GENETIC INVESTIGATIONS, CHARACTERISATION AND FIBRE COLOUR DEVELOPMENT STUDIES IN NATURALLY COLOURED COTTONS (*Gossypium* spp.)

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GENETIC INVESTIGATIONS, CHARACTERISATION AND FIBRE COLOUR DEVELOPMENT STUDIES IN NATURALLY COLOURED COTTONS (*Gossypium* spp.)

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in partial fulfillment of the requirement
for the degree of

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IN

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By

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DHARWAD
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ABBREVATIONS USED

PH	-	Plant height
NM	-	Number of monopodia
NS	-	Number of sympodia
FB	-	Days to first boll burst
NB	-	Number of bolls
BW	-	Boll weight
SI	-	Seed index
LI	-	Lint index
GOT	-	Ginning out-turn
SCY	-	Seed cotton yield
LY	-	Lint yield
FL	-	Fibre length / 2.5 per cent span length
UR	-	Uniformity ratio
FF	-	Fibre fineness
Mic	-	Micronaire value
MC	-	Maturity coefficient
FS	-	Fibre strength
FQI	-	Fibre quality index
C	-	Counts
CSP	-	Counts strength product
MP	-	Mid parent
BP	-	Better parent
CP	-	Colour linted parent / Colour parent
WP	-	White linted parent / White parent
C_1	-	DHH-11
C_2	-	NHH-44
E	-	Epistasis

Introduction

I. INTRODUCTION

Cotton (*Gossypium* spp) is the most important fibre crop on which more than fifty per cent of world's textile industry depends. The major cotton growing countries are China, USA, India, Pakistan etc. The world seed cotton (white) output is about 56 million tonnes. Asia, North and Central America accounts for bulk of the produce. India has the largest area under cotton (8.9 million hectares) followed by USA. China is the top producer of seed cotton yield (13 million tonnes) followed by USA (10.6 million tonnes) and India (8.3 million tonnes). The seed cotton productivity is highest in China (2829 kg/ha) followed by Greece (2687 kg/ha). India's productivity is very low (931 kg/ha) (Anonymous, 1997).

The commercially cultivated cotton is white. But there are different species/genotypes having colour lint or fibre. Most of the wild species of cotton have colour lint or fuzz. But due to easy dye ability of white lint, the white cottons have become popular and are in demand. The fabric manufactured from white lint can be dyed to produce different hues and colours (Apodoca, 1990). The process of dyeing is very polluting and also water intensive. Many of the dyes used are either allergic or carcinogenic. The effluents from dying industry are often let into water bodies like rivers, lakes etc., making water unsuitable for consumption or for any other usage. The fabric manufactured from white cotton and dyed with artificial chemical dyes have been reported to cause some allergies, disorders and skin diseases in many individuals especially young children. Apart from this, the cultivation and use of white cottons is highly chemical intensive and hazardous. White cotton cultivation involves use of large quantity of chemical fertilizers and different kinds of pesticides, which make the final produce highly contaminated. The journey from fibre to fabric is also full of

hazardous chemical dyes, many of which are known carcinogenic (Khadi and Kulkarni, 1996).

All these facts and ecoawarness among general public have lead to revival of colour linted cottons which can do away the process of dyeing thereby reducing water and environmental pollutions. The credit of revival of colour cottons should go to Ms. Sally Fox an American Scientist who started improving yield and quality parameters of colour linted cotton and also started its cultivation on thousands of acres in USA. She also developed market for colour cottons.

As described earlier the cottons have different colour lints like different shades of brown, green, cream, gray etc. The historical and archeological evidences discovered worldwide indicate that cultivation and use of colour linted cottons was known to ancient civilizations. The oldest textiles recovered from firmly dated archeological sites was woven from brown or tan colour lint. These cottons were known to have wide variety of medicinal properties. Brown cotton was used for treatment of topical and internal infection, herpes complex A and as a contraceptive (Vreeland, 1993). The excavation at Huaca Prieta in the Northern Peruvian coast, at Aztec civilization sites in Mexico and Guatemala indicates cultivation and use of colour linted cotton for religious, ceremonial and spiritual purposes. Similarly in ancient Egyptian and Chineses civilizations also the use of colour linted cotton was limited to elite class. In Meso American countries like Peru, Mexico, Guatemala, Brazil, and also in Egypt naturally colour cottons belonged to *G. barbadense*, whereas it was *G. hirsutum* in USA and USSR. In Indian subcontinent colour linted cottons grown were of *G. arboreum* and *G. herbaceum* types. The naturally colour cotton were known as "*Algodon pais*" in Peru, *Coyote* in Mexico and *Cuyuscate* and *ixcoco* in Guatemala (Vreeland, (1993). In erestwhile USSR and parts of USA colour linted cotton was also grown.

In Indian subcontinent cultivation and use of colour linted cotton was known from time immemorial. The diploid cottons with khaki, brown, red and cream shades were cultivated in Bengal, Karnataka, Andhra Pradesh, Assam, Tripura and some tribal belt. Here also it was used for mostly religious and social purposes. In Andhra Pradesh two varieties Cocanadas-1 and Cocanadas-2 were grown during early part of this century. But its cultivation declined and presently is very less (Sikka and Joshi, 1960a&b). The reasons behind this were suitability of white cottons for dyeing, low yields, and poor fibre properties of colour cottons. As colour linted cottons could not be dyed with different colours, the research and improvement work was neglected. In many countries cultivation of colour linted cottons was legally prohibited and its fields were destroyed. In MesoAmerica where cultivation of colour linted cotton was on higher scale, farmers were forced to abandon its cultivation and were punished, but still then colour linted cottons have survived. Recently a project was launched to revive colour linted cotton cultivation in Peru (Vreeland, 1991 and 1993).

Similarly, in other parts of the world efforts are going on to improve colour linted cottons. With the success of Naturally Coloured Cotton Inc, a Sally Fox company the markets are open and there will be demand for naturally colour cottons in near future. If these cottons are grown without chemicals then one can produce totally organic cotton, which will be free from harmful chemicals.

India with its thousands of years experience of cotton growing, genetic resources and textile industry, is well poised to takeup the challenge of developing colour cottons for commercial cultivation. But there are some problems, which have arised because of the neglect of colour cottons over centuries. Some of the problems are its low yielding ability, poor fibre quality, unstability of fibre colour over seasons and locations, pest

susceptibility, requirement of isolation distance etc. Similarly some basic information like how and when pigment develops in fibre, what is the chemical nature of pigment is not clear.

So there was a need to assess available germplasm for variability, to compare its performance with white cottons, to find out lacunae and overcome them. Similarly there is also a necessity to compare genetic behaviour of naturally coloured cottons with white cottons so that further breeding strategies could be developed. Another aspect of naturally colour cotton which is very much important is its suitability for spinning and other textile processes. In white cottons, these parameters have been standardised over centuries, but these aspects are also neglected in naturally colour cottons. Thus most important objective in naturally colour cotton breeding should be to develop high yielding, pest and disease tolerant varieties. So that the chemical component in cultivation is reduced. Possibilities should be tried to grow colour cotton totally organic, so that it will fetch more market and also price. Another objective should be fibre improvement, so as to make them suitable for modern day spinning and weaving.

Thus, with above context a series of experiments were planned and executed at Agricultural Research Station, Dharwad Farm of University of Agricultural Sciences, Dharwad. The studies included genetic variability, correlation and path analysis, heterosis and gene effects. Studies on mutation effect, colour development, colour extraction and electrophorosis were also carried out.

The main objectives were to study;

1. The existing variability for yield, yield components and fibre quality characters.

2. The genetics of fibre colour in both tetraploid and diploid cottons.

3. The character association and analysis of component characters.

4. The heterosis and genetics for various growth, yield and fibre quality parameters.

5. The induction of variability through mutagenesis.

6. The fibre colour development, pigment extraction and its nature.

7. The characterisation of naturally coloured cottons through electrophorosis.

Review of Literature

II. REVIEW OF LITERATURE

Cotton (*Gossypium* Spp.) is the most important fibre, crop, which supplies raw material to half of the world's textile industry. The commercially cultivated cotton is white but there are untapped genotypes that have different colours. In recent days the awareness about the damage caused to the safety of environment due to the indiscriminate use of intensive chemicals in the journey of fibre to fabric of cotton has created interest in naturally colour cottons which can reduce the use of poisonous and hazardous chemicals to a certain extent. In this context the literature available on naturally colour cottons is reviewed under different heads.

2.1 Origin and history of colour linted cottons

The genus (*Gossypium*) comprises of four cultivated and 46 wild and semiwild species. Most of these species bear colour lints but are non-spinnable (Annon, 1992). In phylogenetic pathway of diploid and teraploid cultivated cottons the wild colour linted species of *Gossypium* like *G. anomalum*, *G. herbaceum* race *africanum* and *G. raimondii* have been postulated to be of primary importance. *G. arboreum* arouse by gradual differentiation from *G. herbaceum* and *G. barbadense* was involved in the development of *G. hirsutum* and vice versa. Interspecific hybridization and introgression in combination with spontaneous polyploidy and mutations in nature have played a great role in the continuous evolution of the cultivated cottons (Hutchinson, 1951). The early primitive forms of the cultivated species must have been colour linted to dirty white and near white. The brown appears to be the basic colour (Narayanan and Sundaram, 1996). Other lint colours observed in cotton are dirty grey, black, different shades of brown like mahagony red, khaki, light

green, pista green. The present day predominant white linted cotton was the result of the selection made for fibre length. Thus in the course of evolution through directed human selection and selective breeding pure white linted cultivars were developed from wild colour linted types in all four cultivated species (Harland, 1939). The lint colours of wild species of cotton are given below as per Fryxell (1984).

Region	Species Name	Local Area	Lint colour
America	*G. aridum*	Mexico	Brown
	G. armourianum	Mexico-Baja	Brownish
	G. barbadense	S. America and parts Central America	White usually Creamish
	G. darwinii	Galapagos Islands	Brownish
	G. davidsonii	Mexico	Not described
	G. gossypiodes	Mexico-Central	Grayish
	G. harknessii	Mexico-Baja	Grayish
	G. hirsutum	Middle America West Indies Pacific Islands	White. Tan or Red Brown
	G. klotzschianum	Galapagos Islands	Not described
	G. lanceolatum	Mexico-West	White
	G. laxum	Mexico-Central	Tan
	G. lobatum	Mexico-Central	Whitish to tan
	G. mustelium	Brazil	Brownish
	G. raimondii	Peru	Tan
	G. turneri	Mexico and South Arizona	Almost lintless
	G. tomentosum	Hawai	Red-brown
	G. trilobum	Mexico-West	Tan
	G. thurberi	Mexico-Northwest	Not described
Australia	*G. australe*	Australia-Central & Northern	Brownish
	G. bickii	Australia-Central	Not described
	G. costulatum	Australia-Northwest	Almost lintness
	G. cunninghamii	Australia-North	Not described
	G. nelsonii	Australia-Central	Not described
	G. pilosum	Australia-West	Not described

Region	Species Name	Local Area	Lint colour
	G. populifolium	Australia-Northwest	Not described
	G. pulchellum	Australia-Northwest	Almost lintless
	G. robinsonii	Australia-West	Gravish
	G. sturtianum	Australia-Central	Brownish
	G. sturtianum var. nandewarense	Australia-Southeast	Gravish
Africa			
	G. anomalum	Africa-Southwest And Sub-Saharan	Brownish
	G. capitis-viridis	Africa-Cape Verde	Brownish
	G. herbaceum	Africa	White usually. Gravish
	G. longicalyx	Africa-East	Gravish
	G. somalense	Africa-Somalia	Brownish
	G. triphyllum	Africa-Southwest	Tan-cream
Afro-Asia			
	G. arboreum	Africa.Arabia to West Asia	White to tan
	G. stocksii	Est Africa. Arabia to pakistan	Brownish
Arabia			
	G. areysianum	Arabia	Brownish-gray
	G. incanum	Arabia	Tan

Source:Fryxell (1984)

History

Naturally colour cottons were known to mankind as early as 2500 BC. The pigmented fibre and fabric remains have been recovered from broad range of geographic and cultural context as far flung as Egypt, India, Pakistan, China, North Central and South America, spanning over a time frame of nearly 5000 years. The oldest textiles recovered from firmly dated archeological context in both old and new worlds may have been woven from brown or tan colour lints. These cottons were also known to have wide variety of

medicinal properties. Brown cotton was used for treatment of topical and internal infection, herpes complex A and as contraceptive (Vreeland, 1991 and 1993).

Historical documentation of colour cotton is not very well available. But archeological, cultural and anthropological evidences are available in some countries. The details of which are presented below.

