytomorphic studies were carried out in these plants. These plants were both cytologically and morphologically distinct and had \(2n = 2x = 26\), \(2n = 3x = 39\), \(2n = 4x = 52\) and \(2n = 6x = 78\) chromosomes. A detailed analysis of chromosome pairing in these plants and their origin is discussed.\(^{36}\)

Summary

We could introgress successfully the desired traits from wild *Gossypium anomalum* into cultivated varieties blending both conventional and nonconventional techniques. In spite of the constraints like finely tuned genetic system controlling lint quality, strength and texture,\(^{21}\) hybrid breakdown,\(^{12,73}\) high-negative correlation between high yield and fibre strength,\(^{4,5,7}\) and reduced chisum,\(^{12,73}\) the recovered transgressive segregants\(^{7}\) would afford vast opportunities in selecting plants with desired attributes from segregating populations and introgression of genes from wild *Gossypium anomalum* to commercial cultivars.\(^{28-80}\) If *Bt* gene is incorporated into these hybrids, they will be an excellent source of bollworms tolerance coupled with superior fibre properties and yield.

Reviews on distant/intergeneric hybridization in cotton breeding,\(^{137}\) incompatibility in wide hybridization of *Gossypium* species: causes and remedies,\(^{38}\) colchicine and its use in cotton breeding,\(^{139}\) embryo rescue: a tool to overcome incompatible interspecific hybridization,\(^{140}\) role of wild species in improvement of fibre quality traits,\(^{41-43}\) disease and pest resistance,\(^{144}\) and leaf hairiness pattern in *Gossypium*\(^{145}\) helped us tremendously in solving problems faced by earlier workers. Clear-cut planning, blending of conventional and nonconventional techniques, adoption of appropriate procedures for screening against sucking pests and bollworms, evaluation of fibre quality parameters of lint samples of small quantities and handling of the material, etc. led us to succeed the introgressive breeding which is otherwise tedious and difficult.

50. Anonymous, Fibre Test Report from Director, Central Institute for Research on Cotton Technology (CIRCOT), Mumbai.
RESEARCH ARTICLES


85. Simmonds, N. W., Polyploidy in plant breeding. SPAN, 1980, 23, 73–75.


CURRENT SCIENCE, VOL. 99, NO. 1, 10 JULY 2010


117. Saitwal, V. M., Cytomorphological studies of F1, F2, and backcross generations of interspecific cross between G. arboreum (2n = 2x = 26; AaAa) × G. anomalum (2n = 2x = 26; BbBb). M.Sc Agric. thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, 2002.


ACKNOWLEDGEMENTS. I thank Dr A. B. Joshi, Ex Director, IARI, New Delhi and Ex Vice-Chancellor, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri for his encouragements and guidance. Thanks are also due to earlier and present Vice-Chancellors, Dr Y. S. Nerkar, Dr S. N. Puri and Dr R. B. Deshmukh, respectively. I thank to Indian Council of Agricultural Research, New Delhi, and MPKV, Rahuri for funds, facilities and encouragements. The cooperation and help rendered in evaluation of fibre quality parameters from Central Institute for Research on Cotton Technology (CIRCOIT), Mumbai, is gratefully acknowledged. I also thank to postgraduate students, from MPKV and co-authors of the research papers for permitting to compile and publish our joint research work. Thanks are due to laboratory assistants and technicians who helped in cytological, molecular analysis, field screening against sucking pests, bollworm and recording of other data, compilation of data and statistical analysis as well as photography.

Received 18 October 2009; revised accepted 12 May 2010