

"INHERITANCE STUDIES IN INTERSPECIFIC CROSS OF COTTON"

A Thesis submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI -413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA**

**in partial fulfillment of the requirement for the degree
of
MASTER OF SCIENCE (AGRICULTURE)**

in

**AGRICULTURAL BOTANY
(Genetics and Plant Breeding)**

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by

**Jitendra M. Patil
(Regd. No. 05/024)**

**DEPARTMENT OF BOTANY,
POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI - 413 722,
DIST. AHMEDNAGAR,**

2007

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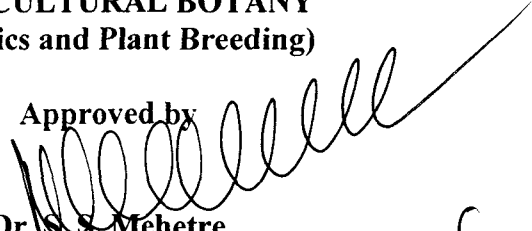
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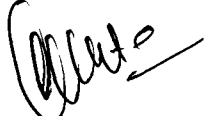
AGRICULTURAL BOTANY
(Genetics and Plant Breeding)

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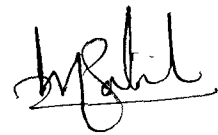
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CANDIDATE'S DECLARATION

*I hereby declare that this thesis or a part
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me or any other person to any
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Place: MPKV, Rahuri

Date: 08 /06/2007



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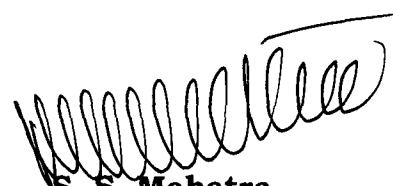
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C E R T I F I C A T E

This is to certify that the thesis entitled “**Inheritance studies in interspecific cross of cotton**” submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra State, India, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in **GENETICS AND PLANT BREEDING**, embodies the results of a *bona fide* research work carried out by **Mr. Jitendra Madhukar Patil**, under my guidance and supervision and no part of the thesis has been submitted for any other degree or diploma or publication in any other form.

The assistance and help received during the course of this investigation and sources of literature referred to have been acknowledged.

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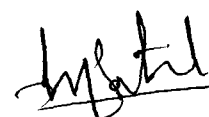
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(J. M. Patil)

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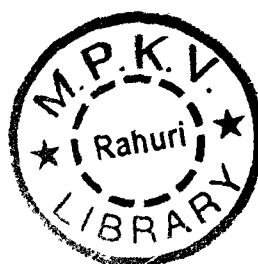
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LIST OF ABBREVIATION

%	:	Per cent
μ	:	Micron
/	:	Per
°C	:	Degree Celsius
cm	:	Centimeter
<i>et al.</i>	:	et alli (co-workers)
Fig	:	Figure
g	:	Gram
ha	:	Hectare
i. e.	:	that is
mg	:	milligram
ml	:	milliliter
mm	:	millimeter
No.	:	Number
PMC	:	Pollen Mother Cells
Spp.	:	Species
Var.	:	Variety
<i>Viz.,</i>	:	Namely
S. D.	:	Standard Deviation
etc.	:	Etcetera
F ₁	:	First filial generation
F ₂	:	Second filial generation
BC	:	Back Cross
SL	:	Span length
mic	:	Micronaire
UR	:	Uniformity ratio
g/tex	:	grams/tex
CIRCOT	:	Central Research Institute for Cotton Technology

ABSTRACT

“INHERITANCE STUDIES IN INTERSPECIFIC CROSS OF COTTON”

By

PATIL JITENDRA MADHUKAR

A candidate for the degree of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL BOTANY

(Genetics and Plant Breeding)

MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI -413 722**2007**

Research Guide : **Dr. S. S. Mehetre**
Director of Research,
MPKV, Rahuri.

The present research work entitled, “Inheritance studies in interspecific cross of cotton” was conducted at Cotton Improvement Project, MPKV, Rahuri during 2006-07. The objectives of present investigation were to study meiotic chromosome behaviour, morphology of all five generations and boll anatomical studies.

The comparative study of morphological characters showed that F_1 was vigorous partial fertile with boll set. In F_2 generation greatly varied for morphological traits studied showing reduction in economical traits *viz.* boll setting, boll weight, seed weight and lint weight. In BC_1 these characters were observed to be improved.

Cytological observations in both the parents indicated normal meiosis, it is definitely due to normal pairing of chromosomes during first meiotic division followed by separation of chromosomes during Anaphase and separation of chromatids during 2nd Anaphase leading to formation of normal sporads and pollen grain.

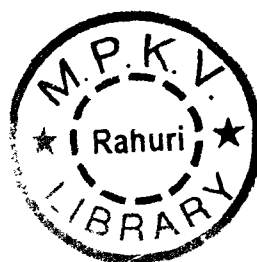
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Abstract contd...
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J. M. Patil

Boll anatomical investigation in all five generation indicated that boll rind toughness show's highest in *G. thurberi* whereas other generations recorded varied observations for this characters. In F₂ generation plant no. 2, 9, 27 has recorded maximum boll rind toughness in addition to low locule damage.

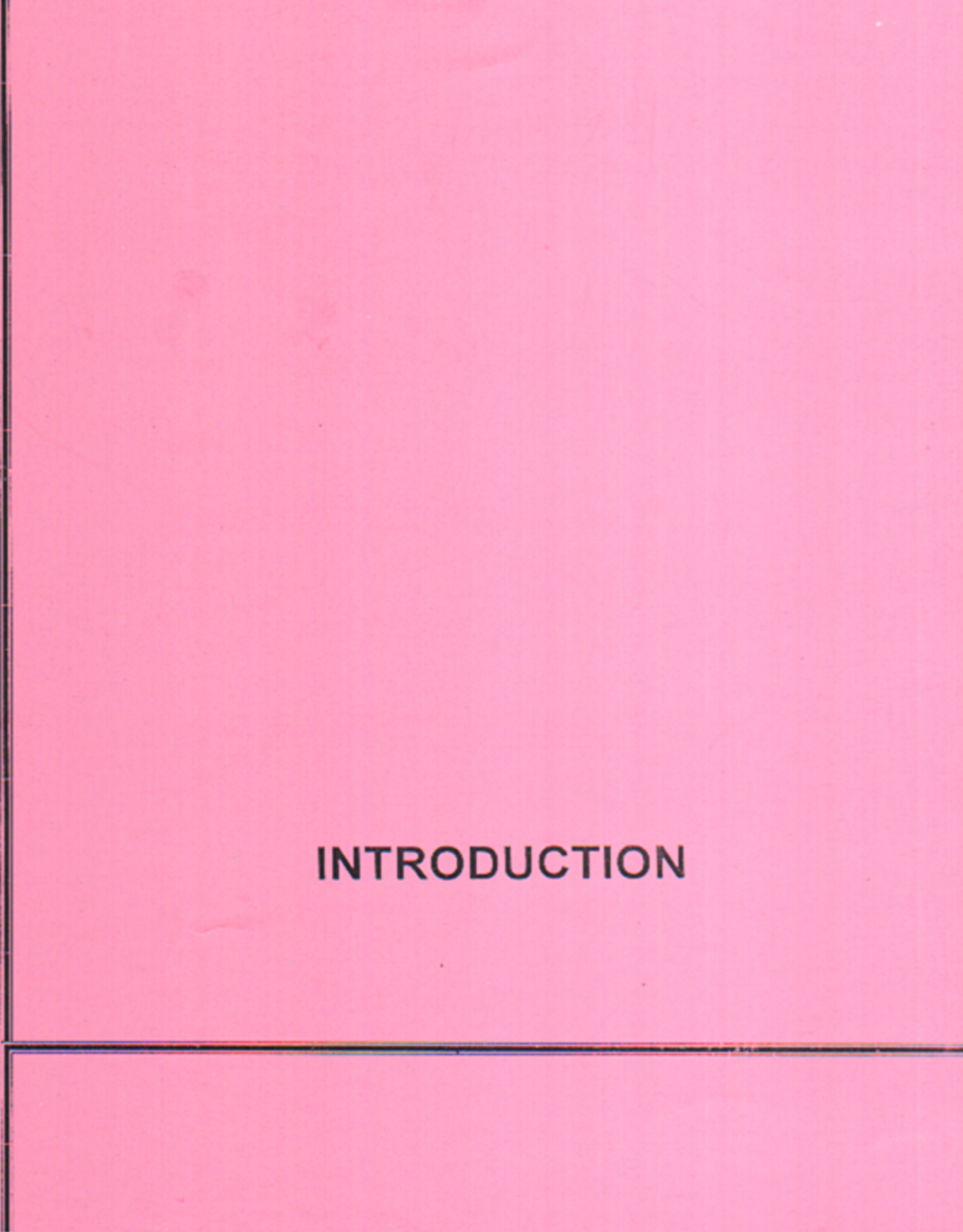
These promising plants from F₂ generations being maintained at Cotton Improvement Project, MPKV, Rahuri for further utilization.

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INTRODUCTION

1. INTRODUCTION

Cotton is one of the oldest fibres known to mankind. Evidence from the 'Indus Valley' civilization traces the history of cotton fabric in Indian subcontinent right back to 4300 years B.C. (Gulati and Turner, 1928). References to cotton materials are also found in the sacred texts like Ramayana, Mahabharata and the Puranas apart from Tamil Sangam literature dated prior to 3rd century A.D. In the ancient Dravidian literature a special mention has also been made regarding the use of cotton seed as food during famines and of lint as material for spinning and fabric making, and its use as wick for lamps. The first improvement in spinning technology was the spinning wheel, which was invented in India between 500 and 1000 A. D. (Smith and Cothren, 1999)

Looking to the history of global human civilization, references indicate that India was carrying on a flourishing trade in cotton as early as 2500 years ago. Today, India is going to be in surge in textile industry ahead of China which become possible only due to cotton crop, which is the very backbone of textile industry. Cotton plays vital role in Indian economy. It sustains the cotton textile industry which consists the single largest segment of organized industries in the country. The cotton cultivation, its trade, processing, manufacturing, exports, etc. provide the means of livelihood to more than 60 million people in India.

Cotton is world's leading fibre, food and commercial crop, which belongs to genus *Gossypium* L. This genus consists of 50 species which have an aggregate geographic range which encompasses the most tropical and subtropical regions of the world. (Percival *et al.* 1999) Among these species, 44 are diploid ($2n = 2x = 26$) and fall into A, B, C, D, E, F, G and K genomes (Endrizzi *et al.* 1985; Steward, 1994, Wendel, 1989) and the remaining are all allotetraploids ($2n = 4x = 52$ AADD) with progenitors of *G. herbaceum* var. *africanum* (A_2A_2) and *G. raimondii* (D_5) (Wendel, 1989). There are four cultivated species, in the world. Allopolyploids *G. hirsutum* and *G. barbadense* ($2n = 4x = 52$, AADD) and the old world diploids *G. herbaceum* L. and *G. arboreum* ($2n = 2x = 26$, AA).

With the modernization of textile and spinning mills the fibre quality requirement of raw cotton should be of high strength, maturity and elongation and of medium micronaire value to suit high-speed machines. To cater to the needs of these mills, it is necessary to reorient the breeding programme. Even though a great variability for the fibre quality traits is available in existing cotton

germplasm, it is not possible to satisfy the changed requirements. One of the ways to create such variability is to work with introgression of gene through wild species hybridization, (Naryanan *et al.*, 1984).

The cotton fibre is an important raw material for the textile industry. As a result of the recent advances in the textile industry in spinning technology, greater fibre quality, particularly strength, is required. (Deuce, 1992) Because of the rigors in ginning, opening, cleaning, carding, combing and drafting, the important breeding objective is to increase the fibre strength. Research on improvement of fibre quality has been primarily focused on increasing the fibre length and fibre fineness. Improved cotton varieties and hybrids with the fibre length falling in the category of medium staple ($\geq 20.00\text{mm}$) to extra long staple ($\geq 32.5\text{ mm}$) have been developed and released for cultivation under different agro-climatic situations. The modernization of textile industry and the use of open-end rotor spinning technologies has put a great demand for cotton varieties and hybrids with higher fibre strength ($\geq 25\text{ g/tex}$) with micronaire ranging from 4.0 to 4.5. There is an urgent need to improve the cotton fibre quality further. However, there is no rapid way to do this by current plant breeding methods and on the basis of current genetic information. In traditional breeding to develop super quality fibre properties, the quality of the fibre can be determined only after harvesting and testing the fibre. As a result, it is difficult, expensive and time-consuming work to develop cotton cultivars with super fibre quality methods.

Plant protection is an important component of successful cotton production. Now a day's cultivating cotton has become costly affair due to pest management. Hargreaves (1948) has reported about 1325 insects inhabiting the cotton. By and large 230 insect pest species affect cotton in the world and 46 insect pest species have been identified as major insects in 32 countries. Around 10-15 principal pests in nine major cotton growing countries cause significant losses. 22.5 per cent crop pesticide is used on cotton alone. In spite of usage of huge amount of pesticides, cotton has become psycho-socio economic tension to the farmers of India.

Hybridization between species serves the purpose of transferring of gene combinations which are not normally available within the limits of species. Interspecific hybridization, involving wild types and cultivated species of *Gossypium*, was attempted by several workers. Wild species are known to

possess characters that would be desirable in the cultivars. Adoption of standardized systems of introgression shows the precise evaluation of the selective value of a particular gene complex. Sophisticated techniques with suitable adjustments in the breeding system for accelerating the rate of introgression and controlled experimentation are necessary to achieve the desired goals in interspecific gene transfer in *Gossypium* like diseases and pest resistance (Mehtre *et al.* 2002, a), the fibre quality parameters (Mehtre, *et al.* 2004).

The old world Asiatic cultivated species *G. arboreum* and *G. herbaceum* in this pests and other wild species *viz.*, *G. thurberi*, *G. trilobum*, *G. armourianum* and *G. somalense* showed appreciable resistance. Reduced insect numbers and amount of seed damages were reported on glabrous and nectariless as compared to a normal nectariless-pubescent variety. Thus, these two traits had an addition effect in lowering larvae number and seed damage. (Wilson and Wilson, 1976) And at the same time high plant hair density is also reported to be a promising mechanism for resistance to the pink bollworm in cotton.

Indiscriminate use of pesticide has developed the resistance in bollworm and resurgence of whiteflies. In *G. thurberi* some resistance has been shown to bollworms in the early stages (Anonymous, 1944) which might be due to repellent substance present in the petals of flower of *G. thurberi* which prevents the oviposition by the moth on the plant. Small and smooth bolls also contribute to this resistance (Ganeshan, 1946). Better spinning and fibre strength are transferred from *G. thurberi* to *G. hirsutum* by using the amphidiploid (*G. arboreum* x *G. thurberi*) x *G. hirsutum* (Anonymous, 1957). Toughness of tissue is an efficient defense mechanism for resistance breeding. Resistance in cotton plant to the pink bollworm involves the absence of bracts, glabrous leaves, cell proliferation, high gossypol content and nectariless characters (Agarwal *et al.* 1976).

Pink bollworm [*Pectinophora gossypiella* (Saunders)] is a major limiting factor in cotton production in many parts of the world. The infestation of *Helicoverpa armigera* is decreasing due to the increase in transgenic (Bt) cotton area. Even if *Helicoverpa* is decreased, the resurgence of the other pests may come out likely. Under such conditions there is a threat of increasing infestation of pink bollworm on cotton. The hidden losses by pink bollworm are too much as

it affects quantity and quality of the product. The infestations of *Helicoverpa* in transgenic cotton decreases considerably but the infestation of pink bollworm remain at 7-10%. At present the pink bollworm is controlled by spraying

with insecticides but the continuous use of insecticides will give rise to the development of resistance of pest.

Hence, it will be worth to plan for the development of resistance to this pest. A genetic source of resistance enables the grower to reduce the attack of pink bollworm. Several morphological mutants and the breeding stocks of cotton possess the resistance for pink bollworm. The nectariless and glabrous traits significantly reduce the pink bollworm larvae and save the seed from damage. High plant hair density is a promising mechanism of resistance to pink bollworm. The characters like glabrous^{us}ness and nectariless, okra leaf and early maturity provide significant resistance to pink bollworm. The antibiotic flavonoid terpenoids contents are essential part of resistance to pink bollworm.

Deshi (*G. arboreum*, L.) varieties of cotton have in built desirable genes for drought tolerance and resistance to insect pests like bollworms, aphids and diseases like black arm, root rot and reddening of leaves and hence, they are suitable for rainfed condition. Hence, earlier attempt made to combine desirable characters of both the species of *Gossypium* has successfully resulted in production of F₁ hybrid (Mehetre *et al.* 2003) in Cotton Improvement Project, MPKV, Rahuri. Exhaustive efforts were made and continued to obtain the desirable germplasm by pre-breeding.

In this present investigation, parents F₁, F₂ and BC₁ generation of interspecific cross *G. arboreum* x *G. thurberi* Tod were studied with following objectives:

- *Morphological and anatomical characters,*
- *Meiotic chromosome behavior, and*
- *Inheritance of qualitative characters fibre strength and pink bollworm reaction.*

Chapter Opener Page

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In the present investigation, an attempt was made to obtain F₁ hybrid of *G. arboreum* x *G. thurberi* for the transfer of boll worm resistance of *G. thurberi* to cultivated *G. arboreum* as well as to tetraploid *G. hirsutum* cottons. The literature related along with this background as well as to the account of the earlier work done, is presented in this chapter.

2.1 Potential of wild species of cotton

The wild species of *Gossypium* form an important source of genes seek to be transferred for improving the cultivated varieties through hybridization, backcrossing and polyploidy breeding. Among the most desirable attributes, which are considered for transferring the potentiality from wild species of cotton, to impart strength and fineness of lint to the cultigens, assumes importance in breeding project (Narayanan and Sreeragasamy, 1973).