Meso-America

Meso-America comprises of countries like Peru, Mexico, Guatemala, Brazil and other neighbouring countries. The domesticated and semidomesticated varieties of naturally colour cotton belonging to *G. barbadense* have influenced socially, economically, ceremonial and political lives of indigenous people for millenia. Naturally colour cottons are known by different names like *algodon pais*, *cocyte* or *coyuche*, *cuyuscate*, *izxcoco* etc. Archeological remains found in the excavations at Huaca Prieta on the North Peruvian coast indicates the cultivation and use of chocolate brown cottons belonging to *G. barbadense*. Deeply pigmented lint was recovered in most other coastal archeological sites in subsequent period (Bird, 1985). In the vicinity of these early archeological sites colour cottons are still cultivated in present farming and coastal fishing villages (Vreeland, 1991 and 1993).

Fabrics made by Andean weavers five millennia age shows two distinct colours light brown and chocolate brown of which dark brown was used to make fishing nets (Vreeland, 1993 and Apodaca, 1993). In Mexico brown cotton constituted a principal from a tribute paid by subjugated peoples to precolonial Aztec and Spaniards after colonization. Brown cotton called *coyote* or *coyuche* continues to be spun by Nahua Indian women till date. Several varieties of perennial and naturally brown cotton known as *cuyuscate* are still

grown in lands of Guatemala and similarly in its highland brown cotton called as *ixcoco* is still spun in several communities (Apodoca, 1990; Vreeland, 1991 and 1993; Berdan, 1987).

U.S.A.

Naturally colour cotton was cultivated by subsistence farmers and by slaves on large plantation estates which was spun and woven by hand. Naturally pigmented cotton was spun into attractive cloth and sold in many southern states of USA. Green and brown cotton yarn and fabric was produced upto World War II in many parts of USA (Vreeland, 1993; Apodoca, 1990; Narayanan and Sundaram, 1996). During colonical period coloured forms from Thailand, Chinese Nankin, Central America and Mexican and Peru were introduced in USA.

Egypt

A bit of brown fuzz dated about 2500 BC was recovered from Afia in Egyptian Nubia. These material could not be assigned to both old world cotton or to the presently grown cotton in Egypt. Pigmentation in Egyptian cotton was first noted in the Ashmouni valley and a variety named after the valley was developed. It had long, strong fibre with a golden brown colour and could be readily ginned from naked seeds. Hand spinners intensively exploited it. Another variety Mit Afifi having rich, darker brown lint with 34 mm length was also developed.

China

Nankin varieties belonging to *G. arboreum* having short staple and pigmented fibre were cultivated. But as in Mexico their use was restricted to the noble class (Vreeland, 1993). Presently 40 colour cotton lines are being maintained. The fibre colour of these lines is reported to be in brown range.

Erstwhile USSR

Due to shortage of dyes during World War II Soviet textile industry resorted to use of naturally pigmented fibres. During World War II USSR had put for sale about 700 metric tons of naturally colour cotton lint (Ware and Bennedict, 1962). A wide range of natural hues was under production in Russia. Russian have indicated three distinct colours "Sand fresh", "Red brown" and "Green brown". Russian workers have been working on colour linted lines for last thirty years during which they have developed some 200 different varieties of pigmented lint including blue, pale blue and violet (Vreeland, 1993; Khadi and Kulkarni, 1996).

India

From the time immemorial, colour cottons are known in diploid cottons and were under cultivation in Asia, particularly in Indian subcontinent, China, Central Asian republics of former Soviet Union etc. In Ayurveda Charithrum there is a reference to development of red and blue cotton using different plant products. In Indian subcontinent colour cottons like brown, khaki and red were grown in specific locations over larger areas. They were commercially used in hand spinning, weaving novelty fabrics and form domestic use. In Assam non-cernum cottons with black, brown, khaki and creamy white linted types were found. In Kumpta cottons grown in Karnataka red tinged types were available. In Bengal world famous Dacca muslins and high-count hand spun fabric was made from white as well as red *G. arboreum* (Narayanan and Sundaram, 1996). In Tripura soft brown types are grown and used in to weaving wrape stripe pattern fabric. This fabric is treated as the most valuable in religious and social customs (Pal, 1989).

In coastal Andhra Pradesh, brown linted cotton varieties like Red Northerns, Cocanadas-1 and Cocanadas-2 were grown during first half of the present century in about

25,000 ha area. These were spun and woven into fabric and some quantity was exported. Systematic research was carried out on colour cotton at Lam (prior to 1940) Narasaraopet and Gurazala (after 1950's). Of this Cocanadas-2 was having deeper colour. Even today few thousand farmers are engaged in cultivation and use of colour cottons (Rangandha Charyulu, 1996; Narayanan and Sundaram, 1996; Basu, 1995).

Presently research and improvement work is carried out at University of Agricultural Sciences, Dharwad, Jawaharlal Nehru Krishi Vishwavidhyala, Khandwa, Jabalpur and Central Institute for Cotton Research, Nagpur. Many lines have been stabilised at these centres. The Khandwa group has stabilised a *G. hirsutum* colour genotype KC-94-2. At Dharwad a *G. arboreum* colour genotype DDCC-1 has be stabilised and recommended for release in Northern Karnataka. Efforts are going on, to develop Naturally coloured cotton genotypes suitable for commercial cultivation. The strategies employed are 1) varietal development, 2) hybrid development, 3) mutation breeding, the results are promising (Khadi *et al.*, 1998c).

Genetic Studies

In naturally colour cotton literature on different genetic studies is very less. In following pages an attempt has been made to review the available literature on different genetic studies, wherever literature is not available on colour cotton, the work on white cotton has been reviewed after noting work on colour cotton.

2.2 Genetic Variability

The different components of genetic variability includes all three types of variances viz., genotypic (VG), phenotypic (VP) and environmental (VE), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and

genetic advances. Galton (1989) observed that continuous variation has a component of heredity. In 1909 Johannsen attributed the variation in a segregation population to both heritable and non-heritable components, and the variation in a pure line to only environmental factors. The heritable variation was further partitioned into additive and non-additive components and the later component was known to contain dominance and other inter-allelic interaction (Fisher *et al.*, 1932; Panse, 1940; Falconer, 1960). The environmental variance is variation of environmental deviations which are attributable to all kinds of non-genetic sources (Dabholkar, 1992).

2.2.1 Variances and Coefficients of variation

2.2.1.1 Growth Parameters

Growth parameters include plant height, number of monopodia and sympodia, and days to first boll burst. Moderate variation was noticed in colour cotton for plant height by Singh *et al.*, (1996), Mandloi *et al.*, (1996) and Bijapur (1996). Later also reported low to moderate variances, phenotypic and genotypic coefficient of variations. Low variability was observed by Bijapur (1996) for days to first boll burst. In case of number of monopodia low variation was reported by Mandloi *et al.*, (1996) whereas Bijapur (1996) indicated high variability with high degree of variance, GCV and PCV. Mandloi *et al.* (1996) reported moderate variation for sympodial number, whereas, Bijapur (1996) reported low variability for the same.

2.2.1.2 Yield

Singh *et al.* (1993) observed high variability in seventeen coloured genotypes studied. The yield ranged from 11.89 g per plant to 68.7 g per plant. Rajesekaran and associates (1993) observed yield ranging from 156 kg per ha to 544 kg per ha. In fifteen genotypes evaluated by Mandloi (1996) yield varied from 6 g per plant to 22 g per plant.

Khadi *et al.* (1996b) evaluated 28 genotypes wherein yield varied from 3.65 to 13.31 q per ha. Similarly in another set of 75 genotypes yield ranged from 2.6 to 12.3 q per ha. They also reported yield variation of 10.9 to 22.5 q per ha in an experiment with ten brown *hirsutum* lines. In another trial with 32 genotypes the yield variation was 3.7 to 20.4 q per ha. Singh *et al.* (1996) reported a yield range of 11.8 to 68.7 g per plant with a mean of 40.9 g per plant. Mandloi *et al.* (1996) observed a variation of 32 and 102 g of seed cotton per plant in a study involving 16 genotypes. He also reported yield range of 3.1 to 17.7 q per ha of seed cotton in a farmers field trial involving fourteen farmers. Bijapur (1996) observed wide variation in yield (19.37 to 72.8 g/pl) and reported high PCV, GCV and variances. Khadi *et al.* (1997, 1998a, 1998b, 1998c, 1999a and 1999b) reported wide range for seed cotton yield in colour cotton genotypes and hybrids.

2.2.1.3 Number of Bolls

Number of bolls per plant in the evaluation of colour cotton germplasm by Singh *et al.* (1993 & 1996) varied widely (7-28). Ravindranath *et al.* (1996) reported low variability for boll number in both *G. hirsutum* and *G. arboreum* colour cotton. Mandloi (1996) observed a wide range (15-38) of boll number per plant. Bijapur (1996) noticed moderate variability for the character. Mandloi (1996) and Bijapur (1996) observed that average number of bolls per plant in coloured genotypes were on par or more than white linted checks. But Singh *et al.* (1993, 1996) and Ravindranath *et al.* (1996) reported exactly opposite situation.

2.2.1.4 Boll Weight

It was observed that boll weight did not show much variation among different genotypes studied by many workers. The range of boll weight in colour cotton genotypes reported by different researchers is as follows.

Authors	No.of Genotypes Studied	Range of boll weight (g/boll)
Singh *et al.* (1993)	17	2.7-4.4
Mandloi (1996)	15	1.5-3.7
Khadi *et al.* (1996b)	20	2.1-4.23
Mandloi *et al.* (1996b)	15	2.7-3.9
Ravindranath *et al.* (1996)		
G. hirsutum	2	3.0
G. arboreum	2	1.5-2.0
Singh *et al.* (1996)	5	3.0-4.0
Bijapur (1996)	26	2.1-4.3

In all above reports it was observed that boll weight of colour cotton genpotypes was usually on par with that of white linted checks used.

2.2.1.5 Seed Index

Seed Index varied widely in studies of Singh *et al.* (1996) and Bijapur (1996). But, Mandloi *et al.* (1996) and Ravindranath *et al.* (1996) reported less variability in colour cotton genotypes in seed index.

Authors	No.of Genotypes	Range for seed index (g)
Singh *et al.* (1993)	17	6.0-10.5
Khadi *et al.* (1996a)	75	5.0-11.0
	10	7.0-10.0
	32	7.0-11.0
Mandloi *et al.* (1996b)	15	7.2-8.9
Ravindranath *et al.* (1996)		
G. hirsutum	3	7.8-8.0
G. arboreum	3	6.0
Bijapur (1996)	26	6.0-12.6
Khadi *et al.* (1998a)	10	7.0-10.0
(1999a)	35	8.0-11.0
(1999b)	66	6.0-11.0

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Seed index of most of the colour cotton genotype was on par with that of white linted checks in almost all studies.

2.2.1.6 Lint Index

Lint Index showed high variability in the studies conducted by Singh *et al.* (1993) Khadi *et al.* (1996b), Bijapur (1996) whereas, Mandloi *et al.* (1996), Singh *et al.* (1996) and Khadi *et al.* (1996b) reported low variation.

Authors	No.of Genotypes	Range (g)
Singh *et al.* (1993)	17	2.1-4.5
Singh *et al.* (1996)	5	2.7-3.9
Mandloi *et al.* (1996)	15	3.1-4.8
Khadi *et al.* (1996b)	75	1.8-5.1
	10	4.3-5.2
	32	2.3-5.4
Bijapur (1996)	26	2.18-6.74
Khadi *et al.* (1998a)	10	4.29-5.33
(1999a)	35	1.97-4.57
(1999b)	66	1.75-5.38

Lint index of colour cotton genotypes was on par with that of white linted check used in all studies except in case of Bijapur (1996) where most coloured genotypes showed lint index less than that of white linted checks.

2.2.1.7 Ginning Outturn

High variability was reported by Singh *et al.* (1993, 1996), Khadi *et al.* (1996). Whereas Rajasekaran *et al.* (1993), Mandloi (1996), Mandloi *et al.* (1996), Khadi *et al.* (1996b), Ravindranath *et al.* (1996) and Bijapur (1996) did not observe much variation.

Authors	No.of Genotypes	Range (%)
Singh *et al.* (1993)	17	19.5-35.1
Rajasekaran *et al.* (1993)	7	25.0-35.8
Mandloi *et al.* (1996)	15	30.4-36.6
Deshpande (1996)	11	34.8-42.8
Ravindranath *et al.* (1996)		
G. hirsutum		34.0-35.0
G. arboreum		33.0-37.0
Mandloi *et al.* (1996)	15	30.0-35.5
Khadi *et al.* (1996b)	75	18.6-30.8
	10	30.0-40.0
	32	20.0-40.0
Bijapur (1996)	26	23.7-36.7
Khadi *et al.* (1998a)	10	30.0-40.0
(1999a)	35	18.6-33.7
(1999b)	66	19.09-40.0

The ginning percentage of colour cotton genotypes in above studies reported by authors was on par with that of white linted check except in case of studies conducted by Bijapur (1996).

