Arboreums in India in the age of transgenics

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ABSTRACT

The diploid species Gossypium arboreum has a long history of cultivation in India. Even after introduction of Upland cotton, Gossypium arboreum *was widely cultivated in the country till Second World War. The trend changed thereafter because of fall in the exports of short staple cotton to Japan and increase in the demand of medium and long staple cotton from the textile industry in the country. This resulted in gradual replacement of* Gossypium arboreum *by* Gossypium hirsutum *after 1950s. Earlier, cultivated arboreums had limitations like shorter staple, very high micronaire, small and non-retentive locules, tall and lanky growth, low seed index, susceptibility to diseases like* Fusarium *and grey mildew. On the other hand, many advantages like very high ginning out turn, deep tap root system, tolerance to water stress conditions and tolerance to* Helicoverpa, *particularly in Central India. Over the years, a good amount of variability has been generated in the germplasm for increased boll weight, high seed index, long staple, shorter internode and excellent technological properties. Use of male sterility has enabled to develop high yielding hybrids with good ideotype and fibers spinnable at 30S-40S count. Work done on these aspects in Ankur Seeds is reviewed here. Probabilities of biotech applications in the crop are also discussed.*

Introduction

Evolutionary history of the genus *Gossypium* has always posed an interesting puzzle. Hutchinson, Silow andStephens (1947) have done a deep study in to the evolutionary history of the diploid cotton. In his continuing research over the subject, Hutchinson (1954) opined that the true linted diploid cottons had diversified since the dawn of civilization. He showed that the primitive diploid *Gossypium herbaceum* race africanum could be regarded as a truly wild species and the closest modern relative to the original forebear of the diploid cottons. Thus, although the center of diversity of the Asiatic cotton was probably the lower Indus valley, the diploid ancestor from which they were derived arose on the southern periphery of the ancient distribution of the genus *Gossypium* in South Africa. Out of the total five genomes of diploid cotton, three are spread in African continent and one each in America, Australia andAsia. This supports the hypothesis that Central Africa was the center of origin of the genus *Gossypium* at a time when climatic and geographical conditions were different from the present.

History of Indian cotton and cotton industry

Since the discovery of the Mohen-jo-daro relics, the history of cotton and cotton manufacture is believed to have started since the beginning of Indus Valley civilization, which flourished in India 5000 years ago. A close study of the fabric from Mohen-jo-daro revealed resemblance of fibers to present day *arboreum* type. Many of the travelers, traders, and warriors described cotton and cotton cultivation that was practiced in India during ancient times. The Greeks named fine muslin as gangitiki after their source i.e. gangetic area. A Mohen-jo-Daro fabric tested at Central Institute for Research on Cotton Technology, Bombay has been found to be made from 34's warp and weft with 60 ends and 20 picks per inch (Sethi *et al*., 1960).

Documentary evidences reveal that India had a flourishing trade of cotton and cotton goods as early as 569-525 BC. Ancient trade with the western world was mostly by road and by sea. Discovery of new sea route via Cape of Good Hope marked a new beginning in the history of Indian cotton. It stepped up entry of Indian fabrics in European market that was predominantly using wool for fabric manufacturing. With the entry of East India Company cotton fabric exports became a regular phenomenon with first consignment of Indian fabrics reaching England in 1631.

With industrial revolution and invention of power looms in England, demand for medium and long staple cottons increased. In order to create an alternative source for American Cottons, the British East India Company began introduction of exotic cottons in different parts of Indian subcontinent. Different problems concerning cotton cultivation came to be studied on scientific lines with the establishment of agriculture departments in various provinces of princely states in 1904. This initiated cotton improvement work in the country.