Many of the various species of both diploid and tetraploid provide the most intriguing sources of genetic variability for cotton variety improvement? Difficulties in the utilization to transfer the relevant genes of these species arise from chromosome structural differences and in differences in chromosome complements between the candidates wild diploids and the tetraploids from where gene transfer is visualized (Niles, 1980). Fertility relationship among species is highly variable, and only about two thirds of the interspecific hybrids studied produce fertile F₁s (Anonymous, 1968 a). The exotic species have provided useful variability for improvement of fiber properties, cold tolerance and resistance to diseases and insects (Fryxell, 1976). Nuclear complements of two upland cottons were combined with cytoplasm of seven other *Gossypium* species; these provide a valuable and unique germplasm source for cotton improvement (Meyer, 1973 and 1975).

Adoption of standardized systems of introgression, precise evaluation of the selective value of a particular gene complex, sophisticated techniques with suitable adjustment in the breeding system for accelerating the rate of introgression and controlled experimentation are necessary to achieve the desired goals interspecific gene transfer. The various aspects of introgressive gene transfer in *Gossypium* for diseases and pest resistance, (Mehetre *et al.* 2002 a), for fiber quality parameters (Mehetre *et al.* 2004), problems of wide hybridization (Mehetre *et al.* 2002 b) and embryo rescue as tool to achieve interspecific hybridization (Mehetre and Aher, 2004) are reviewed critically.

Interspecific crosses between American cottons and some of the wild species like *G. armourianum*, *G. anomalum*, and *G. tomentosum* are reported by Patel and Thakar (1950). They pointed out the possibility of getting hairy type plant, showing good jassid and drought resistance. Further, they warned about the adverse effects of wild genes on staple length too.

Kalyanraman and Santhanam (1954) surveyed the sources of derived genes for useful characters and the role of wild species of *Gossypium*. According to their studies *G. anomalum* an African diploid ($2n = 26$) wild species, possess some what low fibre weight, resistance to black arm disease, jassid and narrow bracts which can be utilized in the improvement of cultivated cottons.

The fineness of lint was transferred from *G. anomalum* to *G. arboreum* by Iyengar, et al. (1958). They studied F_2 and F_3 , 1st and 2nd backcrosses. According to them, for building up homozygous lines from above mentioned material, in respect in ginning percent values to the similar level of *G. arboreum* species can be build up.

Backcross from different crosses using *G. arboreum* x F_1 (*G. herbaceum* x *G. anomalum*), F_1 (*G. arboreum* x *G. anomalum*) x *G. herbaceum*, F_1 (*G. arboreum* x *G. anomalum*) x *G. herbaceum*, F_1 (*G. arboreum* x *G. anomalum*) x *G. anomalum* were reported (Lazareva and Kikter 1984) and they have proposed the possibility to recover plants having lint with fibre fineness of *G. anomalum*.

Investigations of a cross *G. hirsutum* haploid x *G. anomalum* (Mehetre and Thombre, 1982) revealed that the hybrid was vigorous, tolerant to jassids, blackarm and leaf spot was caused by *X. malvacearum*.

The earliest record of the use of *G. thurberi* dates back to 1938 when Mauer crossed doubled F_1 (*G. arboreum* x *G. thurberi*) with *G. arboreum*. The resulting F_1 was then backcrossed to *G. hirsutum* and *G. barbadense*. Artificial tetraploids of *G. arboreum* x *G. thurberi* which were sterile male and fertile female were obtained by Harland (1940). These amphidiploids were found readily crossable with the cultivated American cotton. An amphidiploid of *G. arboreum* x *G. thurberi* was developed by Zhurbin (1941) with colchicine which was sterile but one branch of the doubled plant was female fertile. New world amphidiploids were resynthesised by doubling the chromosome complement of *G. thurberi* x *G. arboreum* (Harland, 1941). They were male sterile but female fertile and would cross with *G. barbadense* and *G. hirsutum*. One flower had produced abundant functional pollen, which resulted in seed development on the tetraploid (Beasley, 1940; 1942). Beasley and Richmond (1940) produced a seed of the doubled hybrid

G. arboreum x *G. thurberi* which was crossed with *G. hirsutum* var. cocker-100. The resulting progeny exhibited poor ginning percentage but finer fibres. The plants of *G. thurberi* x *G. arboreum* were found to yield seeds. Further, bolls have been obtained by crossing *G. thurberi* x *G. arboreum* with *G. hirsutum*. The lint of these bolls was short and silky (Anonymous, 1942). Doubled hybrid crossed with *G. hirsutum* lines produced a lint of over 25 mm long, strong and slightly brown. The seeds were either full Fuzzy or naked. Doubled hybrids of *G. thurberi* x *G. arboreum* showed seasonal rhythm in flowering. A fertile amphidiploid of *G. arboreum* x *G. thurberi* was obtained by Brown (1949) who introduced genes of fibre strength into *G. arboreum* cultivated diploids. The doubled F₁ of *G. arboreum* x *G. thurberi* produced by Ganesan (1946) referred to as 'Thurboreum' and was ^{male} sterile except during monsoon. *Thurboreum* was crossed with *G. hirsutum* and *G. barbadense*.

G. thurberi is an important species relative to transfer the pink boll worm (*Pectinophora Gossypiella* S.) immunity (Harland, 1940) and higher lint strength (Anonymous 1968 b; Stappenfield, 1970) to cultivated cottons. According to Brown and Menzel (1950), earlier workers gave more emphasis to the transfer of fibre strength followed by bollworm resistance (Knight, 1946), resistance to frost, field hardiness and prolific boll bearing. Earlier, Knight *et al.* (1952 and 1953), Cunay (1952), and Ganesan (1946) transferred high-fibre strength and boll worm resistance from *G. thurberi* to 'Sakel' cotton of Sudan and to upland in Texas and North Carolina, in the United States of America (USA) and in India.

In Indore, F₆ progenies from the crosses of *G. thurberi* with *G. arboreum* and the cultivated American species showed considerable heterogeneity in seed characters and most of the progenies had a halo length over 27 mm (Anonymous, 1950 a). The hexaploids had been backcrossed twice with upland cottons seeds produced from plants of doubled *G. arboreum* x *G. thurberi* and were grown and backcrossed to *G. hirsutum* and extremely variable populations were obtained from them some of the plants were found prolific in bearing. The fibres of some of the plants were finer than those of the upland parent, they had fewer convolutions and were stronger (Beasley and Richmond, 1940). According to Brown and Menzel (1950) the character of *G. thurberi* on which most emphasis has been placed in the current breeding programme is of high strength. According to Ndungo *et al.* (1988), the HAT (*hirsutum* - *arboreum* - *thurberi*) hybrids initially combine high fibre strength with a number of unfavorable characters. Studies of Tayyab *et al.* (1994)

listed many superior qualities of different wild species and they can be utilized in cotton improvement when transferred to cultivated cottons.

Cultivated species (*G. hirsutum* and *G. arboreum*), 4 wild species (*G. thurberi*, *G. anomalum*, *G. sturtianum* and *G. bickii*) and one semi-wild species (*G. mexicanum*) are used to create 76 new germplasm lines through 9 types of various methods (Niu *et al.* 1998).

2.2 Fibre strength

The increase fibre strength was observed in the following crosses. *G. hirsutum* x *G. anomalum* (Deodikar 1949); *G. hirsutum* x *G. anomalum* x *G. hirsutum* (Pandya and Patel 1958); *G. hirsutum* x *G. arboreum*, (Anonymous 1981); *G. hirsutum* x *G. arboreum* x *G. raimondii* (Roux 1958 and Ndungo *et al.* 1988); *G. hirsutum* x *G. sturtianum* (Muramoto 1969a, b and c); *G. barbadense* x *G. harknessii* x *G. arboreum* x *G. armourianum* (Kul'Baeva 1974); *G. hirsutum* x *G. thurberi* (Demol *et al.* 1976); *G. hirsutum* x *G. harknessii* (Demol *et al.* 1976); *G. hirsutum* x *G. longicalyx* (Demol *et al.* 1976); *G. herbaceum* x *G. arboreum* x *G. anomalum* (Narayanan and Sreerangasamy 1973); *G. hirsutum* var. *latifolium* x *G. herbaceum* var. *africanum* (Chiavegato *et al.* 1985); *G. hirsutum* x *G. areysianum*. (Andre and Verschrage 1983); *G. hirsutum* x *G. arboreum* x *G. thurberi* (Ndungo *et al.* 1988); *G. hirsutum* x *G. raimondii* back crossed to *G. hirsutum* (Konel and Bell 1999) ^{and} *G. hirsutum* x *G. sturtii* x *G. hirsutum* (Liang *et al.* 1999).

Improvement of fibre strength in the upland cotton, using *G. thurberi* (Kerr, 1951) was reported. Thus, the wild species and primitive forms are useful for various breeding purposes and in some cases may be indispensable.

Fibre characteristic like the fibre strength was transferred from *G. thurberi* into Domains Sakel (Egyptian *barbadense*) and the gene of 'Pilosity' from *G. tomentosum* into *G. barbadense* cultivated tetraploid species (Knight *et al.* 1952 and 1953).

2.3 Morphological study

Four F₁ plants of *G. stocksii* and *G. indicum* were obtained by Afzal and Trought (1933) in which three of them resembled *G. stocksii* parent and the fourth one was intermediate to the parents. All hybrids were sterile.

Kanash (1936a) reported the variegatedness of morphological characters in F₁ and marked the predominance of 52 chromosome parent. F₁ hybrids of *G. barbadense* x *G. arboreum*, *G. hirsutum* x *G. herbaceum* and *G. barbadense* x *G. herbaceum* transgressed the parental limits in most of the morphological characters (Kanash, 1936b). Many of non-parental characters appeared

occasionally. According to him, characters like the lint length up to 50 mm, superiority of boll size from parents, ginning outturn and earliness was observed.

In crosses viz., *G. thurberi* x *G. raimondii*, *G. raimondii* x *G. armourianum* intermediate and fertile hybrids were obtained by Boza Barducci and Madoo (1941) which gave good seeds but failed to give plants. They also obtained seven empty seeds in one boll of *G. raimondii* x *G. harknessii*. They found *G. hirsutum* x *G. raimondii*; hybrid was vigorous and intermediate which gave one plant from unselfed bolls.

Large size of boll was found in a cross between Bishnoor (*G. arboreum*) and Malvi-9 (*G. hirsutum*) by Anonymous (1945) which was nearly dominant. They observed boll size closely associated which was associated with leaf shape. Also intermediate boll size was reported in the crosses between large boll varieties from Punjab and small balled Malvi-upland cotton from Indore.

In transferring the fineness of lint, Iyengar *et al.* (1958) in the cross *G. arboreum* (Karunganni) x *G. anomalum* obtained fine linted, fully fertile plants with good mean fibre length in both F₂ and F₃ from the 1st and 2nd backcross.

Backcross derivation of an interspecific hybrid (*G. arboreum* x *G. anomalum*) was evaluated by Nagarajan and Ponnaiya (1964). They found that the BC₁F₁ and BC₂F₁ exhibited transgressive segregation of economic characters than the F₁ hybrid, which was intermediate to these parental characters.

Heterosis in interspecific hybrid *G. hirsutum* x *G. barbadense* was observed by Popova *et al.* (1980) which included the characters like, height, fruiting and fibre length in F₁. They found that the fibre thickness belonged to *G. barbadense* and fibre yield, boll size and earliness was intermediate. The bract shape of *G. hirsutum* and the leaf shape, flower colour, petal spot, gossypol glands of *G. anomalum* were reported to be dominant (Mehetre and Thombre, 1982) in the F₁ hybrids between haploid *G. hirsutum* x *G. anomalum*.

Variation in size and shape of leaves, bracts, flower colour and self sterility or fertility was reported in the progeny of backcross (*G. arboreum* x *G. anomalum*) x *G. arboreum* studied by Gill and Bajaj (1986).

F₁'s of crosses involving *G. herbaceum*, *G. barbasonum* and *G. anomalum* were intermediate to their parents in the morphological characters (Zhou *et al.*, 1992). In similar studies of a cross *G. arboreum* x *G. nelsonii* in 1994, they reported that the hybrids were intermediate for morphology except some of the characters which were not found in parents. Comparison of parents and hybrid of crosses *G. arboreum* x *G. raimondii*, *G. hirsutum* x *G. rainmondii* (Meshram and

Tayyab 1994) characters were intermediate although they possessed predominant leaf shape characters of female and floral characters of male.

Twenty three hybrids were obtained by Amin, (1940) showed that they were hybrid vigour and were intermediate for most of the characters. They also found that the hybrids were sterile.

2.4 Cytological study of cotton

The review of research work done by different research workers on following aspects have been given in the table below.

Table 1. Meiotic chromosome behaviour in different species of cotton

Sr.	Hybrids	Chromosome behavior at Metaphase-I				Charismata per bivalent	Reference
		I	II	III	IV		
Chromosome behaviour of F ₁ hybrid involving the diploid species of the new and old world cotton.							
1.	<i>G. arboreum</i> with <i>G. thurberi</i>	9.6	7.8	0.2	0.05	1.16	Skovsted (1937)
i.	<i>Arboreum</i> var. <i>nanking</i> with <i>G. thurberi</i>	24.0	1.0	-	-	-	Webber (1939)

2.5 Combine references of morphology and cytology of cotton

Trispecific hybrids, obtained by the crossing allotetraploids of *G. arboreum* x *G. bickii* ($2n = 4x = 52$, $A_2A_2G_2G_2$ genome) with different varieties of *G. barbadense* ($2n = 4x = 52$, AADD genome) were evaluated for morphological and cytological characters. Plant type and leaf type of the hybrids tended to be like those of male parents, *G. barbadense*, with floral characters such as flower colour tended towards *G. bickii*. There were numerous univalent in PMCs of the F₁ hybrids at Metaphase II and the meiotic configuration was $2n = 4x = 52 = 42.8^I + 4.6^{II}$. At anaphase I, chromosomes were separated abnormally, which gave rise to different types of sterile microspore and led to high level of sterility in the trispecific hybrids studied by Ding *et al.* (1999).

A hybrid between the genetic male sterile line of *G. arboreum* (GMS) and *G. thurberi* was obtained and its cytology was compared with those of the male and female parents. The hybrid was intermediate ^{for} all 11 characters and showed dominance of prolificacy in boll setting, forming bolls that contained well developed seed with brownish lint. Thus, the fertility observed in this hybrid showed the possibility of transferring bollworm (*Pectinophora gossypiella*) resistance, high-fibre strength and prolificacy for boll bearing in cultivated *G. arboreum* cotton. The

cytological study indicated the frequent formation of univalent and occasionally, quadrivalents and trivalents. On average, $9.81^I + 7.42^{II} + 0.25^{III} + 0.2^{IV}$ the association of chromosome was observed. This abnormal chromosome behaviour resulted in an abnormal second meiotic division, which led to the formation of abnormal sporads and pollen in size variation and pollen sterility which was studied by Mehetre *et al.* (2003).

Saitwal *et al.* (2003) studied a comparative cytological study of *G. arboreum* and *G. anomalum* and their F_1 , F_2 and BC_1 hybrids was made. The F_1 , F_2 and BC_1 generations were found to have irregular pairings and unequal separation of chromosomes, which led to pollen sterility in their generations. However in BC_1 generation, bivalent frequency and normal tetrad formation were improved. Morphological studies revealed that the interspecific hybrid was partially fertile and vigorous. In the F_2 and BC_1 some good plants were identified with higher pollen fertility and more number of bolls per plant selection from these plants had helped to introgress desired characters, from *G. anomalum* to *G. arboreum*.

Three primers tested OPA-12, OPB-5, OPD-4 showed the recombination events in F_2 progenies. In F_2 -3 progenies of a *G. thurberi* specific amplified with OPA-12 primer whereas with OPB-5 additional band has been in F_2 progenies which indicate the generation of priming site, while rest of primers showing monomorphic banding pattern in the F_2 reported by Kale (2005).

Cytomorphological studies and RAPD analysis was carried out by Kale and Mehetre (2006) in parents, F_1 hybrid, F_2 and BC_1 generations of cross between *Gossypium arboreum* var. MPKV GMS and *G. thurberi*. Substantial variability for the different morphological characters in the F_2 and BC_1 generations was observed. F_1 hybrid showed chromosome configurations $9.4^I + 8.00^{II} + 0.08^{III} + 0.09^{IV}$ indicated sufficient degree of bivalent formation. On an average $8.43^I + 3.77^{II} + 2.59^{III} + 0.57^{IV}$ and $8.4^I + 3.69^{II} + 2.69^{III} + 0.54^{IV}$ chromosome configurations were observed in F_2 and BC_1 generations, respectively. Very low trivalent (0.50) and (0.34) for quadrivalents indicated the homology between the paired chromosomes and the chances of exchange of chromatid formed ^{between} two different species. Thus, the inter genomic transfer of desirable genes responsible for pink bollworm (*Pectinophora gossypiella*) tolerance and better fibre quality parameters from wild *G. thurberi* to cultivated *G. arboreum* is possible.

There was considerable variation in the ability of individual primers to detect DNA polymorphism. The OPA 12 showed the creation of priming

sites during meiosis of one of the parent leading to the generation of new amplification product in F₁ and most probably it is from *G. thurberi*. These unique markers would have originated due to recombination, mutation or random segregation of chromosomes at meiosis during hybrid formation. The F₂-2 progeny showed one additional band than F₁, might be due to reverse recombination event happened in F₁ plant. Similarly, F₂-1 progeny show the recombination event and in F₂-5, F₂-6 and F₂-8 loss of priming site. Sufficient homology observed between A and D chromosomes indicated quite high chances of getting recombinations of pink bollworm tolerance because of repellent scent present in petals of *G. thurberi* which prevent oviposition of the moth on plant.