2.2.2 Heritability and Genetic Advance

Heritability is the measure to know the degree of correspondence between the phenotypic values and the genotype values. Lush (1943) proposed the term heritability and defined it as the ratio of variance due to hereditary differences (σ^2g) to the total phenotypic variance (σ^2p), which was also termed as broad sense heritability, which is valid for homozygous lines. In case of segregating generations where both additive and dominance component are present, narrow sense heritability which is the ratio of additive component in phenotypic variance is used. Since estimates of heritability do not give indication of the amount of the progress expected from selection hence another parameter referred is genetic

advance, which is the improvement in genotypic value of new population as compared with base population. Heritability estimates are most meaningful when coupled with genetic advance values (Panse, 1957).

Heritability and genetic advance studies in colour cotton are rare. Bijapur (1996) observed high heritability for yield and all yield parameters including boll weight. Among growth parameters only number of sympodia had higher heritability. Genetic advance for all characters was less except for yield where it was 27.3. Genetic advance over mean was higher for number of monopodia, number of boll, lint index and yield. For other character it was low to moderate.

2.3 Genetics of lint colour

Lint colour may be white, dull grey, various shades of brown from light cream to mahagony red, bright green which speedily fades to greenish brown, rusty brown when exposed to sunlight. Brown cottons of various shades exist in the Asiatic group and in new world cottons brown are represented in all species. Some species have both brown as well as white lint whereas some others have only colour lint.

In old world cotton Fletcher (1907) remarked that colour lint is dominant over white. Kottur (1923) intercrossed a reddish ting dull white *herbaceum* and white *arboreum*. The F_1 was dull white with reddish ting. The F_2 segregated into three white or dull white and one brown.

Balls (1908) studied crosses of brown *barbadense* and white *hirsutum*. He found F_1 intermediate and F_2 gave 1 brown:2 cream:1 white. Ware (1932) in intra *hirsutum* cross reported that brown with three shades was incompletely dominant over white lint with mono factorial segregation in F_2.

Ramanathan and Balasubrahmanyan (1933) considered that lint colour in the old world cotton is governed by three factors, viz., one basic gene, X which is essential for colour and can produce pigmentation of lint only in the presence of K_1 and or K_2. None of them can impart colour individually. When either K_1 or K_2 was present with X, the lint was cream colour. Both K_1 and K_2 are of equal potency in colour production. The three genes together produce brown lint. Several modifiers seemed to be present.

Hutchinson (1934) first reported that khaki lint colour in the old world cottons is controlled by a single gene K, linked with leaf shape locus L. Later in 1935 after obtaining segregation for colour in backcrosses and postulated the existence of three factors controlling lint colour character.

Harland (1935) studied in an intra *barbadense* cross between dark brown and cream, the F_1 was intermediate but near to brown parent. F_2 segregation was of the blending type which is characteristic of inter-specific crosses. It was established after three back crosses to brown parent that one main factor pair KB-KB conditioned brown and light brown lint. Blending in F_2 was due to the segregation of modifiers as well as the main gene. Another cross of brown *barbadense* and brown *hirsutum* indicated involvement of duplicate genes for lint colour. It was also indicated that the brown lint colour in *G. taitense* was due to the same genes as in *hirsutum* (Harland, 1939).

Silow (1945) indicated that lint colour in asiatic cottons is determined by main genes at four loci Lc_1, Lc_2, Lc_3 and Lc_4 and by a variable complex of minor genes. At Lc_1 only one fully dominant gene Lc_1^K which is not affected by modifiers and is only subjected to slight fading existed. At Lc_2 a multiple allele series occured and included khaki (Lc_2^K), medium brown (Lc_2^M), light brown (Lc_2^B), very light brown (Lc_2^V), and white brown (Lc_2)

Lc_2^K was regarded a duplicate of Lc_1. Lc_2^B reported to have low dominance and highly susceptible to modifier effect and to fading. At Lc_3 only one brown gene Lc_3^B which is duplicate of Lc_2^B was reported. Similarly at Lc_4 only one khaki linted gene Lc_4^K was identified. Brown lint colour genes were reported to have cumulative effect.

Balasubrahmanyam and his associated (1950) studied inheritance of lint colour in Cocanadas. The results indicated that white was recessive to khaki and strain Cocanadas-1 carried the very light brown gene Lc_2^V, and other genotypes viz., 125 and 129 probably carried Lc_2^B, Nankin khaki showed simple dominance over Cocanandas-1, thus indicating that it carried darker allele and cross Cocanadas-1 x A9 exhibited bifactorial differences.

Silow (1944) suggested that lint colour situation in new world cottons had a similarity with old world species. *G. hirsutum* had a high level of modifying complexes but main lint colour were not common. In *barbadense* one main gene for brown colour lint with a strong suppressing modifier background was identified.

Genes determining brown lint in *G. punctatum* and *G. darwinii* were reported to be independent of Lc_1^K. Mahagony was distinct from all others in intensity of colour induced. Similarly two genes for brown were reported in *G. tomentosum*. Some minor genes for lint colour that change white to off white, or even pale brown or dark brown were reported in *hirsutum*, *marigalante*, *barbadense* and *tomentosum* (Hutchinson, 1946).

Brain (1950) reported same series of alleles for lint colour in *hirsutum*, whereas *barbadense* carried two independent loci for character.

Kohel (1985) undertook genetic analysis of fibre colour in eleven brown lines. The dark brown lint lines tested were conditioned by alleles at the Lc_1 locus, except for *morrilli* brown lint. There was no evidence of more than one Lc_1 allele. Lousiana brown carried a second brown lint locus, but the expression of the allele at the locus was so weak that when isolated it could not be identified readily in segregating population.

Morrilli brown (Lc_1, Lc_3) lint was reported to be conditioned by dark brown lint alleles at one new locus which was closely linked to a second new locus carrying light brown alleles (Lc_5). The dark brown locus was assigned the gene symbol Lc_3.

Four light brown lines carried alleles at the Lc_2 locus. Another two lines G255 and TT were reported to be independent of all other brown lint loci and were assigned to gene symbols Lc_4.

Richmond (1944) observed that the lint colours in Nankeen and Texas Rust were conditioned by a single gene which was incompletely dominant in crosses with white. Genes for Nankeen and Texas Rust appeared to be conditioned by single gene which was probably independent of the genes of Nankeen and Texas Rust.

Green lint in *G. hirsutum* would be bright green but fades on exposure to sunlight to brownish green. Hutchinson and Silow (1939) reported that the green lint type is simply dominant to white and the factor responsible was designated Lglg.

In an colour inheritance study (Richmond, 1944) concluded that Texas green lint (TGL) was conditioned by a single gene which was incompletely dominant in crosses with white lint. The genes for Texas green was independent from the genes governing Nankeen and Texas Rust.

Harland (1929 and 1932) reported that green was dominant to white but with a reduced amount of colour. In F_2, Segregation could be followed clearly in some crosses whereas in others blending occurred due to segregation of modifiers. The Technical Committee of U.S. Regional Project concerned with cotton genetics and cytogenetics research has established rules for genetic nomenclature and lists the following genetic mutant markers for coloured lint (Endrizzi et al., 1984,)

Gene symbol	Name	Gossypium species
Lc_1^k	Khaki lint	*arboreum* and *herbaceum*
Lc_2^B	Light brown lint	*arboreum* and *herbaceum*
Lc_2k	Khaki lint	*arboreum* and *herbaceum*
Lc_2^M	Medium brown lint	*arboreum* and *herbaceum*
Lc_2^V	Very light brown lint	*arboreum* and *herbaceum*
Lc_2^B	Light brown lint	*arboreum* and *herbaceum*
Lc_4^k	Khaki lint	*arboreum*
D_w	Dirty white lint	*raimondii*
L_g	Green lint	*hirsutum*
Lc_1	Brown lint	*hirsutum*
Lc_2	Brown lint	*barbadense, darwinii, and tomemtosum*

2.4 Character association

Character association analysis measures association between different characters and helps to determine the components on which selection can be based for improvement. The correlation coefficients studied are phenotypic, genotypic and environmental. The association that is observable and measured is referred as phenotypic correlation which includes genotypic value and environmental deviation. The genotypic correlation is the inherent association between two variables resulting either from pleiotropic effects of genes or linkage of genes governing inheritance of two or more characters or both.

The correlation due to linkage are relatively ephemeral whereas, correlations from pleiotrophy is long lasting and is usually the net effect of all the segregating genes that influence both the attributes (Falconer, 1960, Dabholkar, 1992, Al-Jabouri *et al.*, 1958).

Kottur (1923), noticed an association of short staple with brown lint in Indian cottons. Kearney (1926) reported a correlation in Upland-Egyptian hybrids between length and colour of lint. He reported that gene Kb reduced the lint length in Egyptian cotton by about 5.1 mm in homozygous condition and by 2.7 mm in heterozygous condition. Harland (1929) reported correlation between colour and fineness. The green linted were more fine and silkier than white. Ware (1932) confirmed the same. Bijapur (1996) studied correlation between different characters. He observed significant positive correlation of yield per plant with number of bolls and ginning per cent, which showed highly significant relation with lint index, seed index and boll weight.

As reviews on colour cottons are less hence, some of the reviews pertaining to white cottons are included. Many workers observed significant positive correlation between yield and plant height (Al Rawi, 1989; Chen *et al.*, 1991; Arshad *et al.*, 1993; Carvalho *et al.*, 1994 and Killi, 1995). Boll number per plant and yield (Bodar *et al.*, 1988, Aher *et al.*, 1989; Chen *et al.* 1991; Tariq, *et al.*, 1982; Arshad *et al.*, 1993; Carvalho *et al.*, 1994 and Killi, 1995).

2.5 Path Analysis

The coefficient of correlation expresses association between two variables but does not describe about the causal relations of variable i.e., which variable is dependent and which is independent. Wright (1921) developed path coefficient analysis to overcome the

drawback of correlations and to analyse correlation coefficient. This technique was extended to plant breeding by Dewey and Lu (1959).

A path coefficient is simple standardised partial regression coefficient which measures the direct influence of one variable upon another and thus permits the partitioning of correlation coefficient into direct and indirect effects.

If the observed correlation is mainly due to the direct effect of independent variables of dependent character then relationship between them is true, therefore selections can be practiced for such independent traits in order to improve dependent variable. But if the relation is mainly through indirect effect of a trait through another trait than the breeder has to be cautious while selecting so that the improvement of dependent variable through selecting characters with high indirect effects is achieved (Falconer, 1960).

Path analysis studies in colour cotton are less. Bijapur (1996) studied path for yield and observed that lint index, number of bolls, number of sympodia had high direct positive effects whereas, boll weight had positive indirect effect on yield.

In white cottons a high positive direct and indirect effects of boll weight on seed cotton was reported by Krishnarao and Mary (1990) and Alam and Islam (1991). Bolls per plant were observed to have positive and direct effect on yield (Alam et al., 1991; Tariq et. al., 1982; Tomar and Singh, 1992a; Rajarathinam et.al., 1993; Sambamoorthy et.al., 1994 and Killi, 1995).

2.6 Heterosis

The classical term heterosis, coined by Shull (1914) implies the excellence of F_1 over parents with respect to increase in size, yield vigour etc. The commercial

exploitation of heterosis in cultivated crop species has had profound impact on the world agriculture in the present century. In cotton India is the pioneer in heterosis breeding for commercial use. First cotton hybrid was developed at Main Cotton Research Station, Surat of Gujarat Agricultural University followed by interspecific hybrids like Varalaxmi and DCH-32 from Agricultural Research Station, Dharwad Farm of University of Agricultural Sciences, Dharawad. These hybrids which occupy about 45 per cent area has made India self sufficient in long staple and extra long staple cottons. In colour cottons also efforts are on to develop hybrids. Available literature on hybrids in colour as well as white cotton has been reviewed and presented below.

2.6.1 Heterosis in naturally coloured cottons

Sundarmurthy *et al.* (1994) studied fibre qualities of four colour cotton hybrids. It was observed that for span length, uniformity ratio, fineness and maturity coefficient all hybrids were superior to their colour linted parents.

Amudha and Raveendran (1997) studied heterosis in 51 F_1's and 15 parents for twelve characters. For days to first boll burst heterosis over mid parent ranged from -10.19 to 1.56 per cent, and 46 hybrids had negative heterosis. Five hybrids showed significant positive heterosis over mid parent for seed cotton yield and bolls per plant. Another two hybrids exhibited significant and positive heterosis for number of sympodia and number of bolls. It was also seen that most of the crosses were heterotic for yield but poor in fibre properties particularly for fibre strength.