The total production of cotton in undivided India in 1938-39 was about 5.9 million bales. Pre-independent India had a regular export of *arboreum* cotton to Japan. The entry of Japan in the second world-war resulted in the loss of export market for short staple cotton. Special measures were then taken to curtail production of short staple cottons. With partition of the country, supply position of cotton deteriorated while the demand for raw cotton remained almost unaffected because 98 percent of the textile mills of undivided India were situated in the Indian union. As a result, India had to import medium and long staple bales from Pakistan and East Africa. This necessitated the need for breeding medium and long staple cotton varieties suitable for Indian conditions and the "grow more cotton" campaign was launched. The scheme aimed to increase the area under medium and long staple varieties by about 4 million acres and replacement of short staple cottons in assured irrigation areas with long staple

hirsutums. Fruits of this planning were visible by the end of first five-year plan when production of medium and long staple cotton increased by 23 and 131 percent respectively.

With the increasing demand for medium and long staple cotton, the area under *G. hirsutum* cotton continued to increase. Green revolution and development of first commercial hybrid cotton H-4 gave further boost to area under *G. hirsutum*. During this period, some of the hurdles in diploid cotton, such as susceptibility to pink boll worm (*Pectinophora gossypiella*), gray mildew (*Ramularia areola*) and wilt (*Fusarium oxysporum*) were prominently realized. Pricing factor added to shift from diploids to tetraploids. In spite of this, diploid cottons are still covering about 15% area in North India, Central India andSouthern belts.

Diploid cottons possess certain desirable traits, such as drought tolerance, salinity tolerance, ability to sustain under marginal cultivation practices and better yield potential under adverse conditions compared to *G. hirsutum*. Improvement work in diploid cotton continued in many of the State Agricultural Universities and Central Institutes, which included hybrid development apart from disease resistance. In last decade or two, many diploid hybrids were developed and released *viz.,* G Cot DH 7, G Cot DH 9, DDH 2, and MDCH 201. They didn't cover a significant area because of seed production constraints. Delicate flowers of diploid cottons, poor seed setting and smaller boll size were main hurdles in diploid cotton hybrid seed production.

Present area under G. arboreum

The area under *G. arboreum* (race Bengalense.) has mostly been concentrated in the states of Punjab, Haryana and Rajasthan in the north India. There is a sizeable area under *G. herbaceum* in Gujarat where it is cultivated for its salinity tolerance. In Madhya Pradesh, diploid cotton is grown in Khandwa district andadjoining areas as a mixture of land races. In Maharashtra, *G. arboreum* is grown in Jalgaon, Dhule, Buldana, Akola and Parbhani district. The variety grown here is mostly Y-1. In Parbhani, some long staple varieties are grown. In Andhra Pradesh, there is a sizeable area near Rajmahendri, which grows Y-1 andsome local varieties. In Karnataka, the area surrounding Dharwad grows dryland *G. herbaceum* variety Jaydhar.

Some northern states grow *G. arboreum* under irrigation. The major growing areas of *G. arboreum* mostly receive scanty monsoon rains. Desi cotton there is cultivated under marginal practices and with low inputs under dryland conditions. Some of the commonly observed problems in arboreums are:

1. North India - Spiny bollworm *Erias vitella* and *Helicoverpa armigera*.
2. Central & - Grey mildew, pink boll worm *Pectinophora gossypiella*
3. South India - Fusarium wilt

The reason for continuation of arboreums can be attributed to its tolerance to abiotic and biotic stress and better cost benefit ratio under low management. Arboreums have also been observed to be immune to *Cotton Leaf Curl Virus* disease and moderately tolerant to Leaf miner (*Liriomyza trifoli*). Reddening in cotton in the dryland area, which is commonly observed in *G. hirsutum* at peak boll bearing stage is not observed in arboreums.

Diversity in G. arboreum

After critically studying available germplasm, it is observed that a good range of variability exists in *G. arboreum* genotypes. Range of variability for certain economical and technological characters available with Ankur Seeds is given in Table 3.