2.6 Anatomical basis of resistance to bollworms:

Cotton suffers from many pest problems which has become a serious limiting factor. In India, the most serious pests are *Helicoverpa armigera* Hubner (American bollworm), *P. gossypiella* (Pink bollworm), *Earias vittella* and *Earias insulana* (Spotted bollworms). During 1983 and 1990, the cotton production was seriously affected in Punjab, Haryana and Rajasthan mainly due to American bollworm (*Butter et al.* 1994). There was an out break of American bollworm in 1987-88 and 1992 in Andhra Pradesh and caused heavy losses in cotton production (Alagh, 1988). The bollworm situation in Andhra Pradesh was further alarming during 1997-98 worsening the cotton growers' plight.

Considerable work has been done by several workers on the various chemical and morphological aspects, but until, now very little attention have been paid towards improving the mechanical and physical resistance aspect such as tissue toughness/stiffness of various plant parts and boll rind thickness. Boll rind penetrance is an important resistance parameter which prevents insect feeding and egg deposition possessed high rind penetrance value. Beck (1965) has clearly shown that the strength required for penetrance determines the extent of damage caused by insect pests during its feeding. Since then, boll rind toughness and its thickness were considered as a barrier or permissive factor in selection and preference of food by the pests.

Saxena (1973); Ansingkar *et al.* (1984); Kadapa and Thimmaiah (1983); Narayanan (1995); reported some resistant varieties whose bolls showed improved mechanical properties at an early stage during their growth. Vizia and Patil (1987) reported variability of boll rind toughness in 20 day old green bolls in the genotypes of upland cotton. Kittock *et al.* (1973) reported lesser damage by

pink bollworm with increase in boll rind thickness due to spraying ^{of} the growth regulators.

Singh and Singh (1969 and 1970) also reported that higher degree of boll rind thickness provided resistance to *E. fabia* in cotton. Kadapa (1980 a, b) and Kadapa *et al.* (1983) has also added boll rind thickness as one of the important characters that detracted the bollworms in penetrating the cotton fruiting bodies. Genotype JK 97-LPS had the thickest boll rind at three stages of development. It was found that the strains JK-276-4 and JK-260 possessed bolls with very thick rind as compared to susceptible ones like Laxmi and Sharada varieties. Ilango and Uthamaswamy (1989) found higher boll rind thickness in JK-260 than in Sharada irrespective of the age of the bolls. The thickness of rind was negatively correlated with the incidence of bollworms. Kadapa *et al.* (1988) reported high resistance to the penetration in stem tips of aphid resistant cotton genotypes. Similar observations were made by Singh and Athwal (1976) on leaf veins and shoot thickness by Singh (1989). The thickness and toughness of the tissues may be determined by the compactness of cell arrangement and the extent of air spaces (Thimmaiah, 1992).

Recently Rao *et al.* (1996) reported pest tolerant genotypes that had thicker boll rinds and short boll period, which is established by positive and negative correlations, respectively with yield in protected as well as unprotected conditions.

Thus, boll rind toughness/penetrance and rind thickness are very important in resistance breeding programme. These characters provide mechanical and physical resistance and are governed by the anatomical structures (Baehr and Pinckard, 1970; Ashworth and Hine, 1971; Cauquill, 1975; Punit Mohan and Narayanan, 1995; Punit Mohan *et al.* 1995).

The cotton boll (capsule) comprises four to five valves, each enclosing a lock in its locules. The lock contains six to eight seeds connected to the axial placenta by their micropyle. The body of the boll developed from the ovary wall is known as the pericarp (Eames and Mac Daniels, 1947). At primary stage in green bolls, pericarp is nearly homozygous and not separable into exocarp, endocarp and mesocarp respectively (Eames and Mac Daniels, 1947; Esau, 1953; Ashworth and Hin, 1971 and Baehr and Pinckard, 1970). Strictly, the term 'pericarp' refers only to the modified ovary wall.

The value of the septa as an obstacle to the pathogenic agents depends essentially on their anatomy. Higher degree of lignified sclerenchyma

provides hardness and mechanical hindrance to the movement of the larvae which try to pass from one locule to the other. The internal resistance depends upon the locular structure and their texture (Cauquill, 1975), which is governed by the amount and distribution pattern of mechanical tissues, number of cell layers, compactness and their degree of lignifications (Hector, 1936; Ashworth and Hine, 1971 and Baeh and Pinckard, 1970).

The pericarp of capsule/boll has both the sclerenchyma and the parenchyma tissues in variable distribution (Eames and McDaniel, 1947 Esau, 1953 and Cauquill, 1975). However, Duchaigne (1955); Funk (1912) and Went (1924) reported that collenchyma walls become modified at successive growth and collenchyma develop lignified secondary walls. It, thus becomes changed into sclerenchyma cell. Khadi (1991) reported that boll rind of tolerant genotypes having higher area and the amount of mechanical tissues as found in JK-345-3-3. JK-119 and in JK-276-4. However, the susceptible genotypes showed comparatively more area of parenchyma cells and intercellular spaces.

The above investigations regarding the boll rind thickness and the toughness indicate the advantage of using boll rind toughness and thickness as one of the criteria in bollworm resistance studies and crop improvement programme.

2.6.1 Leaf anatomy

Leaf anatomy in primitive and commercial stocks of upland cotton was studied by Morey *et al.* (1974) and reported a significant difference in lamina thickness and palisade height when plants were two and six months old. The older plants had a thicker lamina, taller palisade and lower tissue relations and were therefore more xerophytic than the younger ones.

The inheritance of leaf anatomical characters in interspecific hybrids involving diploid species and *hirsutum* cotton was studied by Krishnaswamy and Andal (1977). The synthetic tetraploid involving diploid cotton had a leaf structure similar to the Asiatic diploids. The hybrids had leaves with larger leaf blade thickness, a well-developed adaxial palisade and a layer of abaxial palisade.

Significant variation in leaf thickness, palisade height and tissue relation among different cotton species was observed and found that both adaxial and abaxial palisade layers were present in tree and Asiatic cottons (Singh, 1991).

In a study for multiple resistance to sucking pest complex in cotton, Ansingkar *et al.* (1992) suggested that 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 the desirable characters in developing resistance. All these characters are in favourable direction in diploid Asiatic cotton species.

Role of leaf morphology of cotton on incidence of whitefly (*B. tabaci*) was studied by Puri *et al.* (1993). They concluded that, the probable reason for differential reaction of *B. tabaci* toward different cultivars of cotton could be due to differences in their anatomical structures. Genotypes having shorter distance to phloem tissues could help in easy penetration of stylets as compared to cultivars with longer distance. Increased distance of phloem from abaxial epidermis resulted in significant reduction in adult population. Similarly, whitefly adults preferred cotton varieties with thicker mesophyll tissue layer. Wider width of mesophyll tissue might provide an easy and ample food and space for holding the egg peduncle of whitefly. Hence, most of the upland cotton varieties are susceptible to whiteflies as compared to Asiatic cotton.

Amolic (2005) studied length upper palisade layer, lower palisade layer, mesophyll, distance from 1st phloem cytoxylem, distance up to 1st phloem from lower epidermis, no. of cells in upper palisade layer, no. of upper palisade layer per leaf, no. of lower palisade layers per leaf, chlorophyll a, b. and reported correlation of anatomical characters.

The inheritance of two unique anatomical characters in rice was studied. While the presence of extra sclerenchymatous bands (ESB) in the stem is governed by two dominant basic genes with complementary action, the presence of fusoid cells is controlled by a single dominant gene. New genes symbols have been proposed for the two characters, respectively, are: **Esb** and **Fc** (Sethi and Roy, 1985).

2.7 Genetics of morphological features

Various morphological characters play an important role in cotton breeding. Some characters help in reducing the insect incidence while others enhance the utilization of cotton byproducts.

Plant characters are governed by one or few genes which are referred to as oligogenic characters. When a character is governed by single gene, it is called monogenic. When a character is controlled by few genes it is called oligogenic character. In cotton, oligogenic traits include, colour of leaf, stem, flower, anther and pollen, their shapes and surfaces.

By 1930, genetics began to provide important assistance to taxonomy. By studying the crossing and grafting relationships and the behaviour of genes in both intra and inter specific hybrids it became possible not only to divide the genus into a number of natural species, but also in many cases to indicate, however nebulously, the degree of genetic divergence between them. A survey of the literature on cotton genetics for the characters under the study is presented under the following headings.

2.7.1 Leaf shape and lobing

In cotton, leaf shape is of three types *viz.*, normal, okra and super okra. The okra leaf cotton provides better arrangement to increase a light penetration by virtue of their lesser leaf canopy. Genotypes with okra leaf are considered to be more efficient photo-synthetically than normal leaf genotypes. Okra genotypes give high potential for flower production. However, the shedding of fruiting bodies is very high in okra leaf genotypes.

The great variation in the leaf shape of cotton has attracted the attention of a number of genetic workers. In some cases of classification of shape has been founded upon the eye judgment, while in others, the shape of leaf has been expressed by a formula derived from two or three measurements. Occasionally such as length of mid rib, or distance from petiole to sinus, have been studied separately.

Mc Lendon (1912) worked with Upland-Sea island crosses and reported that a simple Mendelian gene governs the leaf shape.

As to okra leaf shape, Peebles and Kearney (1928), Ware (1929) reported the results of crosses of okra leaf and normal leaf plants in the upland cotton. Normal leaf was observed in F₁ generation and 3 normal; 1 okra in the F₂ generation.

In the new world cottons, leaf shape is determined by a series of multiple alleles (Harland, 1939). Mutability at 'O' locus of *hirsutum* has also been reported. Horlacher and Killough (1932) have shown that O⁰ (okra of *hirsutum*) can mutate to normal gene O^N under the influence of X ray irradiation.

Balasubrahmanyam (1951) reported the appearance of a narrow leaved mutant in a progeny of *arborescens* race *indicum* by treating with X ray irradiation. The narrow leaf was found to have the incomplete dominance in its crossing to the normal broad, F₂ and gave narrows, intermediates and broads in 1:2:1 ratio.

2.7.2 Petal colour

The colour of corolla varies from ivory white to deep yellow in the old world cottons, and from pale cream to deep yellow in the New world cottons.

Fyson (1908) studied crosses between yellow and white flowered types. He found that the F_1 was yellow and the F_2 segregated into yellow, pale yellow and white and sometimes yellow and white only. In the latter case there was monohybrid segregation with the complete dominance. In the former case, there was incomplete dominance.

Balls (1912) studied the crosses of Egyptian and Upland for corolla colour and noted that the yellow, when crossed with cream or lemon, resulted in the intermediate (pale yellow), in F_2 1:2:1 ratio of yellow, intermediate and cream or white was reported.

McLendon (1912) investigated the inheritance of corolla colour in crosses of upland and sea island cottons. Yellow petals with yellow anthers when crossed with the white petals and buff anthers gave an F_1 generation in which the colour in each pair characters was intermediate in intensity. Kottur (1923) crossed the full yellow of herbaceum and the white of arboreum. The F_1 was pale and F_2 consisted of pales, full yellows and whites in 39:9:16 ratio, which he explained as being a modified trihybrid ratio. Burd (1926) described the results of an experiment in which the white flowered sea island was crossed with normal yellow. The F_1 was intermediate and in F_2 the ratio of 7 yellow: 21 intermediate: 9 white was obtained. The author considers that a simple genetic difference is involved with at least one modifying factor controlling the depth of yellow pigment in coloured individuals.

2.7.3 Boll shape

The boll shape varies from almost round to long and narrow, and a large number of different true breeding shapes are known. Balls (1912) studied the segregation pattern of boll shape in the derivatives of the cross between the Upland and Egyptian cotton at F_2 generation. The boll shape is expressed as the form i. e. length, width, etc. Crossing of the upland (form 0.75) with the Egyptian (0.58) resulted in F_1 (0.60) thus showing the Upland form as dominant and in F_2 segregation pattern was observed to follow monohybrid ratio of 3:1. In addition to this correlation between wide boll and more spherical boll, wider boll and number of boll loculi was also observed. Kearney (1923) referring to an Upland-Egyptian cross states that the shape of the boll as expressed by the boll index (diameter relative to length) has a frequency distribution in F_2 which indicates that this character involves several factors.

Chapter Opener Page

MATERIAL AND METHODS

3. MATERIAL AND METHODS

The present research entitled “*Inheritance studies in interspecific cross of cotton*” was conducted during the period 2006-2007 in Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist – Ahmednagar, which is located at an altitude of 532 meters, between 19°37 N to 19°57 N latitude and 74°82’ E to 74°91’ E longitude.

3.1 Experimental material

The cotton breeder MPKV, Rahuri supplied the necessary experimental seed material detailed as below:

- i. *Gossypium arboreum* var. MPKV GMS (Regn. No. INRG 03071 and Identity No. IC 29676 (P₁))
- ii. *Gossypium thurberi* (P₂)
- iii. F₁ hybrid, (*G. arboreum* var. MPKV GMS x *G. thurberi*)
- iv. F₂ population of 40 plants
- v. BC₁ population 15 plants.

The seed were delinted by treating with the concentrated sulphuric acid for 5 minutes and then extensively washed in running water. Seed surfaces were sterilized using 5 per cent solution of sodium hydrochloride subsequently, and then the seeds were several times washed in sterile water (Mehetre and Narayanan, 1991) and used for raising the experimental generation. All the recommended cultural and the plant protection practices were adopted to raise a normal crop.

3.2 Observations

The observations on below listed traits were recorded on 5 plants of parents, 10 plants for F₁ & BC₁, while 20 plants for F₂ generation were used for recording data.

3.2.1 Plant height (cm)

The height of the plant in cm was recorded at maturity from the base of main stem at ground level to the tip of last fully opened leaf of main stem.

3.2.2 Sympodia / plant (No.)

The total number of reproductive branches was recorded as sympodia. The sympodia branches are usually spreading. These are direct boll bearing branches.

3.2.3 Monopodia / plant (No.)

The total number of vegetative branches from main stem was recorded as monopodia.

3.2.4 Internodal length (cm)

The lengths between the two nodes of main stem of the plant from middle, lower and top were recorded and average was worked out in cm.

3.2.5 Anthers/ flower (No.)

Five flowers collected to measure style and petal length and were used to count anthers/ flower. Anthers removed carefully with the help of forceps on black paper, count was made and averages were worked out.

3.2.6 Style length (cm)

Style length of all the five generations was taken with help of cm scale upto one-degree precision.

3.2.7 Petal length (cm)

The fresh fully opened flowers were collected. The petal of the flower removed with fine blade from the base. The petals arranged on white paper and the length taken from the base to apical flattened margin with the help of scale after that average was worked out.

3.2.8 Bractioles (No.)

Number of bractiole were recorded on five flowers/ plant and averages were worked out.

3.2.9 Boll diameter (cm)

Mature bolls just before the opening were selected and the diameter was recorded with the help of vernier scale in cm. The diameter of five bolls from the plant were taken and average was worked out. In case when five bolls were not available, maximum bolls were used to record the observation.

3.2.10 Bolls/ plant (No.)

The number of mature bolls were actually picked up during different picking and were counted and total number of bolls/plant was recorded.

3.2.11 Boll weight (g)

In all five well opened bolls/plant were picked up and average boll weight was determined.

3.2.12 Lint weight /boll (g) and 13. Seed weight /boll (g)

The lint with seeds was removed from mature bolls. The lint and the seed from five bolls were separated and weight was taken separately of lint and seeds. Averages were worked out.

3.2.14 Seeds / boll (No.)

After recording the seed weight from five bolls, the seed number was counted and averaged for single boll.

3.2.15 Mots/boll (No.)

Mots are the underdeveloped seeds with some fuzz on external surface. The number was recorded for five bolls and the averages were worked out.

3.2.16 Yield/plant (g)

Seed cotton yield of picking wise from randomly selected plants was summed to obtain yield / plant.

3.3 Methods

3.3.1 Cytological techniques for study of meiosis

In order to study the meiotic chromosome behaviour the flower buds were fixed in Cornoy's Fluid (6:3:1). The buds of 4-6 cm of size were fixed in Cornoy's Fluid during the period from 7.30 to 8.00 a.m. in screw capped 10 ml. Corning vials, then labelled and stored in the refrigerator for 24 hours.

The buds were then stored in refrigerator in 70 per cent alcohol for further use. The alcohol was changed frequently. The stored anthers were smeared in 2 per cent propio-carmin stain.

The slide with coverslip was then pressed firmly and then heated gently. Approximately 15 cells were observed in each case from pachytene to pollen formation stage. Selected slides were made permanent by destaining with

45 per cent propionic acid, replaced with n-butyl alcohol and finally mounted on Canada balsm (Johnson, 1940).

3.3.2 Microphotography

The microphotographs were taken on coloured film with the help of Rico 35 mm camera mounted on Leica Microscope.

3.3.3 Pollen fertility test

Selfed flowers which were collected during 8-10 a.m. were used for pollen fertility test. Pollen fertility was tested by differential stain as suggested by Alexander (1969). The stain was prepared by mixing the ingredients in to the following order of (Alexander, 1969).

1. Malachite green : 10 mg (1 ml of 1 per cent solution in 95 per cent alcohol)
2. Distilled water : 50 ml
3. Glycerol : 25 ml
4. Phenol : 5 ml
5. Chloral hydrate : 5 g
6. Acid fushisin : 0.50 mg (5 mg of 1 per cent solution in water).
7. Orange 'G' : 5 mg (5 ml of 1 per cent solution in water)
8. Glacial acetic acid : 5-10 ml.

Instead of glacial acetic acid, propionic acid gave better results. The stain was stored in coloured bottles in refrigerator.

Pollen grains were dusted on slide in a drop of differential stain, then cover slip was placed. Then slides were labelled and allowed to stain. With a view to get quick results, the solution was acidified by adding a small quantity of propionic acid. The differential stain itself acted as a temporary mounting medium and hence it was not necessary to seal the slide. These slides were observed with number 1000 x magnification. The fertile and viable pollens were stained red whereas the non-viable and sterile pollens were stained green.