Thirty one crosses between white linted females and colour linted males were evaluated by Ahuja *et al.* (1998). It was observed that lint colour was dominant. Some

crosses with LRA5166 and LRK516 were superior than local check variety in seed cotton yield and quality trait as compared to other white linted genotypes K3400-7 and F-305.

Khadi *et al.* (1998b) evaluated fourteen colour linted hybrids which were developed from white x colour and colour x colour crosses. The yield of hybrids ranged from 8.59 to 24.24 q per ha with a mean yield of 15.3 q per ha under rainfed condition. The fibre length of hybrids ranged from 17.33 to 26 mm with a mean fibre length of 22.4 mm. They indicated the possibility of improving colour cottons with hybridisation and it was possible to creat variability for colour. The hybrids developed were on par with white linted hybrids for yield and fibre length.

Punitha and Ravindran (1998) reported heterosis in 40 F_1 hybrids of *G. hirsutum* and *G. barbadense*. Heterosis was reported for the characters like days to first boll burst, plant height, number of sympodia, number of bolls, boll weight and seed cotton yield.

2.6.2 Heterosis in white linted cotton

Heterosis reported by different workers for various characters in white cotton is reviewed below.

2.6.2.1 Plant height

Patel (1984) reported heterosis ranging from -17.07 to 36.07 per cent. Similarly significant heterosis was observed by Mehta *et al.* (1987), Khadi *et al.* (1992) and Upadhyay and Paradkar (1992). Bhatade *et al.* (1994) observed moderate heterosis over better parent (BP) and mid parent in thirty six hybrids. Tomar and Singh (1992b) observed heterosis ranging from -5.9 to 23.9 per cent over better parent. Hiremath (1993) reported significant heterosis over mid parent and lower parent. Singh *et al.* (1995b) observed significant heterosis over BP and commercial check in ten hybrids.

2.6.2.2 Number of monopidia

Patil (1973) observed both negative and positive heterosis over better parent in *G.herbaceum*. High heterosis was observed by Gill and Singh (1982) and Duhoon et al. (1983). Katageri and Kadapa (1989) reported both negative and positive heterosis over MP in *G. hirsutum*. Upadhyaya and Paradkar (1992) observed heterosis in thirty hybrids. Hiremath (1993) reported positive heterosis over lower, mid and better parent. Singh et al. (1995b) observed heterosis over BP andcommerial check in ten hybrids.

2.6.2.3 Number of sympodia

Duhoon and Verma (1988), Patel (1984), Katageri and Kadapa (1989), Upadhyay and Paradkar (1992) and Khadi et al. (1993) observed high heterosis for sympodial number. Non-significant heterosis was observed by Atale and Vitkare (1987). Positive heterosis over lower parent and mid parent and negative heterosis over better parent was reported by Hiremath (1993). Singh et al. (1995b) observed heterosis over BP and commercial check in ten hybrids.

2.6.2.4 Number of bolls

High heterosis was observed by Duhoon (1990) in thirty six hybrid. Khadi et al. (1992) observed significant heterosis over commerical checks in eight *G. herbaceum* x *G. arboreum* hybrids. They also reported high heterosis over better parent, mid parent and commercial check in eight intra *G. arboreum* hybrids. Updhyay and Paradkar (1992) reproted significant heterosis over commercial check in thirty hybrids. Singh and Singh (1993) reported significant heterosis in fifteen hybrids under different irrigation conditions. Khadi et al. (1993) observed significant heterosis over better parent, mid parent and commercial checks in eleven intra hirsutum hybrids. Bhatade et al. (1994) observed significant heterosis over better parent and standard check. Singh *et al.* 1995 a

(1995a) and Jain (1995) observed significant heterosis over better parent and commercial check in ten and twenty four hybrids, respectively. Gunaseelan *et al.* (1996) observed significant heterosis in eight hybrids over better parents. In sixty hybrids Patel and Pethani (1998) observed significant heterosis over better parent and commercial checks.

2.6.2.5 Boll weight

Significant heterosis for boll weight was observed by Sangwan and Yadav (1986), Atale and Vitkare (1987), Jagtap (1986), Gunaseelan and Krishnaswamy (1988), Khadi *et al.* (1992 and 1993) and Singh and Singh (1993). Negative heterosis was observed by Taware *et al.* (1987), whereas Duhoon (1990) observed low heterosis in thirty six hybrids. Khadi *et al.* (1992) observed significant heterosis over commercial check in eight *G. herbaceum* x *G. arboreum* hybrids. They also reported significant heterosis over better parent, mid parent and commercial check in eight intra *arboreum* hybrids. Upadhyay and Paradkar (1992) observed significant heterosis over commercial check in thirty hybrids. Khadi *et al.* (1993) reported significant heterosis over BP, MP and commercial check in eleven hybrids. Similarly Hiremath (1993) reported significant heterosis over BP, MP and lower parents in *G. hirsutum* cottons. Low to moderate heterosis was observed by Bhatade *et al.* (1994). Low to moderate significant heterosis over better parent and commercial check was reported by Bhatade *et al.* (1994), Singh *et al.* (1995a), Jain (1995) and Patel and Pethani (1998). Significant heterosis over BP was observed by Gunaseelan *et al.* (1996) in eight hybrids.

2.6.2.6 Seed cotton yield

High heterosis for seed cotton yield was reported by Aher *et al.* (1989), Sangwan and Yadav (1986), Patel *et al.* (1986), Atale and Vitkare (1987), Tiwari *et al.* (1987), Duhoon (1990), Deshpande and Deosarkar (1991), Patil *et al.* (1991), Chaudhari and

Borole (1992), Chaudhari *et al.* (1992), Narayanan and Singh (1992) and Singh and Singh (1993). Katageri and Kadapa (1989) reported high positive heterosis in intra and inter specific hybrids of *G. barbadense* and *G. hirsutum*. Significant heterosis over commercial check was reported by Khadi *et al.* (1992) in eight *G. haerbaceum* x *G. arboreum* hybrids and over commercial checks, better parent and mid parent in *G. arboreum* hybrid. Upadhayay and Paradkar (1992) also reported significant heterosis over commercial check. Heterosis over lower parent, mid parent and better parent was significant as reported by Hiremath (1993). Khadi *et al.* (1993) observed significant heterosis over commercial checks, BP and MP in eleven intra *hirsutum* hybrids. Significant heterosis over BP and MP was observed by Bhatade *et al.* (1994). Singh *et al.* (1995a), Jain (1995) and Patel and Pethani (1998) reported significant heterosis over BP and commercial checks. Amolik *et al.* (1997) observed heterosis in 56 diploid hybrids for seed cotton yield.

2.6.2.7 Ginning out-turn (GOT)

Significant heterosis for GOT was observed by Ansingkar *et al.* (1990), Duhoon (1990), Deshpande and Deosarkar (1991), Chaudhari and Borole (1992), Chaudhari *et al.* (1992) and Bhatade *et al.* (1994). Heterosis over commercial check was significant in eight *G. herbaceum* x *G. arboreum* hybrids (Khadi *et al.*, 1992). They also reported heterosis over commercial check, better parent and mid parent in intra *arboreum* hybrids. Eleven intra *hirsutum* hybrids also showed significant heterosis over better parent, mid parent and commercial check (Khadi *et al.*, 1993). Jain (1995), Singh *et al.* (1995b) and Patel and Pethani (1998) reported significant heterosis over better parent and commercial checks in 24, 10 and 60 hybrids respectively. Gunaseelan *et al.* (1996) reported significant heterosis over better parents. Amolik *et al.* (1997) observed heterosis for ginning out-turn in fifty six diploid hybrids.

2.2.6.8 Seed index

Heterosis was significant for seed index as reported by Aher *et al.* (1989), Kashalkar *et al.* (1989), Ansingkar *et al.* (1990), Nandarajan and Rangaswamy (1990), Deshpande and Deosarkar (1991), Chaudhari and Borole (1992), Chaudhari *et al.* (1992) and Singh and Singh (1993). Significant heterosis over commercial checks, better parent and mid parent in intra *arboreum* hybrids and over commercial check in diploid intraspecific hybrids was observed by Khadi *et al.* (1992). Similarly, Khadi *et al.* (1993) reported significant heterosis over BP, MP and commercial check in intra *hirsutum* hybrids. Bhatade *et al.* (1994) reported low to moderate heterosis over BP and MP. Whereas Hanuman Singh *et al.* (1995b) observed significant heterosis over BP and commercial checks. Heterosis for seed index was reported by Amolik *et al.* (1997) in 56 diploid hybrids.

2.2.6.9 Lint index

Nandarajan and Rangaswamy (1990) observed heterosis over commercial check in a study involving 60 hybrids. Chaudhari *et al.* (1992) observed significant heterosis for lint index. Khadi *et al.* (1992) reported significant heterosis over commercial checks in eight interspecific diploid hybrids, similarly in same study they observed significant heterosis over commercial check, better parent and mid parent in intra *arboreum* hybrids and in eleven intra *hirsutum* hybrids (Khadi *et al.* 1993). In an evaluation of ten hybrids Hanuman Singh *et al.* (1995b) reported significant heterosis over BP and commercial ckeck. Heterosis was also observed for lint index in 56 diploid hybrids (Amolik *et al.*, 1997).

2.2.6.10 Fibre length

Heterosis for fibre length was reported by Duhoon (1990), Ansingkar *et al.* (1990), Desphande and Deosarkar (1991), Chaudhari and Borole (1992) and Chaudhari *et al.* (1992). Significant heterosis over better parent and commercial check was reported by

Singh *et al.* (1995b) in 10 hybrids and Patel and Pethani (1998) in 60 hybrids. Fibre length showed heterosis in a evaluation of 56 diploid hybrids by Amolik *et al.* (1997).

2.2.6.11 Lint yield

Nandarajan and Rangaswamy (1990) reported significant heterosis in 60 hybrids, so also Amolik *et al.* (1997) in 56 diploid hybrids.

2.7 Gene Effect

Quantitative traits are characterised by continuous distribution. Inheritance of such characters is governed by genes which have small, similar and cumulative effects. The choice of an appropriate breeding method for improvement of quantitative characters also depends largely on nature of gene action. But the effects of these individual genes cannot be measured and non heritable agencies also influence the phenotypic expression of these characters. Therefore, these genes must be considered together and suitable statistical procedure was used to obtain genetic information.

Many gene models given by various workers attempted to describe the action of genes controlling quantitative characters. Fisher (1918) was first to attempt construction of a gene model which include dominance at a single locus. He also indicated that there may be a deviation from simple additive effects between loci if more than one locus affected a given characters, this deviation was referred as epistasis. Fisher *et al.* (1932) used above gene model to describe gene action of any number of genes for a given character. Comstock and Robinson (1948) and Mather (1949) also developed gene models to study and assess the relative importance of additive and dominance gene effects but they assumed epistatic effects to be negligible.

2.7.3 Number of sympodia

Additive effect was governing number of sympodia according to Deshmukh *et al.* (1980), Patel (1980), Katarki *et al.* (1986) and Desai (1990). Whereas dominance effect was influencing the trait as per Duhoon *et al.* (1983), Patel (1980 and 1984) and Hiremath (1993). But Malik *et al.* (1994) reported additive, dominance and additive x additive effects.

2.7.4 Number of bolls

Both additive and non additive gene effects were influencing the trait as per the reports of Gupta *et al.* (1986), Katarki *et al.* (1986), Dhanda (1987), Jagtap (1986), Jain (1983), Deshpande *et al.* (1991) and Bhatade (1992). Non additive effects were reported by Jagtap (1986), Tyagi (1988) and Singh and Chhabra (1991). Additive effect was responsible as reported by Garg and Kalsy (1987), Dessai (1990), Singh and Chhabra (1991) and Vithal *et al.* (1991), whereas Randhawa *et al.* (1991) reported influence of additive, dominance and dominance x dominance effects. Sandhu and Singh (1988) reported additive x additive effect and Hiremath (1993) reported only dominance effect, whereas Malik *et al.* (1994) observed additive, dominant, additive x dominance and dominance x additive effects. Patel and Pethani (1998) reported influence of non-additive gene effects.

2.7.5 Seed cotton yield

Seed cotton yield was influenced by additive gene effects as reported by Jagtap and Kolhe (1986), Garg and Kalsay (1987), Pavasia *et al.* (1990), Nandarajan and Rangaswamy (1991), Basu and Gururajan (1992) and Telang *et al.* (1992). But other workers like Kajjidoni *et al.* (1984), Sandhu and Singh (1988), Deshpande *et al.* (1991), Singh and Chhabra (1991), Vithal *et al.* (1991) and Hiremath (1993), Patel and Pethani (1998) reported dominance gene effect control of seed cotton yield. Both additive and non

additive gene effects were responsible for seed cotton yield as per Gupta *et al.* (1986), Mehta *et al.* (1987), Dhanda (1987), Jain (1987) and Bhatade *et al.* (1992).