Two sources of genetic male sterility are available in *G. arboreum*. Work on development of genetic male sterility has been successfully done at C.C.S. Haryana Agriculture University Hisar and Dr. P.D.K.V., Akola (Singh *et al*., 1992). At CCS HAU genetic male sterility has been developed in the background of DS-5 of *arboreum* cotton. It is governed by single recessive gene designated as ams1. Meshram *et al*. (1994) reported genetic male sterility in asiatic cotton from a cross of *G. anomalum* x *G. arboreum*.

Work Done at Ankur Seeds

In *G. arboreum*, the work in Ankur Seeds is mainly aimed at altering the plant architecture and hybrid development. The focus is also on improvement of the fiber parameters of the fiber improvement goals are long staple, high strength, and micronaire between 4-4.7. The breeding programs in *G. arboreum* in Ankur Seeds are being carried out with following objectives-

- Population development.
- Hybrid development program
- Development of new GMS lines
- Plant ideotype development program
- Introgressive breeding
- Breeding for disease resistance

Population development

The basic objective of development of populations is to develop elite gene pools for economic and technological characters. Recurrent selection is practiced in this program. Good genotypes have been developed through the populations that have been developed. Maturity, boll weight, 2.5% span length, micronaire, lint percent, seed index are considered with lint yield in these breeding populations. Pedigree method of selection is being followed in the development of new genotypes.

Hybrid development program

Impetus of hybrid development program is to de-

velop intra-*arboreum* and interspecific hybrids suitable for dryland conditions. The purpose of using hybrids is to combine two or more important characters in a single genotype which otherwise will take a long time to combine using classical breeding approaches. Genetic male sterility is being utilized in hybrid development program, which has eliminated the problem of seed production. Four hybrids have been developed, all of which are intra-*arboreum* type for different areas. The intra-*arboreum* hybrid ADCH-2 (Swadeshi 1) has topped the All India Co-ordinated Cotton Improvement Project trials in Central Zone (Br 25) consecutively for the past three years and has been released. This hybrid has recorded a yield of 1700 kg/ha over 10 locations under dryland conditions, which is 30% more than check varieties. It has lint percent up to 38 percent and span length is 26 mm. This hybrid is spinnable at 30^s count. Micronaire value of Swadeshi 1 is 4.3, which is equal to standard *G. hirsutum*. Seed index of this hybrid is 7 g, which is better than the existing *arboreum* varieties. Swadeshi 3 is a hybrid with pigmented plant body and is adapted to North Indian conditions and is spinnable at 20^s count. We have also developed a new hybrid named Swadeshi 5, which has a yield potential of 18-20 Q/ha under dryland conditions. Special features of this hybrid are a boll weight of approximately 3.5 g and lint percent of 45%. This is the first commercial hybrid, which has been developed by using cernum race and probably the only hybrid with such a higher boll weight and lint percent. Other advantages of this hybrid include a tight locule, easiness in picking, tolerance to gray mildew and borer pests. This hybrid has span length of 22 mm and is spinnable at 20^s count. This hybrid has already done well in All India Co-ordinated Cotton Improvement Project trials in Central Zone under dryland conditions and is in the third year of testing in the breeding trials.

Under dryland conditions, all these hybrids have proven superior to some of the best *G. hirsutum* hybrids. Our efforts in hybrid project are aimed at developing a high yielding hybrid that is spinnable at 40^s count combined with tolerance to pests and diseases. The properties of our conceptual hybrid are as follows:

a) Days to 50% flowering - 52-55 days
b) Av. boll weight - 3.5-3.75g
c) No. of locules/boll - Predominantly 4
d) 2.5% span length - 27-28 mm
e) Micronaire - 4.5-4.8
f) 1/8" gauge tenacity - 23-24g/tex
g) Lint Percent - 38-39%
h) Seed index - 8.5-9g
i) Yarn Count - $35\text{-}40^s$

It has been observed that the intra-*arboreum* hybrids have been doing better than intra-*hirsutum* hybrids under dryland conditions and under marginal cultivation practices. The fiber parameters are less affected by the stress situation at boll development stage in arboreums than in hirsutums.