3.3.4 Size of pollen grains

The slides prepared with differential stains were used for the measurement of pollen size. The stage and ocular micrometers were used for

this purpose. Hundred pollens were observed per plant and mean, S.D. and C.V. were calculated respectively.

3.3.5 Pollen germination test

The method adopted for the study of in-vitro germination of pollen was as follows.

The pollens were collected at anthesis and placed in sucrose solution of different concentrations contained in the cavity slides and were covered with a coverslips. The care was taken to spread the pollen evenly in sugar solution. Germination of the pollen grains was completed within an hour after their sowing. Glycerine-aceto carmine (1:1) was added for clarity in counting the number of germinated pollen grains (Iyengar, 1939 & 1942).

3.4 Boll Rind toughness and thickness

The growth of boll development was critically monitored every day. The date of the appearance of the first flower bud was recorded for each generation. The period from the appearance of floral bud to anthesis was recorded critically. At the stage of 50 per cent flowering, 100 flowers for non-segregating generation and 400 flowers for segregating generations were tagged. From the date of tagging 15 bolls for P₁ and P₂, 10 bolls for F₁ and BC₁ and 20 bolls for F₂ generation were sampled at 15, 30 and 45 days interval. The observation on boll toughness was recorded with the help of hardness tester at three location of the boll *viz.*, upper, middle and lower portion measured in shore. The boll rind thickness was recorded by cutting boll vertically with the help of blade and the green portion of boll rind thickness was recorded with the help of scale in (mm).

3.5 Qualitative characters

The observations on qualitative characters were recorded at the flowering and boll development stage of the crop.

3.6 Fibre quality parameters

3.6.1 2.5% Span length (mm)

2.5 per cent span length is the length of fibre estimated by digital fibrograph. This is the fibre length representing majority of the fibres and expressed in millimeters.

3.6.2 Micronaire (ug/inch)

The fibre fineness is a relative measure of size, diameter and linear density of fibre which denotes the fineness of the fibre. The instrument “Sheffield micronaire” was used to determine the fineness and expressed in microgram per inch.

The micronaire instrument employs the principle of resistance to air flow through a plug of fibres. It was estimated by placing a lint sample of 3.24 g in the specimen holder and compressing it to a fixed volume. Air at fixed pressure was forced through the plug. The amount of flow is indicated by the position of the float in the vertical tube connected to the compression chamber. Fineness is read directly on the micronaire scale.

3.6.3 Uniformity ratio (%)

The uniformity ratio determined by digital fibrograph 503.

3.6.4 Fibre strength (g/tex)

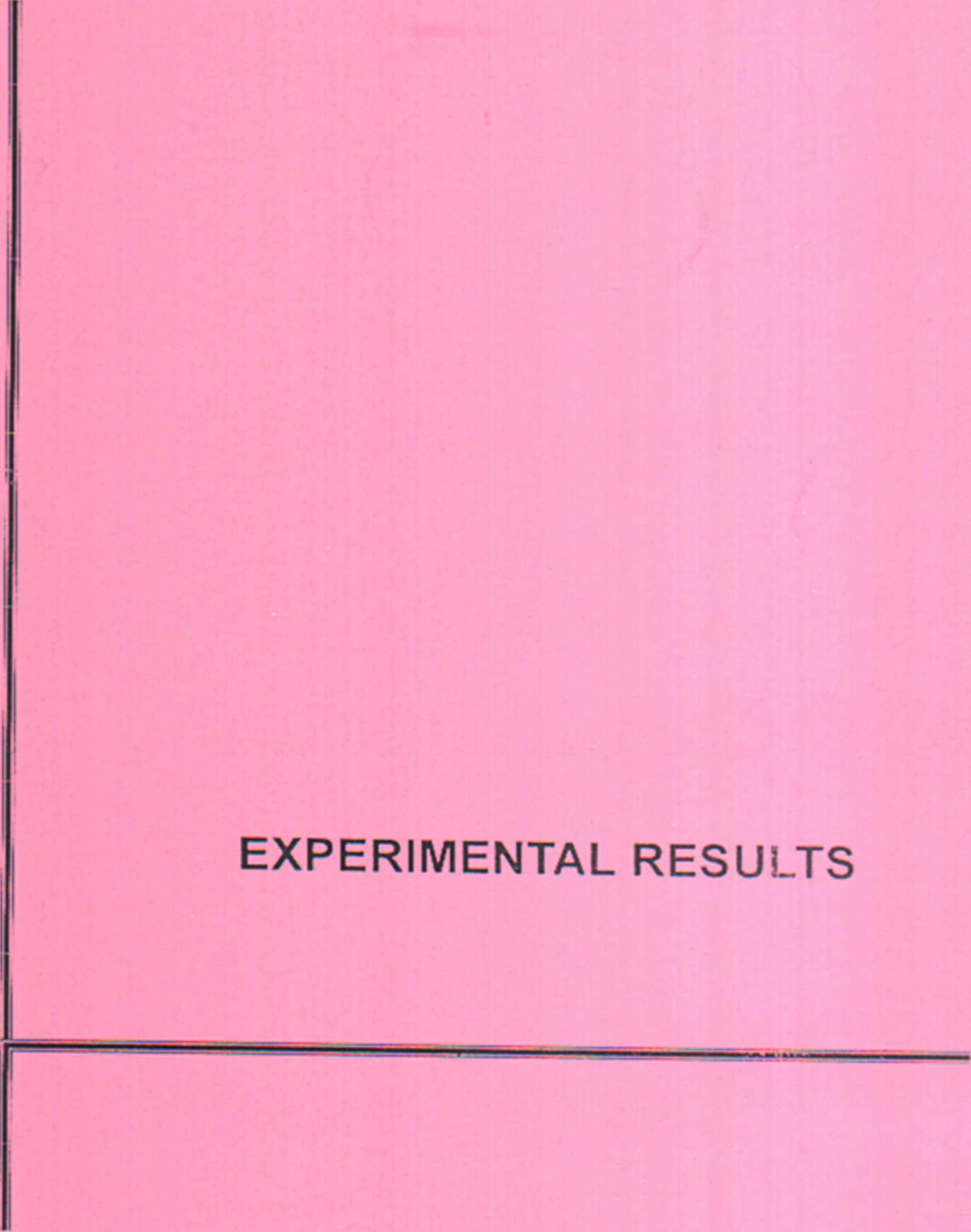
The mean single fiber strength determined is expressed in unit of the “grams/tex”.

The fibre quality analysis was done at CIRCOT, Mumbai as per standard procedure.

3.7 Statistical analysis

For the morphological characters, means and S.D. were calculated as per Syndecor and Conchran (1967).

Chapter Opener Page



EXPERIMENTAL RESULTS

4. EXPERIMENTAL RESULTS

The present work entitled "Inheritance studies in interspecific cross of cotton" was undertaken. The results of different morphological characters of segregating generations and their parents, meiotic chromosome pairing of F_1 , F_2 & BC_1 generations, fertility of hybrid, Boll anatomical observations & qualitative characters inheritance are presented below.

4.1. Studies on morphological characters

Mean data and coefficient of variation for 16 quantitative characters are presented in Table No 2, 3 and Plate I. The percent increase /decrease presented in Table No 4.

4.1.1 Plant height :

In F_1 (118.10 ± 3.48) showed decrease for this trait which was 11.00 per cent and 24.66 per cent over mid parent and better parent, respectively.

In F_2 generation plant height (161.86 ± 23.49) which was 37.02 per cent more than F_1 mean. The range of F_2 generation was 122.4 to 230.3. In BC_1 , showed plant height with average 112.96 ± 24.33 ranging between 80.4 cm to 155.2 cm.

Maximum variation for this trait was found in BC_1 , (21.33) followed by F_2 (14.51), F_1 (2.95), P_2 (2.11) and P_1 (1.59)

4.1.2 Sympodia/ plant (No.) :

The F_1 hybrid (9.6 ± 1.65) showed decrease of 47.83 per cent and 59.66 per cent over mid parent and better respectively.

The range in F_2 generation was 10.0 to 28.0 with average sympodia of 20.55 ± 4.82 which was 114.06 per cent than F_1 . In case of BC_1 average no. of sympodia recorded 13.64 ± 3.80 with range of 8.1 to 21.2.

The highest coefficient of variation was observed in BC_1 (27.86) than F_2 (23.44), F_1 (17.19), P_2 , (15.46) & P_1 (12.31).

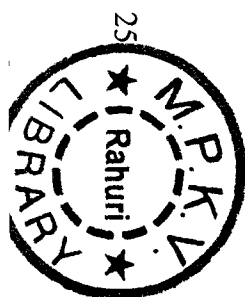
4.1.3 Monopodia / plant (No.) :

The hybrid (4.9 ± 0.94) showed increase of 188.24 per cent and 122.73 per cent over mid parent and better parent respectively.

The range in F_2 was 1.0 to 7.0 with mean of 2.40 ± 1.17 showed decrease in monopodial number by 51.02 per cent over interspecific

Table 2 : Mean Data on different morphological characters recorded in *G. arboreum* and *G. thurberi* and its F1 hybrid

Sr. No.	Measurements of Characters(Average units /plant)	<i>G. arboreum</i> (P ₁)			<i>G. thurberi</i> (P ₂)			F ₁		
		Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)
1	Plant height (cm)	156.08	2.48	1.59	109.38	2.31	2.95	118.13	3.48	2.95
2	Sympodia (No.)	23.80	2.93	12.31	13.00	2.22	19.27	9.60	1.85	19.27
3	Monopodia (No.)	1.20	0.32	26.67	2.20	0.40	26.53	4.90	1.30	26.53
4	Internodal length (cm)	5.66	0.29	5.12	4.11	0.22	4.02	4.98	0.20	4.02
5	Anthers/flower (No.)	37.40	3.26	8.72	54.4	3.22	6.40	56.70	3.63	6.40
6	Length of style (cm)	1.46	0.21	14.38	2.30	0.22	17.22	1.51	0.26	17.22
7	Petal length (cm)	3.36	0.26	7.74	2.96	0.36	8.01	3.62	0.29	8.01
8	Bractiole (No.)	3.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00	3.00
9	Boll diameter (cm)	1.99	0.06	3.02	1.56	0.05	3.55	1.69	0.06	3.55
10	No. of bolls	39.20	1.72	4.39	53.80	2.71	6.26	42.50	2.66	6.26
11	Boll wt. (g)	2.06	0.06	2.91	1.22	0.05	3.75	1.60	0.06	3.75
12	Lint wt/boll (g)	0.78	0.03	3.85	0.55	0.02	3.33	0.60	0.02	3.33
13	Seed wt/boll (g)	1.56	0.08	5.13	0.88	0.07	7.22	0.97	0.07	7.22
14	No. of seeds/boll	24.8	2.03	8.19	10.20	1.60	15.48	16.60	2.57	15.48
15	No. of motes/boll	1.80	0.62	34.44	1.20	0.42	50.00	1.60	0.80	50.00
16	Yield per plant (g)	70.80	3.42	4.83	49.52	5.72	12.20	57.14	6.97	12.20



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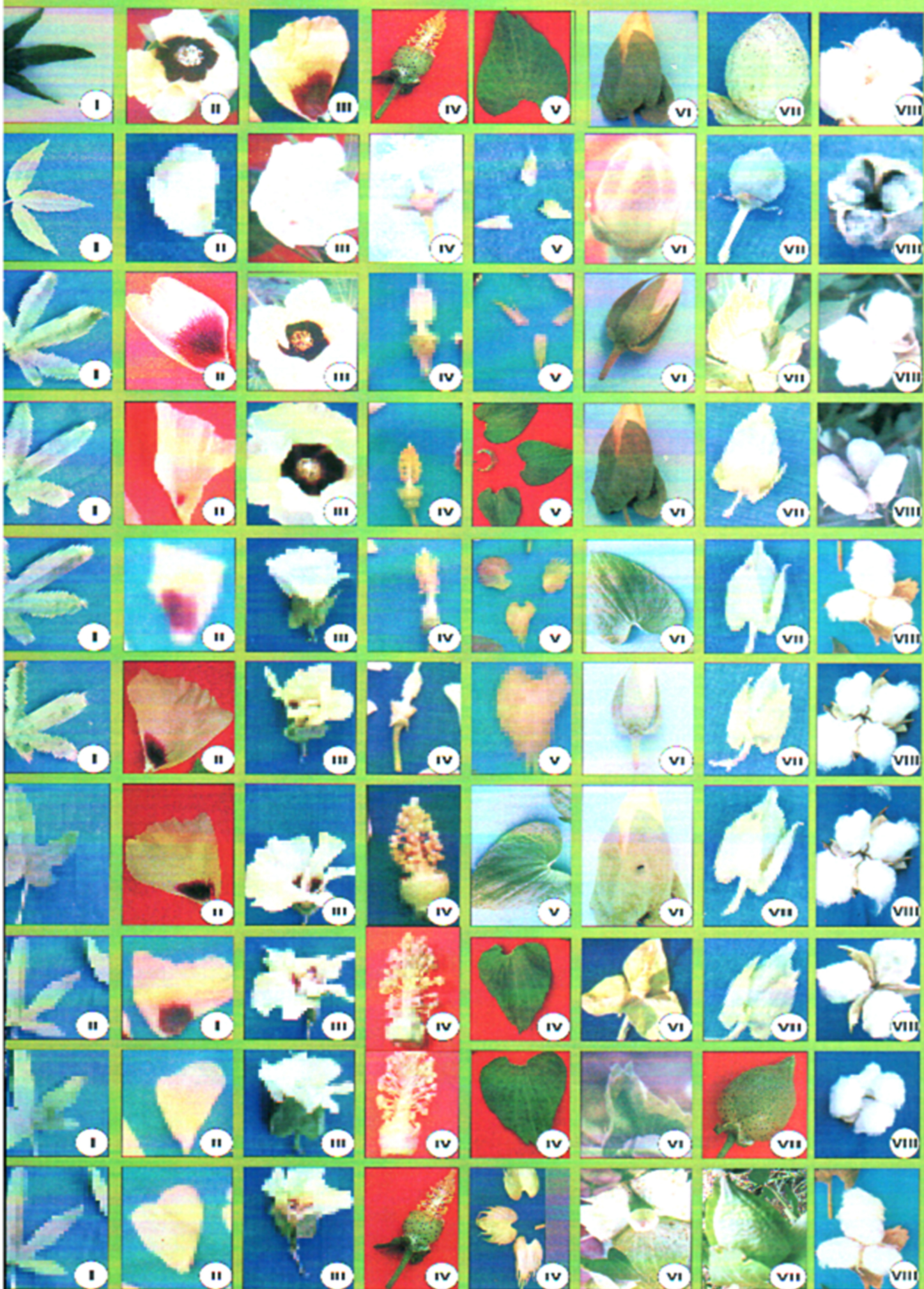
Table 3 : Mean Data on different morphological characters recorded in segregating generation(BC_1 & F_2) of interspecific cross of *G. arboreum* x *G. thurberi*

Sr. No.	Measurements of Characters(Average units /plant)	BC_1				F_2			
		Mean	SD	CV (%)	Range	Mean	SD	CV (%)	Range
1	Plant height (cm)	112.96	24.33	21.53	80.4-155.2	161.86	23.49	14.51	122.4-230.3
2	Sympodia (No.)	13.64	3.80	27.86	8.1-21.2	20.55	4.82	23.44	10.0-28.0
3	Monopodia (No.)	2.40	1.26	52.70	0.0-4.0	2.40	1.67	69.46	1.0-7.0
4	Internodal length (cm)	5.43	0.92	16.96	4.0-6.9	4.57	0.77	16.87	3.6-6.9
5	Anthers/flower (No.)	40.70	7.90	19.42	30.0-53.0	54.85	10.24	18.67	25.0-73.0
6	Length of style (cm)	1.97	0.42	21.27	1.3-2.6	1.39	0.47	33.97	0.8-2.2
7	Petal length (cm)	3.37	0.48	14.21	2.52-4.10	2.84	0.32	11.28	2.3-3.62
8	Bractiole (No.)	3.00	0.00	0.00	3.0-3.0	3.00	0.00	0.00	3.0-3.0
9	Boll diameter (cm)	1.75	0.18	10.42	1.43-2.05	1.69	0.27	15.84	1.23-2.2
10	No. of bolls	41.40	8.72	21.06	25.0-55.0	40.60	7.54	18.58	28.0-55.0
11	Boll wt. (g)	1.66	0.21	12.55	1.3-1.97	1.34	0.17	12.98	0.88-1.7
12	Lint wt/boll (g)	0.62	0.07	11.38	0.5-.074	0.50	0.05	10.81	0.41-0.63
13	Seed wt/boll (g)	1.04	0.12	11.35	0.88-1.28	0.71	0.13	17.80	0.45-0.95
14	No. of seeds/boll	17.90	2.42	13.54	13.0-21.0	20.85	4.83	23.15	10.0-28.0
15	No. of motes/boll	1.40	0.84	60.23	0.0-3.0	1.85	1.09	58.89	0.00-4.00
16	Yield per plant (g)	52.31	17.72	33.86	48.6-70.4	45.24	9.56	21.14	30.2-60.4

Table 4: *Per se* performance, percent increase/decrease in various characters of F1 and F2 generation of interspecific cross of *G. arboreum* x *G. thurberi*.