Randhawa *et al.* (1991) reported that additive, additive x additive, additive x dominance and dominance x dominance gene effects influencing seed cotton yield. But Malik *et al.* (1994) reported that seed cotton yield is influenced by both additive and dominance effect and also by their interaction effects.

2.7.6 Halo length

Randhawa *et al.* (1991) reported that both additive and non additive gene effects were having influence on the expression of halo length.

2.8 Mutation Breeding

When the available variability in the genetic material is limited the breeders usually try to create variability by using mutations. In white cotton also like in other crops, some success has been achieved in obtaining new cultivars. So to overcome some of the shortcomings of colour cotton like yield, fibre quality and colour stability mutation breeding was attempted. Mutation studies in colour cotton are not available hence studies in white cotton has been reviewed. Induced mutations have played a major role in developing breeding with improved characters like earliness, yield, quality parameters etc (Phundan Singh *et al.*, 1994).

2.8.1 Seed cotton yield

Narimov (1964), Atazanov (1965), Abel-El-Hamid *et al.* (1972), Basu (1982), Bhat *et al.* (1987), Ozbeck *et al.* (1992), Arain *et al.* (1998) reported increased seed cotton yield in gamma irradiation induced mutants. Premsekar *et al.* (1987) reported higher

heterosis from irradiated parents by 0.05 kr and 10 kr gamma ray. Duhoon and Verma (1988) obtained higher heterosis in parents treated with 2 or 5 kr gamma rays.

Nazirov and Zalilov (1965) reported 20 per cent more yield in mutants obtained from seeds treated with radio active phosphorus. Arutjunova and Musaev (1968) reported variation in seed cotton yield in mutants obtained by pollen irradiation with 500 R. Cornelius *et al.* (1970) obtained high yielding mutant by X-ray. Mehetre and Thombre (1983) reported a glandless better yielding mutant induced by X-ray. El-Gohary *et al.* (1981) obtained a high yielding glandless mutant in Giza 45 by EMS treatment.

2.8.2 Boll weight

Gamma ray induced mutants with increased boll weight were reported by Ibragimov *et al.* (1964, 1967), Atazanov (1965), Bhute (1966), Ibragimov and Tjaminov (1969), Nazir and Iqbal Khan (1973) and Arain *et al.* (1998). Nazirov and Zalilov (1965, 1966) reported increased boll weight after radioactive phosphorus treatment. Nazirov (1970) and Bhat *et al.* (1987) reported big bolls through irradiation. Sheriff (1974) obtained long boll through spontaneous mutation.

2.8.3 Ginning out-turn

Mutant with superior GOT were obtained through gamma radiation by Ibragimov et al (1964, 1965), Premsekar *et al.* (1987), Arain *et al.* (1998). Cornelius *et al.* (1970), Kanniyan *et al.* (1971) reported higher GOT through X-ray irradiation. Ramaiah and Bholanath (1946) and Bhat *et al.* (1987) reported higher GOT through mutation. Ozbek *et al.* (1992) and Siddiqui and Malik (1998) obtained higher variation in GOT through gamma irradiation. But Abo-Hegazi *et al.* (1996) reported no change in GOT at different doses of gamma irradiation. El-Gohary *et al.* (1981) reported superior GOT through EMS treatment.

2.8.4 Fibre length

Ramaiah and Bholanath (1946) reported improved fibre length through induced mutation. Ibragimov *et al.* (1964, 1965) and Arain *et al.* (1998) obtained improved fibre length through gamma irradiation. Ozbek *et al.* (1992) reported fibre length variation in different doses of gamma radiation in M_2, M_3 and M_4 generations.

Fursov and Konoplja (1966) reported mutants with higher fibre length in Egyptian cotton. Kanniyan *et al.* (1971) recovered mutants with higher halo length through X-ray irradiation. Siddiqui (1971) and Paiziev and Egamberdiev (1971) reported wide variability for fibre length in mutant population obtained through irradiation. Egamberdiev and Paiziev (1977) reported variability in M_2 and M_3 generation due to injection of 0.05 per cent ethyleneimine. Siddiqui and Malik (1998) reported higher variation for fibre length in mutant population.

2.8.5 Lint index

Kanniyan *et al.* (1971) reported that M_2 mutants derived from X-ray irradiation had higher lint index. El-Gohary *et al.* (1981) obtained a mutant in Giza 45 with EMS having superior lint index tha Giza. Ozbek *et al.* (1992) reported similar values of lint index in different doses of gamma rays in M_2, M_3 and M_5.

2.8.6 Seed index

Ozbek *et al.* (1992) reported on par values of seed index at different doses of gamma rays in M_2, M_3 and M_4 generation.

2.9 Electrophorotic studies

Cherry *et al.* (1972) observed isozyme variation for three enzymes viz., esterases (EST), leucine amino peptidases and catalases in twenty nine species within *Gossypium* genus. Rodimtseva *et al.* (1978) reported alcohol dehydrogenase (ADH), glutamate dehydrogenase (GDH) and peroxidase isozymes in two *hirsutum* hybrid seeds of cotton. Hancock (1982) observed ADH isozyme variation in one tetraploids (*G. hirsutum*) and three diploid (*G. raimondi, G. herbaceum* and *G. arboreum*) species.

Zainutdinova *et al.* (1982) studied ADH and malate dehydrogenase (MDH) isozymes in seedlings of three cotton species viz., *G. hirsutum, G. barbadense* and *G. herbaceum*. Pavlovskaya (1986) reported PAGEbanding patterns of ADH obtained from seeds and seedlings. Sun and Liang (1986) made esterase isozyme analysis of 15 species and 23 cultivars of *Gossypium*. Xi and Zhou (1988) used peroxidase isozyme study to know the origin of allotetraploid species of genus *Gossypium*. Tyagi *et al.* (1987) utilized α-amlyase, catalase, esterase and peroxidase banding for studying parental varieties, their intermated progenies and F_3 populations. Gulin *et al.* (1991) reported different degrees of heterozygosity for non specific esterase and glutamate oxalo acetate transaminase.

Nerkar and Rao (1993) reported usefulness of EST and MDH zymograms in discriminating the cultivars. Narajji (1995) analysed selected genotypes belonging to all four cultivated species of cotton and two interspecific hybrids DCH32, DHB 105 with their respective parents for seed and leaf peroxidase, seed ADH, GDH and EST.

Material and Methods

III. MATERIAL AND METHODS

The present investigations were conducted at Agricultural Research Station, Dharwad Farm during *Kharif* 1995-97. The Agricultural Research Station, Dharwad Farm is located at a latitude of 15-27'North, longitude of 76-6'east and at an attitude of 678 meters above mean seal level with an average rainfall of 766 mm, which is distributed from May to November.

To fulfill the objectives of the research programme four different field experiments were conducted. The details of each experiments are given in the following pages.

3.1 Evaluation of Dharwad colour cotton genotypes

3.1.1 Experimental Material

The experimental material for this study was derived from the seventy seven individual plant selected (IPs) evaluated during 1995-96 season at ARS, Dharwad. The experimental genotypes were derived from the bulk of the plants similar in yield, lint colour, morphological characters, fibre length, ginning out-turn, seed index and lint index. In all, twenty two genotypes comprised of eighteen brown *hirsutum* types with varying colour shades, two each of brown *arboreum* and green *hirsutum* were evaluated. The genotypes evaluated are given below.

1. Brown *hirsutum* : DCCV-1, DCCV-2, DCCV-3, DCCV-4, DCCV-5, DCCV-6, DCCV-7, DCCV-8, DCCV-9, DCCV-10, DCCV-11, DCCV-12, DCCV-13, DCCV-14, DCCV-15, DCCV-16, DCCV-17, DCCV-18.
2. Brown *arboreum* : DCCV-19, DCCV-20.
3. Green *hirsutum* : DCCV-21, DCCV-22.

The characteristics of above 22 Dharwad colour cotton genotypes are given in Table 1.

3.1.2 Experimental layout

All 22 genotypes were grown under rainfed condition in a completely randomised block design with three replications with a spacing of 90 cm x 20 cm. The seeds were sown on 22nd June, 1996 in three rows of 4.5 meter length. All recommended agronomic practices and required plant protection measures were followed.

3.2 Evaluation of Dharwad colour cotton hybrids

3.2.1 Experimental material

The experimental hybrids were obtained from the crossing programme undertaken during 1995-96 season. Eighteen entries comprised of ten hybrids, their parents and two white linted checks viz., DHH-11 and NHH-44 were evaluated. These hybrids were developed by crossing different colour linted parents with white linted genotypes. Among these hybrids eight were intra *hirsutum* hybrids and two intra *arboreum* hybrids. The details of hybrids, parents and checks are as below. The characteristics of hybrids and parents are presented in Table 2.

Hybrids	Parents
1. DCCH-1	DBH-95 x DS-28
2. DCCH-2	DS-28 x DBH-95
3. DCCH-3	DBH-95 x Abadhita
4. DCCH-4	Abadhita x DBH-95
5. DCCH-5	DS-28 x DGH-95
6. DCCH-6	DGH-95 x DS-28
7. DCCH-7	DGH-95 x Abadhita
8. DCCH-8	Abadhita x DGH-95
9. DCCH-9	DBA-95 x A-82-1-1
10. DCCH-10	A-82-1-1 x DBA-95

Table 1. Characteristics of the Dharwad colour cotton genotypes

Sl. No.	Genotypes	Plant height (cm)	No.of Sympo-dia	Boll weight (g)	Seed Index (g)	Lint Index (g)	Ginning Outturn (%)	Seed Cotton Yield (kg/ha)	2.5% Span Length (mm)	Fibre Fineness (Micro-naire)	Fibre Strength 3.2 mm gauage g/tex	Fibre Quality Index (FQI)
1.	DCCV-1	113.00	19.60	4.13	10.00	3.39	34.61	932.66	20.7	3.9	14.2	149
2	DCCV-2	92.00	17.80	3.93	10.00	4.94	33.03	650.39	20.4	4.4	16.5	161
3.	DCCV-3	116.80	18.80	3.10	8.33	3.12	26.89	643.38	18.5	3.7	12.2	117
4.	DCCV-4	107.53	20.00	2.76	8.00	5.32	39.86	1133.00	18.8	5.6	14.8	118
5.	DCCV-5	124.20	20.27	5.13	11.33	5.41	32.32	395.34	24.8	3.8	14.9	190
6.	DCCV-6	108.60	17.53	4.53	10.00	5.09	33.56	487.09	26.0	4.3	15.8	198
7.	DCCV-7	118.93	18.33	4.37	10.67	5.59	34.33	496.91	24.9	4.0	15.6	194
8.	DCCV-8	96.13	15.33	3.70	8.67	5.16	36.61	451.40	25.1	4.1	15.8	196
9.	DCCV-9	111.33	16.27	4.40	10.00	4.87	41.75	878.79	23.7	3.8	16.9	206
10.	DCCV-10	106.87	18.80	3.87	10.00	6.55	39.59	1136.38	26.4	3.9	16.2	217
11.	DCCV-11	120.40	19.87	4.50	9.67	6.67	40.60	1338.94	24.8	3.8	15.6	199
12.	DCCV-12	116.73	19.33	3.87	9.67	5.27	35.36	972.50	24.1	3.2	13.1	177
13.	DCCV-13	107.47	17.93	4.27	10.33	6.02	36.65	855.35	22.7	4.8	15.2	158
14.	DCCV-14	82.20	16.67	3.83	10.00	5.42	34.63	512.06	21.7	4.8	13.1	130
15.	DCCV-15	82.20	16.87	3.23	9.00	4.67	34.05	613.64	19.6	5.4	11.9	100
16.	DCCV-16	108.87	16.20	4.23	10.00	4.97	33.10	1222.50	22.1	3.9	11.8	132
17.	DCCV-17	112.53	20.87	3.37	8.00	4.83	37.60	1430.80	19.8	5.3	13.6	117
18.	DCCV-18	101.53	19.27	2.90	8.00	4.03	37.64	1202.80	18.5	5.4	13.4	107
19.	DCCV-19	144.40	23.80	2.37	7.00	5.43	43.60	1310.61	23.3	6.5	14.8	135
20.	DCCV-20	127.47	23.80	2.33	7.00	3.67	34.37	1240.18	24.0	6.5	13.8	130
21.	DCCV-21	115.20	16.73	4.17	10.00	3.64	20.93	450.33	22.2	2.6	14.2	196
22.	DCCV-22	118.20	16.40	4.23	9.67	3.57	27.78	479.80	24.2	2.9	15.0	213

Parents

11. DBH-95	Brown *G. hirsutum*
12. DGH-95	Green *G. hirsutum*
13. DS-28	White *G. hirsutum*
14. Abadhita	White *G. hirsutum*
15. DBA-95	Brown *G. arboreum*
16. A-82-1-1	White *G. arboreum*

Checks

17. DHH-11	Intra *hirsutum* hybrid
18. NHH-44	Intra *hirsutum* hybrid

3.2.2 Layout of experiments

The hybrids, parents and checks were raised under rainfed condition in a completely randomised block design with three replications and with 90 cm x 40 cm spacing. The sowing was undertaken on 10th July, 1996 in three rows of 4.5 mt length. The crop was raised by following all recommended package of practices and plant protection measures.