Development of new GMS lines

We have a stable source of genetic male sterility obtained from crosses with *G. anomalum*. We have succeeded in developing a female line denoted Ca/ag-4 with 28 mm span length, 4.5 micronaire, 3 g boll weight and having naked seed with a seed index 7.5 G. Our attention is on improvement of seed index in this line. A new GMS line Ca/ag-6 has an average span length 29mm and seed index 9.5 G. Both lines serve as good contributors for span length and seed index.

Plant type improvement program

In plant type improvement program, our focus is on increasing no. of locules/boll, reducing internode length and pedicel length and increasing its thickness. By using this approach, we have developed lines in GTDP project, which have 30-40% of the lower bolls with upward boll habit. This prevents losses in lint yield because of shedding of cotton. Improvement of plant structure by incorporating monopodial growth habit in *G. arboreum* is also being carried out. This is done to reduce lodging.

Introgressive breeding

Work on introgressive breeding for incorporating desirable genes from wild relatives as well as new world cottons is underway. Tetraploid arboreums have also been developed with colchicine treatment at 0.05% conc. seed treatment to the germinating seeds to support this work. By using this approach, characters of economic importance from wild and tetraploid cottons are planned. By using this approach, transfer of transgenic traits to *arboreum* is attempted.

Breeding for disease resistance

Grey mildew and Fusarium are major concerns in diploid cottons in India. Ca/a-99, which has been identified as immune to gray mildew, is being used as donor parent in the gray mildew resistance breeding program. Resistance breeding for Fusarium wilt has also been initiated by creating wilt nurseries in infested soils.

Conclusions

Past three seasons have proven that Asiatic cottons can perform much better than hirsutums under adverse climatic conditions. It has also been observed that Asiatic species show better tolerance to pests and diseases under cultivation without pesticides in Central and South India. Thus, they maybe suitable for organic cropping systems. Arboreums also meet the requirements of modern day textile demands and economic production. They can provide a favorable alternative to insect resistant transgenic cotton in India.

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Table 1. *Distribution of cotton area (000 acres) in 50's.*

	Distribution of cotton area (000 acres) in 50's[1]					
Staple Group	50-51	51-52	52-53	53-54	54-55	55-56
Long Staple (Above 7/8")	3416 (23)	4839 (30)	4521 (29)	5945 (34)	6080 (33)	6965 (35)
Medium Staple (<7/8"->11/16")	7563 (52)	7071 (44)	7448 (47)	7600 (44)	8684 (47)	9313 (46)
Short Staple (Below 11/16")	3577 (25)	4288 (26)	3724 (24)	3637 (22)	3920 (20)	3952 (19)

[1] Figures in parenthesis indicate percentage.

(Source: *Cotton Monograph*, **1**: 36)

Table 2. *Area and production of* Gossypium arboreum *in India.*

Sr.No.	Year	Area (000ha)	Production (000 bales of 170 kg)
1	1965-66	3962.40	2525.60
2	1969-70	4252.10	2657.50
3	1975-76	2527.00	1803.50
4	1979-80	2450.40	1974.30
5	1985-86	1461.40	1233.90
6	1991-92	1608.10	1467.50
7	1992-93	1812.40	1847.50

(Source: Cotton Advisory board of Textile Ministry andDirectorate of Cotton Development).

Table 3. *Variability for some economical and technological characters in Gossypium arboreum.*

Sr. No.	Character	Range
1	50% Flowering	52-76 days
2	Crop duration	145-190 days
3	Boll weight	1.1-7.4 g
4	Seed Index	4.8-9.6 g
5	Ginning outturn	32-46%
6	2.5% span length	15.5-30 mm
7	Micronaire	3.9- above7
8	1/8" gauge tenacity	14.6-27g/tex
9	SCotton	