Sr. No.	Characters	Mid Parent Value	Better Parent value	Increase (+) / Decrease (-) in F1		Increase (+) /Decrease(-) in F2 over F1
				Mid Parent	Better Parent	
1	Plant height (cm)	132.73	156.80	-11.00	-24.66	37.02
2	Sympodia (No.)	18.40	23.80	-47.83	-59.66	114.06
3	Monopodia (No.)	1.70	2.20	188.24	122.73	-51.02
4	Internodal length (cm)	4.89	5.66	1.95	-12.01	-8.31
5	Anthers/flower (No.)	45.90	54.40	23.53	4.23	-3.23
6	Length of style (cm)	1.88	2.30	-19.68	-34.35	-8.28
7	Petal length (cm)	3.16	3.36	14.56	7.74	-21.62
8	Bractiole (No.)	3.00	3.00	0.00	0.00	0.00
9	Boll diameter (cm)	1.78	1.99	-4.79	-15.08	-0.09
10	No. of bolls	46.50	53.8	-8.60	-21.00	-4.47
11	Boll wt. (g)	1.64	2.06	-2.44	-22.33	-16.03
12	Lint wt/boll (g)	0.67	0.78	-9.77	-23.08	-16.33
13	Seed wt/boll (g)	1.22	1.56	-20.49	-37.82	-27.06
14	No. of seeds/boll	17.5	24.8	-5.14	-33.06	25.60
15	No. of motes/boll	1.50	1.20	6.66	33.33	15.62
16	Yield per plant (g)	60.16	70.8	-5.02	-19.29	-20.83

Plate - I



Average style length in F_2 was (1.39 ± 0.47) ranging between 0.8 cm and 2.2 cm. Reduction in style length was found 8.28 per cent over hybrid. In BC_1 range of style length was 1.3 cm to 2.6 cm with mean of 1.97 ± 0.42 cm was recorded.

The highest range of variation was observed in F_2 (33.97) then BC_1 (21.28), F_1 (17.22), P_1 (13.01) and P_2 (9.57).

4.1.8 Petal length (cm) :

Petal length in F_1 (3.62 ± 0.29) was noticed which showed 14.56 per cent and 7.74 per cent increase over mid parent and better parent, respectively.

Mean petal length in F_2 was 2.84 ± 0.32 cm ranging between 2.3 cm to 3.62 cm which recorded 21.62 reduction over F_1 . For BC_1 generation range of petal length was 2.52 cm to 4.10 cm with mean length of 3.37 ± 0.48 cm.

Maximum coefficient of variation was observed in BC_1 (14.21) followed by F_2 (17.28), P_2 (12.16), F_1 (8.01) and P_1 (7.74).

4.1.9 Bracteole (nos) :

In all generation bracteole no. remains constant i.e. 3.

4.1.10 No. of bolls/Plant :

In F_1 hybrid average 42.5 ± 2.66 bolls/plant observed showing decrease by 21.00 per cent over better parent and 8.60 per cent over mid parent.

Boll number further reduced to 40.60 ± 7.54 in F_2 generation with average range between 28.0 to 55.0. This reduction was 4.47 per cent over F_1 . BC_1 showed average $41.4 + 8.72$ bolls/plant ranging from 25 to 55.

For this character highest coefficient of variation was observed in BC_1 (21.06) followed by F_2 (18.58), F_1 (6.26), P_2 (5.04) and P_1 (4.39).

4.1.11 Boll weight (g):

The F_1 hybrid ($1.6 + 0.06$ g.) showed decrease of 22.33 per cent over better parent and 2.44 per cent over mid parent.

The range in F_2 generation was 0.88 to 1.7 g with average boll weight of 1.34 ± 0.17 showing 16.03 per cent reduction over hybrid. In case of BC_1 average boll weight 1.66 ± 0.21 g with range of 1.3 g and 1.97g.

The highest coefficient of variation was observed in F_2 (12.98) than BC_1 (12.55), P_2 (4.10), F_1 (3.75) and P_1 (2.91).

4.1.12 Lint weight/boll (g) :

The F₁ (0.6 ± 0.02) recorded reduction in lint weight, which was 23.08 per cent and 9.77 per cent over better parent and mid-parent, respectively.

The range in F₂ was found between 0.41 to 0.63 g with average lint weight of $0.50 + 0.05$ gm, showing 16.33 per cent reduction over hybrid. In case of BC₁ mean lint weight was 0.62 ± 0.07 g/boll ranging between 0.5 to 0.074 g.

Highest coefficient of variation for this trait was observed in BC₁ (11.38), followed by F₂ (10.81), P₁ (3.85), P₂ (3.64) and F₁ (3.33).

4.1.13 Seed weight/boll (g) :

Hybrid seed weight (0.97 ± 0.07) showed decrease in seed weight by 20.49 and 37.82 per cent over mid parent and better parent, respectively.

In F₂ generation seed weight 0.71 ± 0.13 g was recorded which was 27.06 per cent loss than F₁ mean. The range of F₂ generation was 0.45 g and 0.95 g. In BC₁ , showed seed weight with average of 1.04 ± 0.12 g ranging between 0.88 to 1.28 g.

Maximum variation was found in F₂ (17.80) for this character followed by BC₁ (11.35), P₂ (7.95), F₁ (7.22) and P₁ (5.13) .

4.1.14 No.of seeds/boll :

In F₁ (16.6 ± 2.21) showed decrease for this trait, which was 5.14 per cent and 33.06 per cent over mid and better parent respectively.

In F₂ generation mean seeds/boll were 20.85 ± 4.83 showing range from 10.0 ± 28.0 . F₂ generation recorded 25.50 per cent increase over F₁. Similarly in BC₁ average 17.9 ± 2.42 seeds per boll noticed range between 13.0 to 21.0.

Highest coefficient of variation was observed in F₂ (23.15) then BC₁ (13.54), P₂ (13.54), F₁ (13.31) and P₁ (8.19).

4.1.15 No.of motes/boll :

In hybrid $1.6 + 0.08$ motes were observed which showing increase by 6.66 per cent and 33.33 per cent over mid parent and better parent respectively.

In F₂ generation this character ranged between 0.0 to 4.0. The average motes/boll were recorded 1.85 ± 1.09 in F₂ showing 15.62 per cent

increase over F_1 . In BC_1 , generation average motes/boll 1.4 ± 0.84 ranging from 0.0 and 4.0.

Maximum coefficient of variation was observed in BC_1 (60.23) followed by F_2 (58.89), F_1 (50.0) P_1 (15.56) and P_2 (15.83).

4.1.16 Yield/plant (g) :

In F_1 average yield /plant 57.14 ± 5.86 decrease^d for this trait which was 5.02 per cent over mid parent and 19.29 over better parent.

F_2 generation mean yield per plant 45.24 ± 9.56 showing range from 30.2 g to 60.4 g. F_2 generation recorded 20.83 per cent reduction over F_1 . In BC_1 generation average yield per plant 52.13 ± 17.72 ranging from 48.6 g to 70.4 g.

Maximum coefficient of variation was observed in BC_1 (33.86) followed by F_2 (21.4), F_1 (5.86), P_2 (5.72) and P_1 (4.83)

4.2 Cytological studies

The data obtained on chromosome pairing during first meiotic division (metaphase-I), separations of bivalent chromosome during second meiotic division (anaphase-I), formation of sporads/PMC, and pollen size, fertility and germination observed in P_1 , P_2 , F_1 and F_2 and BC_1 are presented in the tables 5,6 & 7 respectively.

4.2.1 Chromosome pairing during first meiotic division (metaphase-I)

The observations on the chromosome pairing and chromosome associations observed in the female (*G. arboreum* var. GMS) and male (*G. thurberi*) indicated perfectly normal chromosome pairing during first division of meiosis leading to formation of perfectly 13 bivalents (Table No. 5, Plate II). Meiosis in F_1 hybrid was found abnormal. Many chromosomal anomalies viz, univalent, bivalents were noticed. On an average 8.00 bivalents were observed. Range was 6-9 in addition to bivalents, 9.4 univalent, 0.80^{III} and 0.90^{IV} were noticed.

From the data presented in Table 5 it is observed that the number of bivalents increased in F_1 (3), in F_2 (3.77) and BC_1 (3.69) that has resulted in increased pollen fertility (67.1 % and 77.1 % respectively with corresponding germination 48.0 and 54.9 as against F_1 fertility 64.25 % and germination 59.78). Similarly, seven plants of the backcross progeny of (*G. arboreum* x *G. thurberi*) x *G. arboreum* were studied cytologically. The mean

chromosome association with range was 8.4 ^I (6.9-10.2), 3.69 ^{II} (2-4.8), 2.69 ^{III} (2-3.1), 0.54 ^{IV} (0.4-0.7).

Table 5. Mean associations of chromosomes during meiotic metaphase-I in F₁, F₂ and BC₁ plants of *G. arboreum* x *G. thurberi* interspecific hybrid.

F ₂ / BC ₁ Plant No	Chromosome associations during meiotic metaphase I				Chromosome no. 2n=26	PMCs observed (no.)
	I	II	III	IV		
F ₁						
<i>G. arboreum</i>	0.0	13.0	0.0	0.0	26.0	17
<i>G. thurberi</i>	0.0	13.0	0.0	0.0	26.0	24
F ₁ Hybrid	9.4	8.00	0.08	0.09	26.0	28
F ₂						
Plant 1	11.0	6.0	1.0	0.0	26.0	18
Plant 2	8.0	2.7	3.0	0.9	26.0	29
Plant 3	8.0	5.0	2.0	0.5	26.0	16
Plant 4	10.0	3.6	2.0	0.7	26.0	24
Plant 5	8.0	2.9	3.0	0.8	26.0	16
Plant 6	10.4	2.6	3.2	0.2	26.0	19
Plant 7	4.1	3.4	4.1	0.7	26.0	19
Plant 8	8.5	2.9	3.1	0.6	26.0	25
Plant 9	7.9	4.8	1.9	0.7	26.0	22
Average	8.43	3.77	2.59	0.57	26.0	20.89
BC ₁						
Plant 1	10.2	2.0	3.0	0.7	26.0	23
Plant 2	8.0	4.8	2.0	0.6	26.0	20
Plant 3	7.3	4.4	2.5	0.6	26.0	14
Plant 4	8.7	3.2	3.1	0.4	26.0	17
Plant 5	9.7	2.8	2.9	0.5	26.0	17
Plant 6	8.0	4.2	2.4	0.6	26.0	19
Plant 7	6.9	4.4	2.9	0.4	26.0	27
Average	8.4	3.69	2.69	0.54	26.0	19.57

4.2.2 Separation of bivalents at Anaphase-I

Separation of bivalents and chromatids during first and second anaphase was found normal in both the parents. It leads to the separation of 13 chromosomes (Table No. 6 & Plate No. II).

The abnormal meiosis and reduced frequency of bivalent formation lead to unequal separation of chromosomes during Anaphase I. The number of chromosome reach to each pole and with no. of PMCs were 20-6 (I), 19-7-(2), 18-8 (5), 17-9 (2), 16-10 (2), 15-11 (8), 14-12 (7), 13-13 (1).

Table 6. Bipolar separation of chromosomes observed during anaphase-I in F₂ and BC₁ plants of *G. arboreum* x *G. thurberi* interspecific hybrid.

F ₂ / BC ₁ Plant No	Chromosome distribution at each pole								PMCs (nos) observed
	20-6	19-7	18-8	17-9	16-10	15-11	14-12	13-13	
F₁									
<i>G. arboreum</i>	3	4	2	2	3	3	3	2	22
<i>G. thurberi</i>	5	3	1	4	3	2	2	2	22
F ₁ Hybrid	1	2	5	2	2	8	7	1	28
F₂									
Plant 1	2	2	3	4	3	2	2	2	20
Plant 2	2	2	4	5	3	2	2	2	22
Plant 3	3	2	3	6	5	3	1	2	25
Plant 4	1	3	2	5	3	3	3	1	21
Plant 5	2	1	4	6	7	5	1	1	27
Plant 6	3	2	3	4	4	3	1	2	22
Plant 7	2	1	4	5	3	2	1	2	20
Plant 8	2	3	4	5	5	2	3	1	25
Plant 9	1	3	3	5	6	5	2	2	27
Average	2.0	2.1	3.3	5.0	4.3	3.0	1.8	1.7	23.22
BC₁									
Plant 1	3	2	4	6	5	4	3	3	30
Plant 2	1	4	3	6	5	3	2	1	25
Plant 3	1	3	4	5	5	2	1	2	22
Plant 4	2	1	2	7	4	3	1	1	21
Plant 5	2	3	3	5	5	4	2	1	25
Plant 6	2	3	3	7	5	4	3	3	30
Plant 7	3	2	2	6	4	3	1	1	22
Average	2.0	2.6	3.0	6.0	4.8	3.3	1.9	1.7	25

Exceptionally normal separation ^{was} observed. Single cell might have resulted in normal formation of sporads (Table 7) and to pollen fertility (64.25 %) and germination (59.78 %). Further, the observations on chromosome pairing indicated 8.43 I, (4.1-11.0), 3.77 II (2.7-6.0), 2.59 III (1.0-4.1) and 0.57 IV (0-0.8).

4.2.3 Formation of normal sporads

Formation of normal sporads i.e. 4 spores/PMC (Table No. 7 & Plate No. II) observed in both the parents.

Table 7. Sporads/PMC observed in F₂ and BC₁ plants of *G. arboreum* x *G. thurberi* interspecific hybrid.

F ₂ / BC ₁ Plant No	Sporads/PMC (no).				Average sporads/ PMC (No)	PMCs Observed (No.)
	3	4	5	6		
F₁						
<i>G. arboreum</i>	9	6	3	2	4.50	18
<i>G. thurberi</i>	3	8	6	8	6.25	25
F ₁ Hybrid	5	3	7	6	5.25	21
F₂						
Plant 1	6	7	8	4	5.25	25
Plant 2	5	9	8	6	7.00	28
Plant 3	2	6	7	3	4.50	18
Plant 4	2	5	7	2	4.00	16
Plant 5	5	9	10	5	7.25	29
Plant 6	5	8	7	3	5.75	23
Plant 7	3	6	5	2	4.00	16
Plant 8	2	7	8	2	4.75	19
Plant 9	3	9	8	2	5.50	22
Average	3.67	7.33	7.56	3.22		21.78
BC₁						
Plant 1	5	9	9	3	6.50	26
Plant 2	3	5	4	3	3.75	15
Plant 3	3	6	8	2	4.75	19
Plant 4	4	8	9	3	6.00	24
Plant 5	3	7	6	2	4.50	18
Plant 6	2	5	4	2	3.25	13
Plant 7	3	7	7	2	4.75	19
Average	3.28	6.71	6.71	2.42		19.14

4.3 Pollen grain studies in Parents, F₁, F₂ & BC₁ generation:

During the investigations pollen fertility tested by differential stain, pollen germination and pollen size (μ) were studied in P₁, P₂, F₁, F₂ & BC₁ progeny. The results obtained are presented in Table No 8, 9 and Plate II.

4.3.1 Pollen fertility:

Parents exhibited greater fertility i.e. 95.12 ± 1.88 per cent in *G. arboreum* and 94.26 ± 1.52 per cent in *G. thurberi*. The pollen fertility in F₁ was observed to be 63.13 ± 2.24 .

In F₂ mean pollen, fertility was found to be 64.24 ± 5.92 per cent. The range for pollen fertility in F₂ was 58.9 to 74.4 per cent. This reduction in fertility in F₂ over F₁ was due to unequal separation of chromosome resulting in per cent of normal tetrad formation.

Table 8: Mean Data on Pollen fertility, germination and size recorded in *G. arboreum* and *G.thurberi* and its F₁ hybrid

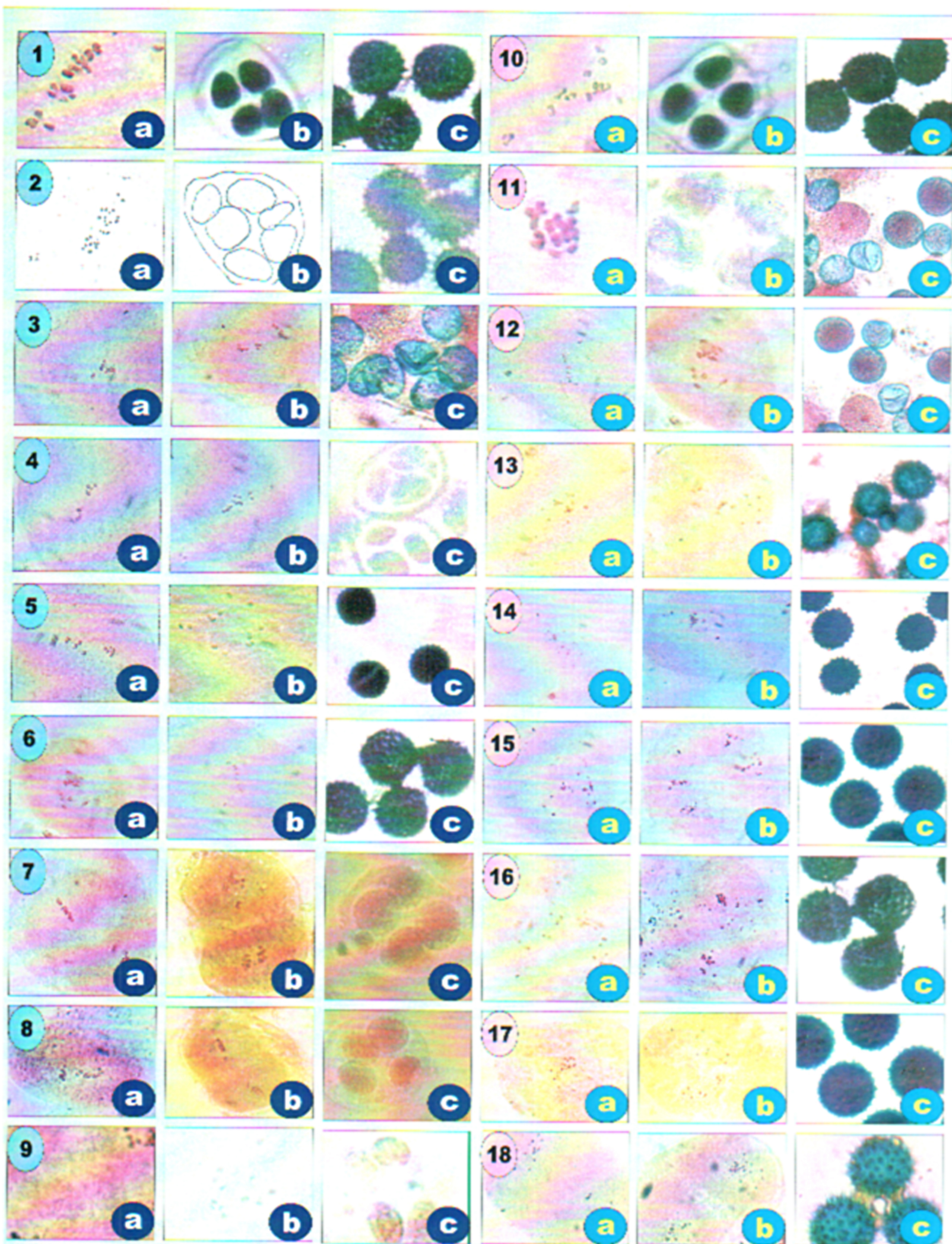
Sr. No.	Measurements of Characters (Average units /plant)	<i>G. arboreum</i> (P ₁)			<i>G.thurberi</i> (P ₂)			F ₁		
		Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
1.	Fertility %	95.12	1.88	1.98	94.76	1.52	1.61	63.13	2.24	3.55
2.	Germination	90.66	1.64	1.81	87.76	1.35	1.54	59.11	2.28	3.86
3.	Size (μ)	122.76	3.59	2.92	111.2	3.42	3.08	105.6	2.71	2.57

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Table 9: Mean Data on Pollen fertility, germination and size recorded in segregating generation (BC₁ & F₂) of interspecific cross of *G. arboreum* x *G.thurberi*

Sr. No.	Measurements of Characters (Average units /plant)	BC ₁				F ₂			
		Mean	SD	CV	Range	Mean	SD	CV	Range
1.	Fertility %	74.47	6.8	9.13	69.4-82.4	64.24	5.92	9.22	58.9-73.4
2.	Germination	53.92	4.59	8.51	49.4-58.4	50.08	5.52	11.02	39.2-59.1
3.	Size (μ)	91.32	3.37	3.69	87.4-98.4	93.27	7.2	7.72	84.6-100.1

Plate - II



Backcross generation showed 74.47 ± 6.8 per cent average pollen fertility which was greater than F_2 pollen fertility. The range for BC_1 was 69.4 to 82.4 per cent.