3. 3 Generation Mean Analysis

3.3.1 Experiment material

The experiment material include six generations viz., P_1, P_2, F_1, F_2, B_1 and B_2 of five crosses between colour linted and white linted parents. The material was generated in 1995-96 by effecting cross between parents, back cross, and selfing F_1. The details of the crosses are as follows.

1. DS-28 x DGH-95
2. DS-28 x DBH-95
3. Abadhita x DGH-95
4. DBH-95 x DGH-95
5. DBA-95 x A-82-1-1

3.3.2 Experimental layout

The experiment was laid in randomised block design with two replication. Seeds of non-segregating generations viz., P_1, P_2 and F_1 were sown in single row each. Seeds of segregating generations viz., F_2 in ten, B_1 and B_2 in two rows per replication were sown respectively. The sowing was undertaken on 9th July, 1996 with a spacing of 90 cm x 20 cm and row length of 4.5 m.

3.4 Mutation studies

In order to creat variability for yield, fibre and colour, mutation studies were undertaken. The two major genotypes brown *hirsutum* and brown *arboreum* were treated with different mutagens like Ethyl Methyl Sulphonate (chemical mutagen) and gamma rays (physical mutagen) to obtain M_1. The M_1 plants were harvested individually and advance to further generations. The treatments are as follows;

1. EMS treatment : 0.2 per cent, 0.3 per cent and 0.4 per cent
2. Gamma rays : 20 kr

The number of M_2 lines evaluated during 1995-96 in each treatment in both genotypes are as follows;

EMS Treatment (%)	No.of M_2 lines evaluated		No.of M_2 plants advanced to M_3 generation	
	Brown *hirsutum*	Brown *arboreum*	Brown *hirsutum*	Brown *Arboreum*
0.2	23	27	31	77
0.3	24	26	71	69
0.4	13	20	38	29
Irradiated (20 kr)	-	34	-	66

Individual plants of each M_2 line were evaluated for yield, fibre length and visually for fibre colour and strength. Superior individual plants were advanced to next generation viz., M_3 and were evaluated as M_3 families during 1996-97. The characters studied in these M_3 families were seed cotton yield, ginning out-turn, seed index, lint index and fibre length.

Statistical analysis performed include mean, range, variance and standard deviation.

3.5 Observations

3.5.1 Observations in Dharwad colour genotypes and hybrids

In 3.1 and 3.2, five plants in each genotype were selected and observations were recorded in each replication. The average of these five plants was used for statistical analysis. In case of yield, plot yield was considered.

3.5.1.1 Plant height

It was measured at maturity from the base of plant just above ground to the tip of the plant in cm.

3.5.1.2 Number of monopodia

The number of vegetative branches per plant were counted at final stage of the crop.

3.5.1.3 Number of sympodia

The total number of fruiting branches per plant were counted and noted.

3.5.1.4 Days to first boll burst

Number of days required from sowing to first boll burst was observed and noted.

Table 2. Characteristics of Dharwad colour cotton hybrids and their parents

Hybrids	Plant height (cm)	No.of bolls	Boll weight (g)	Seed Index (g)	Lint Index (g)	Ginning Outturn (%)	Seed Cotton Yield kg/ha	2.5% Span length (mm)	Fibre Fineness (Micro-naire)	Fibre Strength 3.2 mm guage g/tex	Fibre Quality Index (FQI)
DCCH-1	134.93	12.00	5.13	10.00	6.57	39.83	1741	26.7	3.8	18.1	248
DCCH-2	127.93	12.47	5.10	10.00	6.32	37.96	1446	29.2	3.5	17.6	275
DCCH-3	129.27	15.90	4.77	10.00	6.10	37.65	1950	25.2	3.9	19.0	243
DCCH-4	130.53	14.03	5.33	10.67	6.24	39.20	1574	25.2	3.7	19.1	250
DCCH-5	128.53	9.70	5.20	10.33	5.95	36.51	1040	27.1	3.8	19.0	264
DCCH-6	137.53	10.30	5.13	9.67	6.35	38.39	1403	28.4	3.9	18.8	271
DCCH-7	121.93	12.27	4.30	10.33	6.14	37.29	1371	24.1	3.7	18.9	237
DCCH-8	137.13	13.73	4.57	11.33	6.31	35.72	1257	25.9	4.1	19.8	253
DCCH-9	189.60	19.90	2.43	7.33	4.54	39.83	1578	22.4	7.0	16.3	137
DCCH-10	161.27	22.00	2.17	7.00	5.14	41.56	1295	22.1	7.1	15.2	126
DBH-95	115.87	11.83	4.40	10.00	4.73	42.21	907	23.0	4.5	16.8	182
DGH-95	115.20	5.63	3.10	10.33	3.10	23.01	300	23.0	3.8	15.8	186
DS 28	121.93	10.07	5.93	10.33	8.62	45.46	1144	28.2	4.1	15.7	219
Abadhita	134.33	14.33	4.23	9.33	6.70	41.58	1677	27.1	4.2	17.8	235
DBA-95	165.20	18.67	2.33	7.00	4.40	38.61	862	23.5	6.4	14.3	133
A-82-1-1	149.93	19.13	2.23	7.33	4.96	40.32	1021	19.5	7.4	16.4	118

3.5.1.5 Number of bolls

The total number of good open bolls per plant were counted and averaged over five plants.

3.5.1.6 Boll weight

Weight per boll was derived from twenty boll weight.

3.5.1.7 Seed Index

The weight of 100 seeds was taken as seed index.

3.5.1.8 Lint index

Lint index was computed by using the following formula (Santhanam, 1976).

$$\text{Lint Index} = \frac{\text{Lint weight}}{\text{Seed weight}} \times \text{seed Index}$$

Lint and seed weight were obtained after ginning from known quantity of seed cotton.

3.5.1.9 Ginning out-turn (GOT)

A known sample of seed cotton was taken from total yield and ginned with a laboratory gin. The ginning out-turn was computed as per the following formula (Santhanam, 1976).

$$\text{GOT} = \frac{\text{Weight of lint (g)}}{\text{Total weight of seed cotton (g)}} \times 100$$

3.5.1.10 Seed cotton yield

Seed cotton yield per hectare was computed by multiplying yield per plot with hectare factor.

3.5.1.11 Lint yield

Lint yield was computed by multiplying seed cotton yield with GOT.

Fibre quality characters

The fibre quality is determined by parameters like fibre length, fineness, maturity, uniformity and strength. The procedure for their estimation are presented below. The fibre quality analysis was carried out by CIRCOT unit ARS, Dharwad as per CIRCOT standards. The fibre colour was categorised visually in both DCCV and DCCH.

3.5.1.12 2.5 per cent span length

The distance spanned by a specific percentage of the fibres in the test beard is called span length. 2.5 per cent span length is the distance from the clamp on a fibre beard to a point upto which only 2.5 per cent of the fibre extend. The length was measured on digital fibrograph. The classification based on span length is;

Category	2.5% span length in mm
Short B	20.0 or less
Short A	20.5-24.5
Medium	25.0-29.0
Long	29.5-32.5
Extra long	33.0 and above

3.5.1.13 Uniformity ratio

The ratio of 50 per cent span length to the 2.5 per cent span length expressed as percentage and termed as uniformity ratio. The classification based on their parameters is as follows.

Category	Range
Poor	Below 42
Fair	42 to 43
Average	44 to 45
Good	46 to 47
Excellent	Above 47

3.5.1.14 Maturity coefficient

Fibre maturity is the index of the extent of wall thickness of the fibre. The maturity coefficient can be derived using the micronnaire instrument. Two compressions are done on the same plug using a 3/8" spacer. From the difference of two compression with spacer (WS) and no spacer (NS) maturity coefficient can be calculated.

MC = Difference (WS-NS) x 0.1753 + 0.3934

The classification of fibre maturity is as below;

Category	Range (%)
Very immature	Below 30
Immature	30 to 50
Average immature	51 to 67
Good immature	68 to 84
Very high immature	Above 84

3.5.1.15 Fibre strength

Bundle strength was measured by the stelometer. In this method the specimen was held between two clamp 3.2 mm apart. These were loaded in the slots on the top of the stelometer and the beam was released. The movement of the beam applied tension to the

bundle by pulling apart the two parts of the clamps. The uniform rate of loading used was 1 kg per sec. As soon as the bundle breaks the pointer stops, indicating the breaking load on the scale. The broken fibres were collected from the clamps and weighed accurately in milligrams. The bundle tenacity was obtained by dividing breaking load by weight of the sample and was expressed in gm per tex. The classification based on strength is given below;

Category	Range 3.2 mm guage
Very low	Below 17
Low	17.0 to 19.5
Average	19.6 to 25.0
Good	25.1 to 29.0
Very good	Above 29.0

3.5.1.16 Fineness

The fineness was determined by the average fibre weight per unit length of the fibre. The micronaire instrument gives the measurement of resistance to the flow of air passed at 40 atmosphere pressure through a plug of 3.24 gm in weight. The micronaire value is the fibre weight per unit length in micrograms per inch. The categories based on micronaire value are;

Category	Range of micronaire value 10^{-6} g/inch
Very fine	Below 3.0
Fine	3.0 to 3.9
Average	4.0 to 4.9
Coarse	5.0 to 5.9
Very coarse	Above 6.0

3.5.1.17 Fibre quality index (FQI)

Fibre quality index is usually evolved on the basis of minimum number of important fibre properties which are known to have their effect on yarn strength. Here following formula given by CIRCOT was used to compute FQI.

$$FQI = (LS)/\sqrt{F}$$

Where,

L = 2.5 per cent span length in mm

S = Fibre bundle tenacity (g/tex)

F = Micronaire value

3.5.1.18 Count

Count is the number of hanks of 1000m each which together weigh one kg. For instance 20 counts of yarn would indicate that one kilograme of yarn would contain 20 hanks of 1000m each. The Counts were computated by the following formula given by CIRCOT

$$Counts = 0.196(FQI)-16.26$$

3.5.1.19 Count strength product (CSP)

The yarn quality was assessed in terms of count-strength product, which is the product of the count of yarn and breaking strength in pounds of one lea (120 yards) of the yarn. The optimum spinning performance was expressed as the highest standard count, which is the maximum count of yarn that can be spun from the given sample of cotton which will have CSP in accordance with the standard adopted. As spinning of all samples was not possible following formula given by CIRCOT was used to compute CSP.

CSP = 1.74 (FQI) + 1617

Standard CSP values are given below;

Count	CSP
20's	1870
30's	1955
40's	2040
50's	2125
60's	2210
70's	2295
80's	2380
90's	2465
100's	2550
110's	2635
120's	2720

3.5.2 Observations recorded in Generation mean analysis

In this experiment observations were recorded on individual plants for following plant characters.

3.5.2.1 Plant height

3.5.2.2 Number of monopodia

3.5.2.3 Number of sympodia

3.5.2.4 Days to first boll burst

3.5.2.5 Number of bolls

3.5.2.6 Yield per plant (g)

3.5.2.7 Boll weight (g)

3.5.2.8 Halo length

From each plant three halos were prepared by combing and halo length was measured by halo disc standardised by CIRCOT Mumbai

3.6 Fibre Colour development studies

To know the accurate picture of colour development in fibre, this experiment was undertaken during 1995-96. Flowers were tagged on the day of opening in three genotype viz., BH, GH and BA. Tagged bolls from all three genotypes were cut opened at 30 days after pollination (DAP). This experiment was continued for knowing the exact day of colour development during *Kharif* 1996-97. A large number of flowers were tagged on continuous days for a period of 20 days. The bolls were opened from 29 DAP till the colour was seen clearly in the fibre.

3.7 Electrophoretic studies

The characterization of colour cotton genotypes along with white was undertaken.

3.7.1 Genotypes

Seven *G. hirsutum* colour genotypes, one *G. arboreum* colour genotype and one white linted in each species were used for the study. The genotypes are ;

1. DDBH (Deep dark brown *hirsutum*)
2. MBH (Medium brown *hirsutum*)

3. BH (Brown *hirsutum*)
4. LBH (Light brown *hirsutum*)
5. Cream (Cream *hirsutum*)
6. Sahana (White *hirsutum*)
7. GH-1 (Green *hirsutum*)
8. GH-2 (Green *hirsutum*)
9. BA (Brown *arboreum*)
10. A-82-1-1 (White *arboreum*)

3.7.2 Reagents/stock solutions

The following stock solutions were prepared for electrophorosis analysis (Wendel and Weeden, 1991).

1) Monomer solutions

Acrlymide	30.00 g
Bisacrylamide	0.80 g
H_2O	100.00 ml

2) Polymerisation catalyst

a) Ammonium persulphate – 0.14% (It was prepared freshly on the day of use).

b) TEMED

3) Stacking gel buffer (0.5 m Tris – Hcl pH 6.8)

Tris	- 6.0 g
Adjusted to pH 6.8	- 48 ml
with 1N Hcl	
H_2O	- 100 ml

Resolving gel buffer (3 M Tris – Hcl pH 8.8)

Tris	- 36.6 g
Adjusted to pH 8.8	- 48 ml
with 1N Hcl	
H_2O	- 100 ml

Tank buffer (0.05 M Tris, 0.0384 M Glycine, pH 8.3)

Tris	- 6.0 g
Gylcine	- 2.80 g
H_2O	- 1000 ml

Extraction buffer

a) Tris – HCL (pH 6.8)

Tris	- 1.21 g
Sucrose	- 17.00 g
Cysteine	- 0.10 g
Ascorbic acid	- 0.10 g

Adjusted to pH 6.8 with 1N Hcl

Staining solution

1) Coomassie Brilliant blue R250		- 100.00 mg
	Methanol	- 50.00 ml
	Acetic acid	- 10.00 ml
	Water	- 40.00 ml

1) Destaining solution I

Acetic acid	- 7.00 ml
Methanol	- 40.00 ml
H_2O	- 53.0 ml

Destaining solution II

Acetic acid	- 7.0 ml
Methanol	- 5.0 ml
H_2O	- 88.0 ml

Isozymes

1) Peroxidase

Na – Acetate buffer (0.2m, pH 5.6)	- 100 ml
Benzidine	- 100 ml
H_2O_2	- 0.10 ml

Benzidine and buffer mixture was boiled and cooled down to room temperature. The solution was filtered and H_2O_2 was added to it just before incubation. The fixation was in seven per cent acetic acid after development of bands.

3.7.3 Extraction of seed protein

Bold and well filled seeds were selected, decorticated and powdered. The seed powder was defatted using acetone. The extraction was carried out by using 1 ml of extraction buffer and defatted seed powder. This was kept in a refrigerator overnight. The contents were then centrifuged at 15000 rpm for 20 minutes. The supernatent was used for electrophoresis.

3.7.4 Extraction of leaf enzymes

Ten day old cotylendonary leaves from pot sown plants were used for extraction of enzymes. The leaves were macerated in a prechilled mortor pestle. Other steps were same as that of seed protein.

3.7.5 Gel preparation and run

The recipe for gel preparation is tabulated below per Davis (1964).

Recipe for gel preparation (for glass plate of 18 cm x 16 cm size) is as follows

Stock solution	Stacking gel (ml)	Resolving gel (ml)
Monomer solution	0.875	5.0
Stacking gel buffer	0.5	--
Resolving gel buffer	--	4.0
Distilled water	3.75	11.0
Ammonium per sulphate (Aps)	0.05	0.1
TEMED	0.005	0.50

The preparation, casting, loading of extract running, staining and destaining of gel was carried out as per Narajji (1995) and Narajji *et al.* (1998).

3.7.6 Zymogram preparation

After the development of protein or isozyme bands on the gel, the reaction was stopped with 7 per cent acetic acid. The relative migration (Rm) of each band was calculated as follows;

$$Rm = \frac{\text{Distance migrated by protein or isozyme band from the origin (cm)}}{\text{Distance migrated by the tracking dye (C)}}$$

The bands were categorized as dense, medium, light and very light depending on the intensity of the bands.

3.8 Studies on extraction and nature of fibre colour in naturally coloured cottons

Preliminary studies to extract colour from colour cotton lint were planned with following solvents.

1. Form aldehyde, 2. Glycerol, 3. Dichloromethane, 4. Methanol,
5. Propanol 6. Hexane, 7. Dimethyl ether, 8. NaOH.

Two gram of three colour linted genotypes viz., dark brown *hirsutum*, brown *arboreum* and green *hirsutum* were treated with above solvents at different concentrations and time duration. The different concentrations of NaOH i.e,. 5, 10, 15 and 20 per cent were tried for varying time duration like 2, 4, 6 and 24 hours. The three colour genotypes were treated with 20 per cent NaOH overnight and the extracts were read at different wavelength by taking NaOH as blank.

3.9 Statistical analysis

Statistical analysis of the data was carried out as presented below.

3.9.1 Analysis of variance

Analysis of variance as outlined by Cochram and Cox (1959) was computed by using mean values of the genotypes for different characters. The ANOVA is as follows.

Source	DF	Sum of squares	Mean sum of squares	Expected sum of squares
Replication	(r-1)	Rss	Mssr	
Genotype	(v-1)	Vss	Mssv	$\sigma^2e + r\sigma^2g$
Error	(r-1)(v-1)	Ess	Msse	σ^2e
Total	(rv-1)	Tss		

Where,

r = Number of replication

v = Number of genotypes

Mssr = Mean sum squares due to replication

Mssv = Mean sum squares due to genotypes

Msse = Mean sum squares due to error

$\sigma^2 e$ = Error variance

$\sigma^2 g$ = Genotypic variance

Significance was tested by comparing calculated F values to table F at 1 per cent and 5 per cent level of significance.

3.9.2 Components of variance

The component of variances computed were genotypic, phenotypic and environmental levels.

a) Environmental variance

$$\sigma^2 e = Msse$$

b) Genotypic variance

$$\sigma^2 g = \frac{Mssv - Msse}{r}$$

c) Phenotypic variance

$$\sigma^2 p = \sigma^2 g + \sigma^2 e$$

3.9.3 Coefficient of variation

Genotypic and phenotypic coefficient of variations were computed according to Burton and De Vane (1953).

3.9.3.1 Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sigma^2 p}{\bar{X}} \times 100$$

3.9.3.2 Genotypic Coefficient of variation (GCV)

$$GCV = \frac{\sigma^2 g}{\bar{X}} \times 100$$

Where,

$\sigma^2 p$ = Phenotypic variance

$\sigma^2 g$ = Genotypic variance

$\bar{X}$ = Grand mean of the characters

PCV and GCV were classified as below;

0-10%	: Low
10-20%	: Moderate
20% and above	: High

3.9.4 Heritability

Broad sense heritability was estimated as the ratio of genotypic variance to the phenotypic variance and expressed in percentage.

$$\text{Heritability } (h^2) = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

The heritability percentage was categorised as per Robinson *et al.* (1949) and group are;

0-30%	: Low
30-60%	: Moderate
>60%	: High

3.9.5 Genetic advance (GA)

Genetic advance (GA) was computed by formula given by Johanson *et al.* (1955).

$$GA = ih^2 \sigma p$$

Where,

i = Selection intensity (2.06) at 5%

h^2 = Broad sense heritability

σp = Phenotypic standard deviation

Genetic advance in percentage over mean (GAM) was also computed by using the following formula,

$$GAM = \frac{GA}{\bar{X}} \times 100$$

3.9.6 Correlation studies

Different correlation coefficients viz., genotypic (rg), phenotyic (rp) and environmental (re) were estimated as per Al Jabouri *et al.* (1958).

$$\text{Environmental correlation} = r_{xy}(e) = \frac{\text{Cov } e_{(xy)}}{\sigma^2(e_x) \times \sigma^2(e_y)}$$

$$\text{Genotypic correlation} = r_{xy}(g) = \frac{\text{Cov } g_{(xy)}}{\sigma^2(g_x) \times \sigma^2(g_y)}$$

$$\text{Phenotypic correlation} = r_{xy}(p) = \frac{\text{Cov } p_{(xy)}}{\sigma^2(p_x) \times \sigma^2(p_y)}$$

Where,

Cov $e_{(xy)}$ = Environmental covariance between X and Y
Cov $g_{(xy)}$ = Genotypic covariance between X and Y
Cov $p_{(xy)}$ = Phenotypic covariance between X and Y
σ^2 (ex) = Environmental variance of character X
σ^2 (gx) = Genotypic variance of character X
σ^2 (px) = Phenotypic variance of character X
σ^2 (ex) = Environmental variance of character Y
σ^2 (gx) = Genotypic variance of character Y
σ^2 (px) = Phenotypic variance of character Y

3.9.7 Path coefficient analysis

The path analysis was performed as per Wright (1921), Dewey and Lu (1959). This analysis gives cause and effect interrelationship between two variables.

The path coefficients were obtained by solving the simultaneous equations which expresses the basic relationship between path coefficient and correlation coefficients, the general formula may be written as;

Rij = Pj1r1i + Pj2r2i + ... + Pjnrni

Where, "e" is a cause in the chain of causation leading to 'j" effects and i=1,2,...n correlated causes. Pji are the path coefficient or standardised partial regression coefficients and are given by;

$$Pji = \frac{bi\sigma ii}{\sigma jj}$$

Where,

bi = is the regression coefficient

σii = is the standard deviation of "i" cause

σjj = is the standard deviation of "j" effect

The unexplained residual variation not accounted by all other variables can be determined by the following formula.

$$Pxj = (1-R^2)^{1\,2}$$

$$R2 = \sum P_2ji + 2\sum Pij + pjk + rij$$

3.9.8 Heterosis

Heterosis was calculated as per the per cent increase or decrease of F_1 over better parent (BP), mid parent (MP) and standard check (SC) by using methods suggested by Turner (1953) and Hayes *et al.* (1955).

$$\text{Per cent heterosis over better parent} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Per cent heterosis over mid parent} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Per cent heterosis over standard check} = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

$$\text{Per cent heterosis over colour linted parent} = \frac{\overline{F_1} - \overline{CP}}{\overline{CP}} \times 100$$

$$\text{Per cent heterosis over white linted parent} = \frac{\overline{F_1} - \overline{WP}}{\overline{WP}} \times 100$$

Where,

$\overline{F_1}$ = Mean of F_1

$\overline{BP}$ = Mean of better parent

$\overline{MP}$ = Mean of mid parent

$\overline{SC}$ = Mean of standard check (DHH-11 and NHH-44)

$\overline{WP}$ = Mean of white linted parent

$\overline{CP}$ = Mean of colour linted parent

Testing significance of heterosis

The standard error for testing significance of heterosis are as below;

a) For mid parent

$$SE = (3/2\ EMS/r)^{1/2}$$

Where, r – Replication

b) For all other parents and checks CD at 1 and 5 per cent for the respective character was used.

3.9.9 Estimation of gene effects

To obtain information on the nature of gene action governing the traits under study all the six components of generation means were computed by following procedures given by Hayman (1958). Generation means, variances and standard errors were computed by using observations taken on individual plant and same was used to estimate gene effects. The notations used were as per Hayman (1958) are as follows.