4.3.2 Pollen germination

Pollen germination studies revealed that normal pollen germination in parents with 90.66 ± 1.64 per cent in *G. arboreum* and *G. thurberi* with 87.76 ± 1.35 per cent. In F_1 hybrid, the pollen germination reduced to 59.11 ± 2.28 per cent.

More variation was found in F_2 generation in which pollen germination per cent ranged from 39.2 to 59.1. The mean pollen germination per unit was found to be 50.08 ± 5.52 .

Pollen germination in BC_1 was found to be 53.92 ± 4.59 per cent ranging from 49.4 to 58.4 per cent.

4.3.3 Pollen size (μ)

The average pollen grain size for *G. arboreum* and *G. thurberi* was found to be 122.76 ± 3.59 microns and 111.2 ± 3.42 microns, respectively. The size of pollen grain in F_1 hybrid was found intermediate i.e. 105.6 ± 2.71 microns.

The pollen grain size in F_2 ranged from 84.6 to 100.1 microns with mean of 93.27 ± 7.2 microns. In case of BC_1 mean pollen grain size was observed to be 91.32 ± 3.37 microns ranging between 8.72 to 98.4 microns.

4.4 Qualitative character Study:

Qualitative character data for various marker characters in P_1 , P_2 , F_1 , F_2 & BC_1 is presented in Table 10.

Table 10 : Qualitative character data for various marker characters in P_1 , P_2 , F_1 , F_2 & BC_1

Generation	Flower colour	Leaf shape	Boll shape	Seed fuzziness
P_1	DY	LNL	EL	F
P_2	W	LL	O	N
F_1	DY	LNL	Obl	F
F_2				
Plant No.1	DY	LNL	EL	F
2	W	LL	O	N
3	DY	LL	EL	N
4	DY	LNL	EL	F
5	DY	LNL	EL	F
6	W	LL	O	N
7	DY	LL	EL	N
8	DY	LNL	EL	F
9	DY	LNL	EL	F

10	DY	LNL	EL	F
11	W	LL	O	N
12	W	LNL	EL	F
13	W	LL	O	N
14	DY	LNL	EL	F
15	W	LL	O	N
16	W	LL	O	N
17	DY	LL	EL	N
18	DY	LNL	EL	F
19	W	LNL	EL	F
20	DY	LNL	EL	F
21	W	LL	O	N
22	DY	LNL	EL	F
23	W	LNL	EL	F
24	DY	LNL	EL	F
25	DY	LNL	EL	F
26	DY	LNL	EL	F
27	W	LNL	EL	F
28	DY	LNL	EL	F
29	W	LL	O	N
30	W	LL	O	N
31	DY	LL	EL	N
32	W	LNL	EL	F
33	DY	LNL	EL	F
34	W	LL	O	N
35	DY	LNL	EL	F
36	DY	LNL	EL	F
37	DY	LNL	EL	F
38	W	LNL	EL	F
39	W	LL	O	N
40	W	LNL	EL	F
BC₁				
Plant No.1	DY	LNL	EL	F
2	W	LL	O	N
3	W	LL	O	N
4	DY	LL	O	F
5	W	LL	O	N
6	DY	LNL	EL	F
7	DY	LNL	EL	F
8	DY	LNL	EL	F
9	W	LL	O	N
10	DY	LNL	EL	F
11	DY	LNL	EL	F
12	W	LL	O	N
13	W	LL	O	N
14	DY	LL	O	F
15	W	LL	O	N

DY: Dark Yellow ;W:White; LNL: Long Narrow lobe; LL: Long lobed ; EL:Elongated; O: Oval ; F:Fuzzy; N:Nacked

As the plant population in F₂ generation (40 Plants) and BC₁ generation (15 plants) is less hence the genetics of marker character was not worked out.

4.4 Boll Anatomical studies in Parents, F₁, F₂ & BC₁ generation:

Mean data and coefficient of variation for boll rind toughness and boll rind thickness at different stages of boll development in P₁, P₂, F₁, F₂ & BC₁ were presented in Table No.11, 12 & Plate III, IV, V & VI. The percent increase /decrease of these traits were presented in Table No 13 .

4.4.1 Boll Rind toughness (Shore):

4.4.1.1 At 15 days:

In hybrid, boll rind toughness (9.29 ± 1.3) showed decrease over mid parent by 37.38 per cent and 59.38 per cent over better parent.

In F₂ generation for this trait (12.4 ± 2.18) which was 33.48 per cent more than F₁ mean. The range of F₂ generation was 8.67 to 17.00 shore. In BC₁, average boll rind toughness recorded 8.0 ± 1.28 ranging between 6.00 to 9.33 shore.

Maximum variation was found in F₂ (17.58) followed by BC₁ (16.0), F₁ (13.99), P₁ (12.21) & P₂ (11.41)

4.4.1.2 At 30 days:

The F₁ hybrid (19.53 ± 1.86) showed decrease of 16.54 per cent and 35.76 per cent over mid parent and better parent, respectively.

The range in F₂ generation was 14.0 to 41.67 shore with average boll rind toughness 23.58 ± 7.32 which was 20.74 per cent more than F₁. In case of BC₁ generation average boll rind toughness recorded 18.17 ± 2.18 with range of 13.33 to 20.67 shore.

The highest coefficient of variation was observed in F₂ (37.04) followed by BC₁ (12.00), F₁ (9.52), P₂ (9.50) & P₁ (8.48)

4.4.1.3 At 45 days:

In F₁ hybrid boll rind toughness (36.30 ± 2.28) showed decrease at this stage 8.87 per cent and 25.09 over mid parent and better parent, respectively.

In F₂ generation, boll rind toughness was 81.67 to 42.0 shore with average of 36.56 ± 2.89 which was meagerly higher than F₁. In case of BC₁, generation average boll rind toughness was 38.73 ± 2.08 with range of 34.33 to 41.33 shore.

Maximum variation was found in F₂ (7.90) followed by F₁ (6.28), BC₁ (5.37), P₁ (4.91) & P₂ (3.91).

Table 11: Mean data on boll rind toughness and boll rind thickness recorded in parent and its hybrid the interspecific cross of *G. arboreum* x *G. thurberi*.

in

Sr. No.	Measurements of Characters(Average units /plant)	<i>G. arboreum</i> (P ₁)			<i>G. thurberi</i> (P ₂)			F ₁		
		Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
I.	Boll Rind Toughness (Shore)									
	1. At 15 Days boll age	6.80	0.83	12.21	22.87	2.61	11.41	9.29	1.30	13.99
	2. At 30 Days boll age	16.40	1.39	8.48	30.40	3.89	12.80	19.53	1.86	9.52
	3. At 45 Days boll age	33.67	4.96	14.73	46.00	1.80	3.91	36.30	2.28	6.28
II.	Boll Rind Thickness (mm)									
	1. At 15 Days boll age	1.14	0.14	12.28	0.89	0.24	26.97	0.90	0.08	8.89
	2. At 30 Days boll age	1.95	0.12	6.15	1.30	0.05	3.85	1.51	0.13	8.61
	3. At 45 Days boll age	2.00	0.11	5.50	1.77	0.08	4.51	1.76	0.11	6.25
III.	Locule Damage(%)	9.42	1.08	1.08	0.00	0.00	0.00	7.59	0.84	11.07
IV.	Pink Boll Worm Larvae per 20 Green Boll	1.87	0.19	0.19	0.00	0.00	0.00	1.66	0.22	13.25

Table 12: Mean Data on Mean Boll Rind toughness and boll rind thickness recorded in segregating generation (BC₁ & F₂) of interspecific cross of *G. arboreum* x *G.thurberi*

Sr. No.	Measurements of Characters (Average units /plant)	BC ₁				F ₂			
		Mean	SD	CV	Range	Mean	SD	CV	Range
I.	Boll Rind Toughness(Shore)								
	1. At 15 Days boll age	08.00	1.28	16.00	6.00-9.33	12.40	2.18	17.58	08.67-17.00
	2. At 30 Days boll age	18.17	2.18	12.00	13.33-20.67	23.58	7.32	31.04	14.00-41.67
	3. At 45 Days boll age	38.73	2.08	05.37	34.33-41.33	36.56	2.89	7.90	31.67-42.00
II.	Boll Rind Thickness(mm)								
	1. At 15 Days boll age	0.98	0.12	12.24	0.77-1.18	1.77	0.43	24.59	01.34-2.67
	2. At 30 Days boll age	1.64	0.19	11.59	1.48-1.78	2.29	0.56	24.45	01.70-3.03
	3. At 45 Days boll age	1.80	0.13	07.22	1.64-1.91	2.81	0.21	7.47	02.32-3.67
III.	Locule Damage(%)	9.98	1.75	17.54	7.48-13.01	8.87	1.72	19.39	6.23-14.20
IV.	Pink Boll Worm Larvae per 20 Green Boll	2.33	0.42	18.03	1.36-2.84	2.05	0.42	20.49	0.92 -2.49

Table 13: *Per se* performance, percent increase/decrease in various characters of F1 and F2 generation of interspecific cross of *G. arboreum* x *G. thurberi*.

Sr. No.	Measurements of Characters	Mid Parent Value	Better Parent value	Increase (+) / Decrease (-) in F ₁		Increase (+) / Decrease(-) in F ₂ over F ₁
				Mid Parent	Better Parent	
I.	Boll Rind Toughness(Shore)					
	1. At 15 Days boll age	14.84	22.87	-37.84	-59.33	33.48
	2. At 30 Days boll age	23.40	30.40	-16.54	-35.76	20.74
	3. At 45 Days boll age	39.84	46.00	-8.87	-21.09	0.72
II.	Boll Rind Thickness(mm)					
	1. At 15 Days boll age	1.02	1.14	-11.33	-21.05	96.67
	2. At 30 Days boll age	1.63	1.95	-7.36	-22.56	51.66
	3. At 45 Days boll age	1.89	2.00	-6.63	-12.00	59.66

Plate -III
(Boll Anatomical studies in parents and its hybrid)

- A) Boll rind toughness reading at 15 days, 30 days, 45 days in *G. arboreum* var. x MPKV-GMS.
- B) Boll rind toughness reading at 15 days, 30 days, 45 days in *G. thurberi*.
- C) Hardness tester, Boll rind toughness reading 30 days, 45 days in *G. arboreum* var. x MPKV-GMS.

1. *G.arboreum* var.MPKV GMS

- Sr. No. I : 1A ;At 15 day old boll
1B; At 30 day old boll
1C; At 45 day old boll
- Sr. No. II : 1A; Longitudinal section of 15 day old boll
1B; Longitudinal section of At 30 day old boll
1C; Longitudinal section of At 45 day old boll
- Sr. No. III : 1A; Cross section of 15 day old boll
1B; Cross section of At 30 day old boll
1C; Cross section of At 45 day old boll

2. *G.thurberi*

- Sr. No. I : 2A ;At 15 day old boll
2B; At 30 day old boll
2C; At 45 day old boll
- Sr. No. II : 2A; Longitudinal section of 15 day old boll
2B; Longitudinal section of At 30 day old boll
2C; Longitudinal section of At 45 day old boll
- Sr. No. III : 2A; Cross section of 15 day old boll
2B; Cross section of At 30 day old boll
2C; Cross section of At 45 day old boll

3. Hybrid (*G.arboreum* x *G.thurberi*)

- Sr. No. I : 3A ;At 15 day old boll
3B; At 30 day old boll
3C; At 45 day old boll
- Sr. No. II : 3A; Longitudinal section of 15 day old boll
3B; Longitudinal section of At 30 day old boll
3C; Longitudinal section of At 45 day old boll
- Sr. No. III: 3A; Cross section of 15 day old boll
3B; Cross section of At 30 day old boll
3C; Cross section of At 45 day old boll

Plate - III

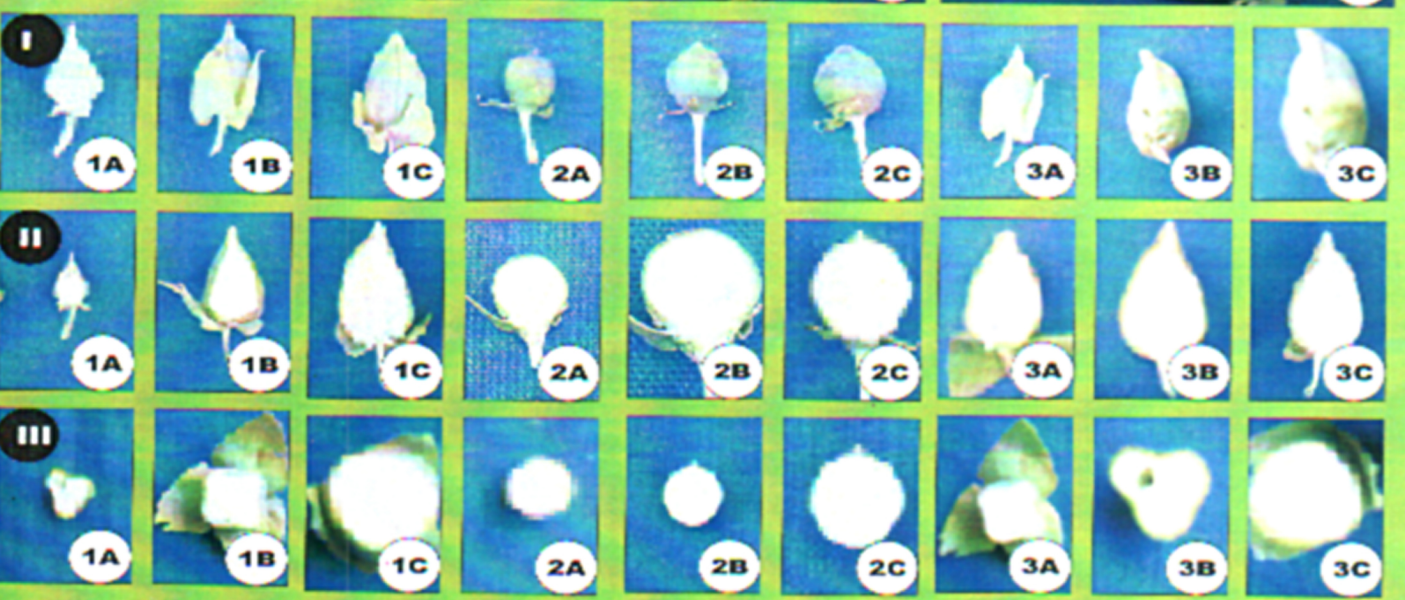
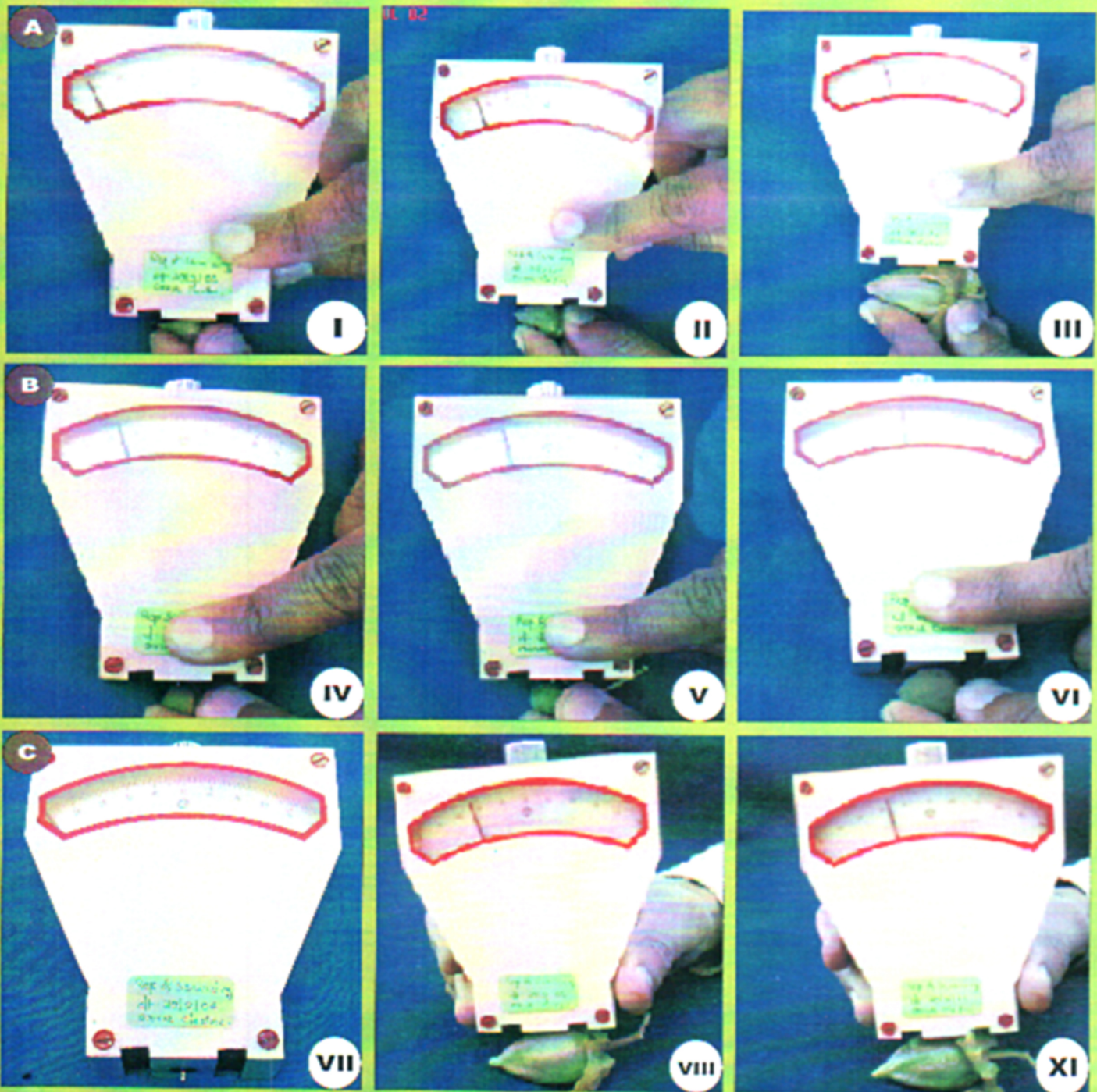
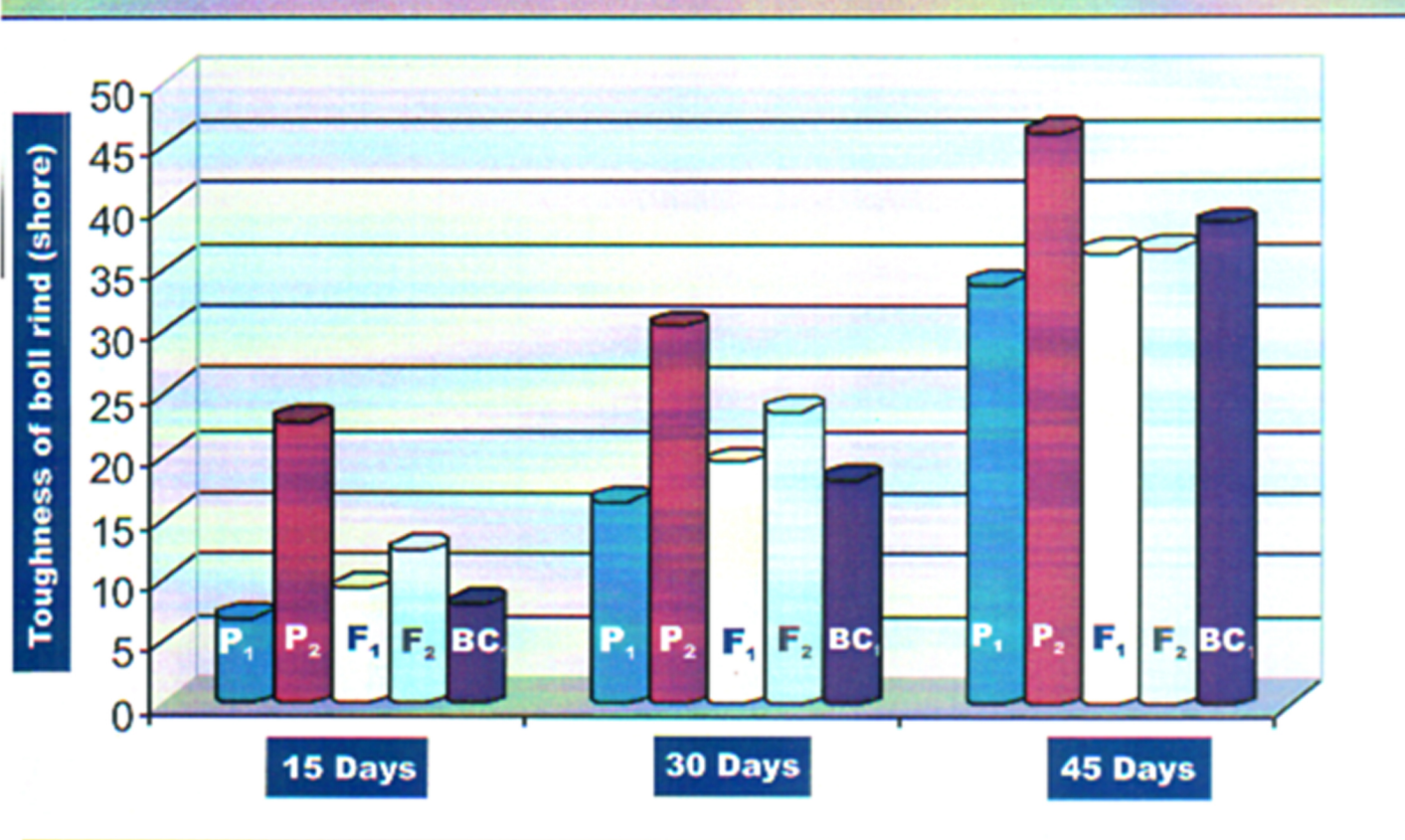
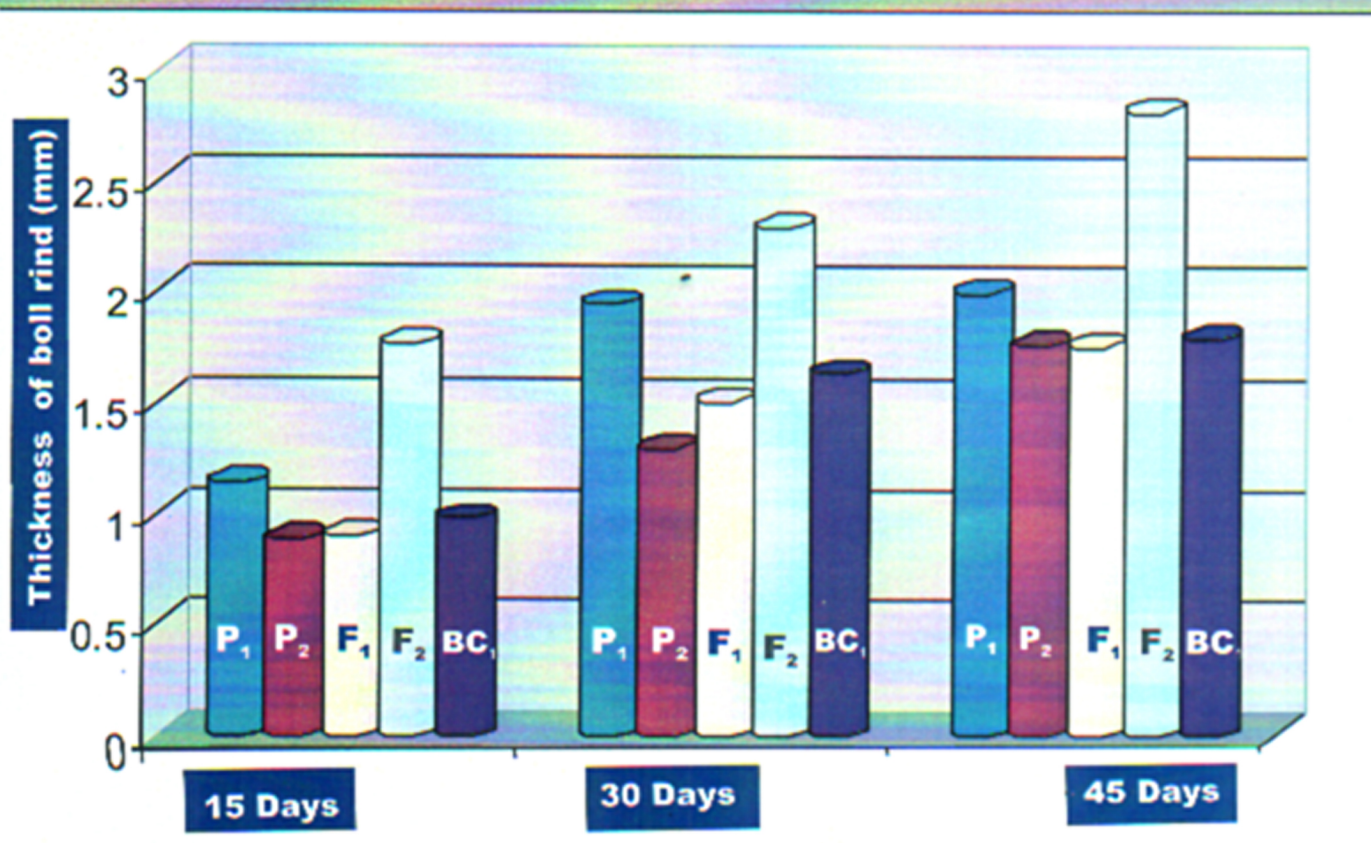


Plate-IV



Toughness (shore) of boll rinds measured at different ages in parents (P₁ & P₂), F₁, F₂ and BC₁ generations of interspecific (*G. arboreum* x *G. thurberi*) cross of cotton.

Plate-V



Thickness of boll rind measured at different ages in parents (P₁ & P₂), F₁, F₂ and BC₁ generations of interspecific (*G. arboreum* x *G. thurberi*) cross of cotton.

4.4.2 Boll rind thickness (mm):

4.4.2.1 At 15 days:

Mean boll rind thickness was in F_1 was 0.90 ± 0.08 mm which showed 11.33 per cent and 21.05 per cent decrease over mid parent and better parent respectively.

Average boll rind thickness in F_2 was 1.77 ± 0.43 mm with range 1.34 to 2.67 mm, showing increase in thickness by 96.31 per cent over F_1 . For BC_1 generation 1.64 ± 0.19 mm boll rind thickness which ranged between 1.48 to 1.78 mm.

Variation observed for this trait was F_2 (24.29), followed by BC_1 (11.59), F_1 (8.61), P_1 (6.15) and P_2 (3.85).

4.4.2.2 At 30 days:

In hybrid, boll rind thickness (1.51 ± 0.13) showed decrease 7.36 per cent and 22.56 per cent over mid parent and better parent, respectively.

Further, in F_2 generation boll rind thickness was 2.29 ± 0.56 mm ranging between 1.70 to 3.03 mm. Increase of 51.66 per cent was recorded over F_1 . Similarly, for BC_1 average boll rind thickness was 1.80 ± 0.13 ranging between 1.64 to 1.91 mm.

At this stage the highest coefficient of variation was observed in F_2 (24.45), followed by BC_1 (11.59), F_1 (8.61), P_1 (6.15) & P_2 (3.85).

4.4.2.3 At 45 days :

In F_1 hybrid boll rind thickness was (1.76 ± 0.11) showed 6.63 per cent decrease over mid parent and 12.00 per cent over better parent.

Mean boll rind thickness in F_2 generation was to 2.81 ± 0.21 ranging between 2.32 to 3.63 mm recorded 59.66 per cent increase over F_1 and for BC_1 generation range of boll rind thickness was 1.64 to 1.91 mm with average of 1.80 ± 0.13 mm.

Maximum coefficient of variation was observed in F_2 (7.47) followed by BC_1 (7.22), F_1 (6.25) P_1 (5.5) & P_2 (4.51).

4.4.3 Locule damage:

For this trait *G. thurberi* shows immune reaction where as *G. arboreum* recorded 9.42 per cent locule damage. In F_1 hybrid 7.89 per cent locule damage was observed. In segregating generation BC_1 9.98 per cent ranging from 7.48 to 13.01 per cent where as, in F_2 generation average locule damage was 8.87 per cent with range of 6.23 % to 14.2 per cent.

4.4.4 Pink bollworm larvae per 20 green boll:

On the parent *G. thurberi* there was no incidence pink boll worm larvae, where as in *G. arboreum* average 1.87 larvae was recorded. In F₁ hybrid 1.66 larvae were observed. In F₂ generation average $\pm 2.05 \pm 0.42$ larvae was recorded with ranging from 0.92 to 2.49. Similarly, in BC₁ generation average pink boll worm larvae recorded 2.33 ± 0.42 with range from 1.36 to 2.84.

4.4.5 Correlation between boll rind toughness and locule damage incidence in parents, F₁, F₂ & BC₁ generation:

The correlation of boll rind toughness with locule damage was estimated by using Karl Pearson's Coefficient of correlation. The results obtained are presented in Table 14.

Table 14: Correlation between boll rind toughness and locule damage incidence in Parents, F₁, F₂ & BC₁ generation

Character	Boll rind toughness at 30 days	Boll rind toughness at 45 days	Locule damage (%)
Boll rind toughness at 15 days	0.985	0.924	-0.545
Boll rind toughness at 30 days	-	0.885	-0.428
Boll rind toughness at 45 days	-	-	-0.426

It was revealed from table 14 that there was considerable indication about the negative relationship of boll rind toughness with locule damage.

4.5 Fibre quality parameters

Out of F₂ segregating plants of *G. arboreum* x *G. thurberi* studied, 8 plants showed good amount of fertility of boll set. So that spinnable lint could be obtained. In F₂ population partial fertility was recorded hence insufficient lint samples were obtained. The lint samples tested with HVI method and results could be obtained 4 plants viz., plant No. 2, 9, 15 and 27 and female parent *G. arboreum* var. MPKV GMS. The data are presented in Table 15.

* **Table 15.** Fibre quality parameters recorded in F₂ populations

Generations	2.5 % SL	U.R. (%)	Mic.	Strength (g/tex)	Extension ability (%)
<i>G. arboreum</i> var. MPKV GMS (P ₁)	25.8	50	5.1	17.0	5.0
<i>F₂</i> generation					
Plant No. 2	23.3	52	5.5	21.4	5.2
9	23.6	50	5.2	21.0	5.0
15	23.3	52	5.2	19.6	5.0
27	21.9	52	5.2	19.9	5.0

* **Tested at CIRCOT, Mumbai.**

For all the lint samples showed shorter fibre (21.9 mm, plant No. 27) to 23.6 mm (Plant No. 9). As regards the UR (%), the MPKV GMS fibres were 50 % uniform while an increased uniformity was observed plant No. 2, 15 and 27 while plant No. 9 produce fibre of uniform equal to (50 %) the female parent *G. arboreum* var. MPKV GMS. It was interesting know that the micronaire (Mic) was higher than female parent (5.1). It was 5.5 and 5.2 Mic in plant no. 2 and 9, 15, 27, respectively. Further it was also interesting to know that fibre strength was also increased in plant No. 2 (21.4 g/tex), 9 (21.0 g/tex), 27 (19.9 g/tex), 15 (19.6 g/tex) as compared to female parent (17.0 g/tex) extensibility was 5.0 (%) in case of female parent while it was found same 5.0 (%) in plant No. 9, 15, 2 and 5.2 (%) in Plant No. 2.

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DISCUSSION

5. DISCUSSION

The present investigation entitled, "Inheritance studies in interspecific cross of cotton" was carried out at Cotton Improvement Project, MPKV, Rahuri. The morphological, cytological and boll anatomical characters of five generations (P_1 , P_2 , F_1 , F_2 and BC_1) were studied. The results obtained during the investigation are discussed below:

5.1 Morphological characters

Vigorous healthy and rapid growth and profuse monopodial branching characterized the interspecific hybrid. These observations are in accordance with Deodikar (1949) in interspecific hybrid.

The interspecific hybrid recorded increase in quantitative characters like monopodia per plant, anthers per flower, petal length over both mid parent value and better parent value as indicated in Table 4

Increase over only mid parent was observed in case of monopodia per plant, internodal length, anthers per flower and petal length for these characters decrease over better parent was recorded.

Reduction in plant height, number of sympodia, length of style, boll diameter, no. of bolls, boll weight., seed weight, lint weight, number of seeds per boll and yield per plant was recorded over both mid parent and better parent value.

Amin (1940) and Zhou *et al.* (1992) during their studies of different interspecific hybrids reported that mostly interspecific hybrids were intermediate to their parents. During present studies the hybrid was found intermediate for the characters like plant height, number of sympodia, internodal length, anthers per flower, length of style, boll diameter, number of bolls, boll weight and yield per plant.

The interspecific hybrid crossed parental characters exhibited transgression in case of monopodia per plant, anthers per flower and petal length. For these characters, results obtained were in accordance to Kanash (1936) who reported transgression of parental limits in morphological characters.

The decrease in characters like boll per plant, seeds per boll, seed weight and lint weight due to post fertilization barriers, lower pollen



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fertility and under development of bolls and seeds due to unequal pairing of chromosomes and irregular separation.

5.2 Morphological characters of F₂ generation

F₂ generation varied greatly for the different quantitative characters studied (Plate I, Fig. 4 to 8). The variation will be very useful to select desired combination eliminating the undesired characters as mentioned by Deodikar (1949).

In F₂ progeny, plants with one or few desirable qualities were observed like dwarf and completely sympodial habit, some plants with increased boll set and earliness. These plants may be useful in further improvement in *G. arboreum*. However, in F₂ traits like monopodia per plant, number of bolls, boll weight, anthers per flower decrease which can hamper the selection of desirable types and their multiplication. In F₂ generation increase was noticed in plant height, sympodia per plant and number of seeds per boll which can be utilized for obtaining desired types of plants.

5.3 Morphological characters of BC₁ generation

Backcross breeding is most appreciated method by plant breeders as it allows to obtain plants with desirable qualities lacking in superior parent used in hybridization. The characters which showed reduction in F₂ generation exhibited some improvement in BC₁ generation. The BC₁ generation recorded improvement over F₂ generation in respect of important economic traits *viz.*, bolls/plant, boll weight and boll diameter.

In backcross, Iyengar et al. (1958) reported progeny improvement in morphological characters and Zarzervan and Kitker (1984) reported the improvement in the fibre properties earliness, drought and wilt resistance by repeated back crossing the interspecific hybrid. In present studies fertility of plants, boll setting, lint weight with finer boll weight and boll diameter were improved in BC₁ generation as compared to F₂ generation. Overall improvement in all the traits except a few was observed in BC₁ generation over F₂ generation.

5.4 Cytological Studies

The cytological observations in both the parents indicated the normal meiosis; it is definitely due to normal pairing of chromosomes during first meiotic division followed by separation of chromosome during first

anaphase and separation of chromatids during IInd anaphase lead into normal sporads and normal pollen grains (Endrizzi, 1962). Both the parental lines had high degree of pollen fertility and germination however, F₁ hybrid showed chromosome configurations 9.4 I, 8.00 II, 0.08 III and 0.09 IV indicated sufficient degree of bivalent formation. The results obtained here are different from the results of Skovsted (1937), who reported 9.6 I, 7.8 II, 0.02 III and 0.05 IV while in another cross *G. nankin* x *G. thurberi*, Webber (1939) reported 24 I and 1 II. The differences in the data of chromosomal pairing might be because of genetic constitutions in the present study is different from earlier worker. The bivalent formed might be due to homologous pairing A and D genomes of *G. arboreum* and *G. thurberi* respectively. While the univalent chromosomes might be because of non-homology between the constituent A and D genomes. While the very low trivalent (0.50) and (0.34) quadrivalent indicated the homology between the paired chromosomes and the chances of exchange between chromatid formed two different species (Phillips, 1962). Thus, it has increased the possibility of inter genomic transfer of genes responsible for bollworm tolerance and better fibre quality parameters from *G. thurberi* to *G. arboreum*.

The observations on the chromosome pairing observed in the hybrid was similar to Skovsted (1937) and Mehetre *et al.* (2003) who reported sufficient high degree of chromosome pairing in the hybrid between *G. arboreum* x *G. thurberi*. Further, unequal separation of chromosomes (Table 9) and chromatids during I and II Anaphase led to the formation of unequal sporads with higher and lower sporads per PMCs than normal number 4 also confirmatory to earlier reports.

Earlier, Harland, 1940, Beasley, 1940 and 1942 reported female fertility but male sterility in *G. arboreum* x *G. thurberi* hybrids. Our results do not agree with these results as sufficient degree of fertility was reported (Ganeshan, 1946). Ganeshan used the cross *G. arboreum* x *G. thurberi* which was self sterile and he could not backcross to either of its parents.

Later on Mehetre (1979) Thombre and Mehetre (1981) reported 7.35^I, 8.8^{II}, 0.3^{III}, in F₁ hybrid of *G. hirsutum* haploid x *G. thurberi* and some degree of fertility in this hybrid and indicated its use for transfer of desired genes into *G. hirsutum* cotton. Higher degree of self and cross fertility was

attributed to regular pairing of chromosomes contrary few germinable seeds were obtained from which a population of plants were raised and studied which showed combination of characters from both the parents and hence these plants will be as excellent source for combining natural defense to stand against biotic stresses and drought existing in A genome chromosomes of *G. arboreum* (Innes, 1966).

Since sufficient homology exist between A and D chromosomes. There are quite high chances of getting recombination/s. Such recombination/s might have pink bollworm tolerance because of repellent scent present in petals of *G. thurberi* which prevent oviposition of the moth on plant and confirm the immunity to bollworm (Ganesan, 1946).

Further, in addition to these characters, it has resistant to wilt, frost, most importantly, the character prolificacy of boll, high lint yield, petal colour spinning and high lint fineness and strength (Narayanan et al. 1984) are also the important economic characters. Thus, the recombinants recovered during segregation of subsequent generation may likely to yield built in inherent characters combinations as mentioned above. Such improvement, genetic enhancement as a result of will be a source material for transfer of characters to the backgrounds of other *G. arboreum* genotypes. This will help in developing varieties/genotypes with fibre quality parameters as per needs of modern textile and spinning mills as they require high strength, maturity and elongation and medium micronaire value to suit high spirit machine (Mehetre et al. 2005).

Efforts in these directions are underway. The introgression of characters is confirmed on the basis of segregation data (Table 10) which indicated combination of characters. It is interestingly noted that one plant had petal colour of *G. thurberi* while its seeds are without fuzz (naked). Both the characters are descended from *G. thurberi* and they may located on the chromosome of *G. thurberi*. The petal colour will have relation with bollworm tolerance. Since this plant is fairly fertile produced few bolls with well developed seeds and lint with slightly brown tinge. The fill up lint is silky and its testing will be done.

5.5 Boll anatomical studies

From Plate No. IV and V it is seen that P₁ (*G. arboreum*) had lowest toughness of boll rind (6.80, 16.40, 33.67 shore) at all the three stages i. e. 15, 30 and 45 days followed by BC₁ generation (8.00, 18.17,

38.73 shore) F₁ (9.29, 19.53, 36.30 shore) and F₂ (12.40, 23.58, 36.56 shore). The highest toughness was recorded in P₂ (*G. thurberi*) (22.87, 30.40, 46.00 shore) with more cell compactness was observed (Plate No.VI).

The pink bollworm moth lay eggs in flower immediately after fertilization. First instar larvae emerged after 4-15 days which is the most important stage for entrance of larvae inside the boll for this mechanical resistance of boll rind toughness plays an important role. If the boll rind toughness is high, there is more resistance for infestation for pink bollworm larvae. The highest boll rind toughness was recorded in *G. thurberi* at all three stages of boll development. The percent locule damage and no. of pink boll worm observed on 20 green boll in *G. thurberi* was nil which reveals its resistance to pink boll worm. This is confirmed through correlation as it significant negative correlation was found between toughness with locule damage. Punit Mohan et al. 1995 also reported similar results. This toughness of boll rind of *G. thurberi* is highest among the different generation at all three stages. The importance of boll rind thickness in of larvae penetration and boll rind toughness in resistance breeding is already emphasized by Mohan and Kaironi (1999). Similar results regarding mechanical and physical resistance based on anatomical structure has been already reported by Baher and Pincard (1970), Ashworth and Hire (1971), Cauquill (1975), Punit Mohan and Narayanan (1995) and Punit Mohan et al. (1995).

It is revealed that the toughness of boll rind was lowest in *G. arboreum* amongst the all generation studied at 15 days boll age (6.80 shore) which was further increased to 30 days boll age (16.40 shore) and 45 days boll age (33.67 shore). However, the highest bollworm infestation in *G. arboreum* was recorded as compared to *G. thurberi* which might be due to at the time of entrance of pink bollworm larvae at earlier stage i. e. after fertilization since the boll rind toughness was low. It was easy to enter the larvae in the boll. Though it has toughness increase at 30 and 45 days boll age, they hasn't play positive role of suppression of bollworm as the larvae has already entered inside the boll. Due to which correlation value were negative for locule damage. Punit Mohan, et al (1995), reported similar findings. For imparting to resistant for pink bollworm boll rind thickness plays a significant positive role.

Similar trend was observed in F₂ generation (Table 12) the plant number 2, 9, 27 has shown toughness which was more or less to *G. thurberi*. This indicates that the anatomical character of boll rind toughness is genetically controlled and segregation in Mendelian fashion exacts genetics could not be worked out. Similar observations were record in rice by Sethi and Roy (1985).

5.6 Fibre quality parameters

The earlier Kalyanaraman and Santhanam (1953) indicated that transfer of fibre strength and boll worm immunity to American varieties. Later on Ganeshan (1953) attempted doubling of *G. arboreum* x *G. thurberi* and observed that due to the break down of genetic system of parental types and newly recombination obtaining in the segregating generation, those later showed transgressive segregation for morph physiological and ecological characters by the progressive selective elimination of minimum inferior quality where as less variability was found in leaf character than the boll, seed and economic characters. The economic potentiality of the material in staple length and fibre strength was discussed by Ganeshan in the light of cytogenetic knowledge.

As discussed by Bhat and Patel (C. F. Ganeshan, 1953) the most of the variability wided out in few Ganeshan showing that genes and gene combinations were responsible for linear survival and reproductive characters reported to associated with greater variability which is according to Fisher (C. F. Ganeshan, 1953) was the characteristics of genotypes with surgical value. The results fibre property obtained during present investigation are of extremely significance as except 2.5 % span length (mm), UR (%), fineness (Mic), strength (g/t) and extensibility(%) had same either more or less value to the female parent *G. arboreum* var. MPKV GMS.

This indicates that there is a great scope for combining either one or more fibre quality parameters in further segregating generation accompanied by desired fibre length and tolerance to the pink boll worms. This pre-breeding efforts will serve as treasure of variability for the character of parental matter indicated above and will able to synthesize a ideal plant type. *G. arboreum* deshi cotton which will be a boon to rainfed cotton growers of Marathwada, Vidharbha and Khandesh region. Further of Bt (Cry 1A/Cry 1b/Cry 1 Ac) is having in this background, it will also a ever problem solution of prior cotton market region of the Maharashtra.

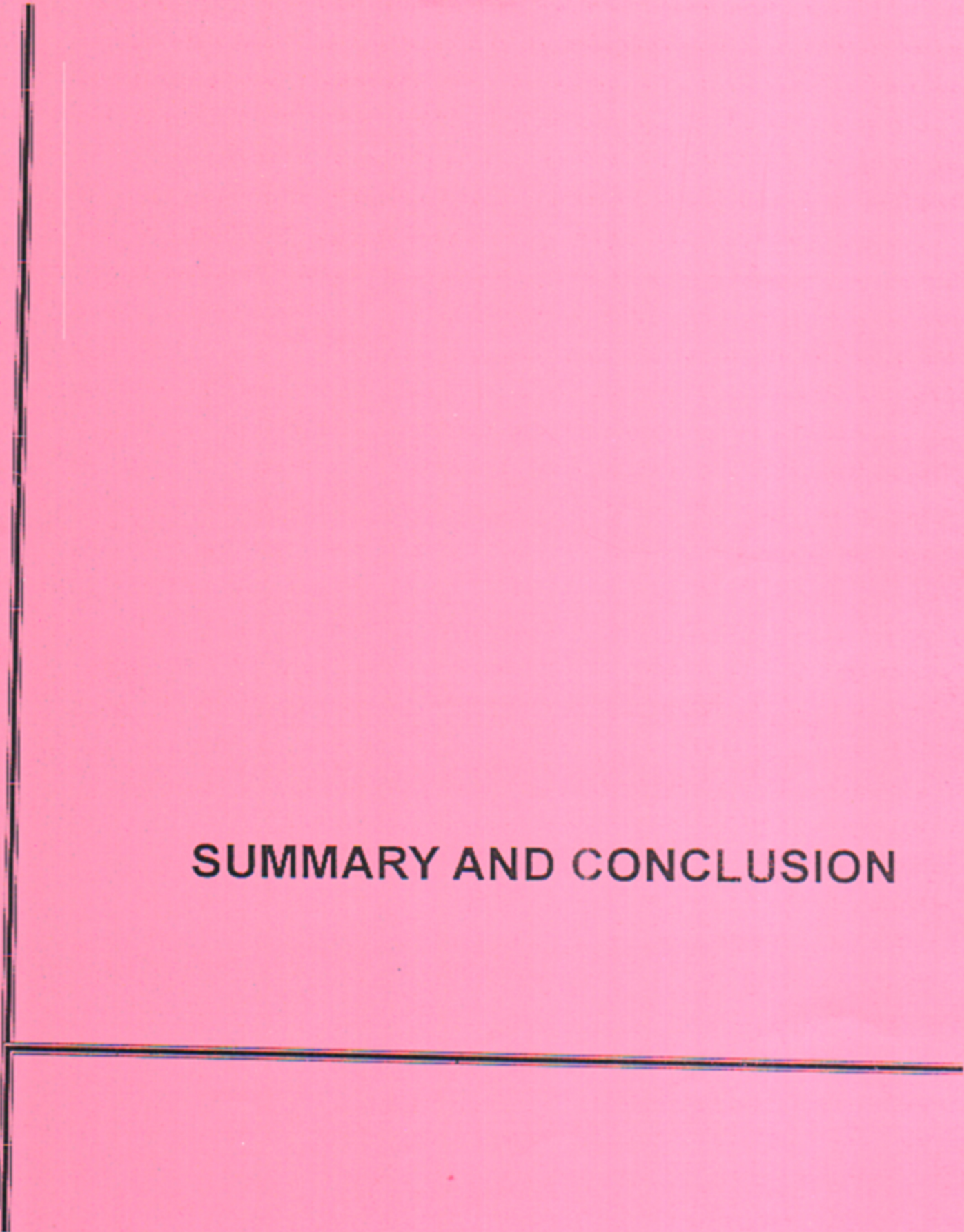
Either the cotton breeder or entomologist or molecular geneticist may frame a project for molecular tagging for the character responsible for tough boll rind and fibre strength contributed by *G. thurberi* and drought tolerance contributed by *G. arboreum*. Further, it will also be interesting to isolate the recombinants or novel de-nevo combinations for altered leaf anatomy conferring higher tolerance to sucking pest.

According to Paranjape (1953) *Thurbo-hirsutum* in pure cultures and segregation have one useful character i. e. size of bractiole. The bractioles are narrow, triangular in shape that helps in obtaining clean picking of cottons.

5.7 Future line of work

The available F₂ and BC₁ generations will be an excellent material for molecular studies. The marker assisted selections from F₂ and BC₁ plants will be able to identify the plants with introgressed genes from both species and targeted selection can be made. These will help in rectifying defects pre-breeding effects will enable to combine high fibre strength and pink bollworm resistance of *G. thurberi*, drought tolerance and high yield from *G. thurberi*.

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SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSION

The present research worked entitled, "Inheritance studies in interspecific cross of cotton" was conducted at Cotton Improvement Project, MPKV, Rahuri during the period from 2006 to 2007. The results of investigation are summarized below:

6.1 Summary

6.1.1 Morphology studies in parents their F₁, F₂ and BC₁ generation

Vigorous, healthy and rapid growth and profuse monopodial branching characterized the interspecific hybrid. It recorded increase in quantitative characters like monopodia per plant, anthers per flower and petal length, and also it showed crossing of parental limit for the same characters.

Variation observed for different characters studied in F₂ generation was higher than F₁ generation. The characters *viz.*, boll setting, boll weight, seed weight, lint weight recorded mean reduction over interspecific hybrid which may be due to irregular pairing and unequal separation of chromosomes.

The economical characters *viz.*, bolls/plant, boll weight and boll diameter were found to be increased in BC₁ over F₂. In present studies overall improvement of characters was observed in BC₁ which will enable improvement of *deshi* type by backcross method.

6.1.2 Cytological studies in parents their F₁, F₂ and BC₁ generation

The cytological observation in both the parents indicated normal meiosis, it is definitely due to normal pairing of chromosomes during first meiotic division followed by separation of chromosomes during Anaphase and separation of chromatids during 2nd Anaphase lead into normal sporads and normal pollen grain.

The pollen fertility, pollen germination and pollen grain size were reduced due to irregular pairing and unequal separation of chromosomes as well as various abnormalities observed.

6.1.3 Boll anatomical studies in parents their F₁, F₂ and BC₁ generation

The boll rind toughness was highest in *G. thurberi* at all three stages. Whereas, it was lowest in the *G. arboreum* at all three stages. In the F₂ population sufficient variability for boll rind toughness with boll rind thickness was observed. However, the boll rind thickness was maximum in

G. arboreum at all three stages of boll development, and was minimum in *G. thurberi* during same stages of boll development. However, the highest locule damage was recorded in *G. arboreum* due to less physical mechanical resistance.

6.1.4 Fibre quality parameters

The results on fibre property obtained during present investigation are of extremely significance as except 2.5 % span length (mm), UR (%), fineness (Mic), strength (g/t) and extensibility(%) had same either more or less value to the female parent *G. arboreum* var. MPKV GMS.

This indicates that there is a great scope for combining either one or more fibre quality parameters in further segregating generation accompanied by desired fibre length and tolerance to the pink boll worms.

6.2 Conclusion

The morphological studies revealed that interspecific hybrid was partial fertile and vigorous. In F_2 and BC_1 generation some good plants were identified having higher pollen fertility and more numbers of bolls/plant.

The cytological studies showed that F_1 , F_2 and BC_1 generations were having irregular pairing and unequal separation of chromosomes. This led to pollen sterility in these generations. However, in BC_1 generation bivalent frequency and normal tetrad formation found to be improved. In F_1 and F_2 generation pollen size, germination, fertility was found to be decreased. In BC_1 improvement in these characters was observed over F_2 .

In case of boll anatomical studies, the hybrid generation recorded indeterminate boll rind toughness and boll rind thickness. In segregating generation (F_2) some ideal plant types were observed having maximum boll rind toughness coupled with low locule damage. Selection of such plants will help to introgressed desired characters viz., high fibre strength and resistance to pink bollworm from *G. thurberi* to *G. arboreum*. The introgressed lines will have multiple resistance viz., sucking pests and drought (from *G. arboreum*) and pink bollworm and fibre strength from *G. thurberi*.

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Chapter Opener Page



VITA

7. VITA

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