Gene effects	Notations of Hayman (1958)
Mean	[m]
Additive	[d]
Dominance	[h]
Additive x Additive	[i]
Additive x Dominance	[j]
Dominance x Dominance	[l]

The expectations of generation mean in terms of gene effects are as follows;

$P_1 = m + [d] + [i]$

$P_2 = m - [d] + [i]$

$F_1 = m + [h] + [l]$

$F_2 = m + \frac{1}{2}[h] + \frac{1}{4}[l]$

$B_1 = m + \frac{1}{2}[d] + \frac{1}{2}[h] + \frac{1}{4}[i] + \frac{1}{4}[j] + \frac{1}{4}[l]$

$B_2 = m + \frac{1}{2}[d] + \frac{1}{2}[h] + \frac{1}{4}[i] - \frac{1}{4}[j] + \frac{1}{4}[l]$

Means of six generations viz., $\bar{P}_1$, $\bar{P}_2$, $\bar{F}_1$, $\bar{F}_2$, $\bar{B}_1$ and $\bar{B}_2$ were used to estimate six parameters as follows;

$[m] = \bar{F}_2$

$[d] = \bar{B}_1 - \bar{B}_2$

$[h] = \bar{F}_1 - 4\bar{F}_2 - \frac{1}{2}\bar{P}_1 - \frac{1}{2}\bar{P}_2 + 2\bar{B}_1 + 2\bar{B}_2$

$[i] = 2\bar{B}_1 + 2\bar{B}_2 - 4\bar{F}_2$

$[j] = \bar{B}_1 - \frac{1}{2}\bar{P}_1 - \bar{B}_2 + \frac{1}{2}\bar{P}_2$

$[l] = \bar{P}_1 + \bar{P}_2 + 2\bar{F}_1 + 4\bar{F}_2 - 4\bar{B}_1 - 4\bar{B}_2$

The variances were estimated as below;

$Vm = V(\bar{F}_2)$

$Vd = V(\bar{B}_1) + V(\bar{B}_2)$

$Vh = V\bar{F}_1 + 16V\bar{F}_2 + \frac{1}{4}V\bar{P}_1 + \frac{1}{4}V\bar{P}_2 + 4V\bar{B}_1 + 4V\bar{B}_2$

$Vi = 4V\bar{B}_1 + 4V\bar{B}_2 + 16V\bar{F}_2$

$Vj = V\bar{B}_1 + \frac{1}{4}V\bar{P}_1 + V\bar{B}_2 + \frac{1}{4}V\bar{P}_2$

$Vl = V\bar{P}_1 + V\bar{P}_2 + 4V\bar{F}_1 + 16V\bar{F}_2 + 16V\bar{B}_1 + 16V\bar{B}_2$

Where variance of mean = $V\bar{P}_1$ = variance / n

Similar errors were computed as given below;

$SE(m) = (Vm)^{1/2}$

$SE[d] = (Vd)^{1/2}$

$SE[h] = (Vh)^{1/2}$

$SE[i] = (Vi)^{1/2}$

$SE[j] = (Vj)^{1/2}$

$SE[l] = (Vl)^{1/2}$

The 't' test was used at 1 and 5 per cent level of significance. The formula for 't' test are given below;

$$t(m) = \frac{[m]}{SE(m)}$$

$$t[d] = \frac{[d]}{SE[d]}$$

$$t[h] = \frac{[h]}{SE[l]}$$

$$t[i] = \frac{[i]}{SE\,[i]}$$

$$t[j] = \frac{[j]}{SE\,[j]}$$

$$t[l] = \frac{[l]}{SE\,[l]}$$

The calculated 't' values were compared with table 't' values viz., 1.96 and 2.57 at 5 and 1 per cent level of significance respectively at pooled degrees of freedom i.e., sum of the degrees of freedom of various generations studied.

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of the studies on genetics of naturally colour cotton are presented below under different heads.

1. Analysis of variance
2. *Per se* performance
3. Genetic variability
4. Character association
5. Path analysis
6. Heterosis
7. Gene effects
8. Mutation studies
9. Fibre colour development studies
10. Electrophorotic studies
11. Extraction and nature of fibre colour

4.1 Analysis of variance

The mean sum of squares due to various sources of variation for eleven quantitative characters in twenty two Dharwad colour cotton genotypes and Dharwad colour cotton hybrids are presented in Table 3 and 4 respectively.

The variation observed in Dharwad colour linted cotton genotypes was highly significant for all characters except seed index where the variation was significant at five per

Table 3. Analysis of variance for different quantitative characters in twenty two Dharwad colour cotton genotypes

Source of variation	DF	Plant height	No.of Mono-podia	No.of Sympo-dia	Days to first boll burst	No.of bolls	Boll Weight	Seed Index	Lint Index	Ginning Out-turn	Seed Cotton yield	Lint yield
Replication	2	158.06	0.03	0.33	3.63	2.77	0.15	0.24	1.38*	23.48**	75652.00	15703
Genotypes	21	581.64**	0.62**	15.25**	65.29**	52.98**	1.64**	4.06*	3.05**	71.43**	3419.00*	65565
Error	42	91.20	0.24	3.85	6.19	9.19	0.17	0.21	0.33	6.19	352.90	5163
S.Em±		7.79	0.40	1.60	2.03	2.47	0.34	0.37	0.47	2.03	153.39	58.66
CD at 1%		15.29	0.78	3.14	3.98	4.85	0.66	0.73	0.92	3.98	300.64	158.57
CD at 5%		20.04	1.03	4.12	5.22	6.36	0.87	0.96	1.20	5.22	394.21	118

*,** - Significant at 5% and 1% level

Table 4. Analysis of variance for different quantitative characters in Dharwad colour cotton hybrids and their parents

Source of variation	DF	Plant Height	No.of Mono-podia	No.of Sympo-dia	Days to first boll burst	No.of bolls	Boll weight	Seed index	Lint Index	Ginning Out-turn	Seed Cotton Yield	Lint Yield
Replication	2	532.34**	0.28	20.48**	3.13	0.58	0.34	1.17*	0.25	14.14**	10.98**	9820*
Genotypes	17	1090.72**	5.58**	19.99**	117.40**	1.19**	4.39	5.46**	4.21**	68.31**	46.62**	87404**
Error	34	127.77	0.22	4.99	12.05	6.57	0.22	0.58	0.55	6.27	5.13	7342.7
S.Em±		9.22	0.36	1.83	2.75	2.09	0.38	0.62	0.61	2.04	1.85	69.96
CD at 1%		25.38	1.06	5.02	7.79	8.05	1.04	1.71	1.67	5.62	5.09	191.02
CD at 5%		18.84	0.79	3.73	5.79	5.98	0.77	1.27	1.22	4.17	3.77	142.32

*, ** - Significant at 5% and 1% level

cent. Significant variation due to replication was noticed for only two characters viz., lint index and ginning out-turn.

In case of Dharwad colour cotton hybrids, the analysis of variance indicates highly significant variation among hybrids, their parents and checks for most of the characters except boll weight which showed significant variation only at 5 per cent level of significance. The characters viz., plant height, number of sympodia, ginning out-turn and seed cotton yield per hectare showed highly significant block variation. The seed index also showed significant variation due to replication.

4.2 *Per se* performance of Dharwad colour cotton genotypes

4.2.1 Growth and yield parameters

The plant height varied from 82.0 (DCCV-14) to 144.40 cm (DCCV-19) with an average of 110.71 cm. The number of monopodia did not show much variation. The monopodia number ranged from 1.08 in DCCV-12 to 3.13 in DCCV-20. The mean monopidia number was 1.89. The variation in the number of sympodia was moderate with a range of 15.33 (DCCV-8) to 23.8 (DCCV-19 and DCCV-20), with an average value of 18.66 sympodia per plant. The genotype DCCV-22 required least number of days to first boll burst (122 days) whereas genotpye DCCV-20 needed highest number of days (140 days) for the same. The mean number of days for first boll burst was 133.55 days. It was observed that two diploid genotypes DCCV-19 and DCCV-20 were significantly above average for number of monopodia, sympodia, plant height and days to first boll burst. The two green linted genotypes DCCV-21 and DCCV-22 were below average for number of sympodia, monopodia, and days to first boll burst. The remaining brown *hirsutum* genotypes showed variation for characters like plant height, number of sympodia and monopodia and days to

Table 5. Mean performance of twenty two Dharwad colour cotton genotypes for various growth, and yield components

Sl. No.	Genotypes	Plant height (cm)	No.of Mono-podia	No.of Sympo-dia	Days to first boll burst	No.of bolls	Boll weight (g)	Seed Index (g)	Lint Index (g)	Ginning Outturn (%)	Seed Cotton Yield (kg/ha)	Lint Yield (kg/ha)
1	DCCV-1	113.00	1.90	19.60	130.33	10.00	4.13	10.00	3.39	34.61	932.66	321.66
2	DCCV-2	92.00	2.18	17.80	132.20	15.07	3.93	10.00	4.94	33.03	650.39	215.59
3	DCCV-3	116.80	2.03	18.80	136.33	11.43	3.10	8.33	3.12	26.89	643.38	173.68
4	DCCV-4	107.53	1.69	20.00	138.00	18.57	2.76	8.00	5.32	39.86	1133.00	450.56
5	DCCV-5	124.20	1.13	20.27	138.67	4.98	5.13	11.33	5.41	32.32	395.34	130.76
6	DCCV-6	108.60	2.20	17.53	134.33	4.03	4.53	10.00	5.09	33.56	487.09	169.14
7	DCCV-7	118.93	2.00	18.33	132.67	6.07	4.37	10.67	5.59	34.33	496.91	174.91
8	DCCV-8	96.13	2.20	15.33	132.67	11.72	3.70	8.67	5.16	36.61	451.40	346.82
9	DCCV-9	111.33	2.47	16.27	128.00	7.92	4.40	10.00	4.87	41.75	878.79	279.90
10	DCCV-10	106.87	1.67	18.80	136.00	8.73	3.87	10.00	6.55	39.59	1136.38	451.33
11	DCCV-11	120.40	1.47	19.87	138.00	10.40	4.50	9.67	6.67	40.60	1338.94	544.71
12	DCCV-12	116.73	1.08	19.33	132.33	10.00	3.87	9.67	5.27	35.36	972.50	343.04
13	DCCV-13	107.47	1.50	17.93	132.67	11.03	4.27	10.33	6.02	36.65	855.35	314.26
14	DCCV-14	82.20	1.87	16.67	136.33	9.04	3.83	10.00	5.42	34.63	512.06	177.27
15	DCCV-15	82.20	2.27	16.87	138.67	8.00	3.23	9.00	4.67	34.05	613.64	214.11
16	DCCV-16	108.87	1.60	16.20	137.33	11.13	4.23	10.00	4.97	33.10	1222.50	406.82
17	DCCV-17	112.53	1.67	20.87	134.33	15.73	3.37	8.00	4.83	37.60	1430.80	537.78
18	DCCV-18	101.53	1.33	19.27	131.67	16.07	2.90	8.00	4.03	37.64	1202.80	429.20
19	DCCV-19	144.40	2.22	23.80	137.67	17.73	2.37	7.00	5.43	43.60	1310.61	571.53
20	DCCV-20	127.47	3.13	23.80	140.00	12.07	2.33	7.00	3.67	34.37	1240.18	426.70
21	DCCV-21	115.20	1.60	16.73	123.00	5.27	4.17	10.00	3.64	20.93	450.33	93.88
22	DCCV-22	118.20	1.42	16.40	122.00	4.87	4.23	9.67	3.57	27.78	479.80	130.48
	Range (Min)	82.20	1.08	16.33	122.00	4.03	2.33	7.00	3.57	20.93	395.34	93.88
	(Max)	144.40	3.13	23.80	140.00	18.57	5.13	11.33	6.67	43.60	1430.50	571.55
	Mean	**110.71**	**1.89**	**18.66**	**133.55**	**10.46**	**3.78**	**9.33**	**4.93**	**34.40**	**878.80**	**313.83**
	CD at 1%	15.29	0.78	3.14	3.98	4.85	0.66	0.73	0.92	3.98	300.64	158.47
	CD at 5%	20.04	1.03	4.12	5.22	6.36	0.87	0.96	1.20	5.22	394.21	118.57

first boll burst (Table 5). The field view of DCCV-15, DCCV-16 and DCCV-17 is presented in Plate 1.

The variation observed in the yield and related attributes was significant. The yield ranged from 395.34 kg per ha in DCCV-5 to 1430.80 kg per ha in DCCV-17 under rainfed conditions. The mean yield per hectare was 878.86 kg. The lint yield ranged from 93.88 (DCCV-21) to 571.53 kg per ha (DCCV-19) with a mean of 313.83 kg per ha. The genotype DCCV-6 recorded lowest number of bolls (4.03) whereas DCCV-4 had maximum number of good open bolls (18.57). The average number of bolls per plant was 10.46.

The diploid genotypes DCCV-19 and DCCV-20 recorded least boll weight (2.37 and 2.33 g, respectively). The highest boll weight was found in DCCV-5 (5.13 g). The mean boll weight was 3.78 g. The seed index varied from 7.00 g in diploid genotypes DCCV-19 and DCCV-20 to 11.33 g in brown *hirsutum* genotype DCCV-5. The average seed index was 9.33 g. Lint index showed moderate variation with a range of 3.57 (DCCV-22) to 6.67 g (DCCV-11). The mean lint index was 4.93 g. The variation noticed for ginning out-turn was high and ranged from 20.93 in DCCV-21 to 43.6 per cent in DCCV-19. The average ginning out-turn observed was 34.40 per cent. The green genotypes DCCV-21 and DCCV-22 were below average for characters like yield, ginning out-turn, lint index, boll weight and boll number per plant whereas, they were above average for seed index. The diploid genotypes DCCV-19 and DCCV-20 were high yielding with above average performance for parameters like number of bolls, ginning out-turn, but they were below average for boll weight and seed index. The lint index of DCCV-19 was more than average value. Whereas, it was less than average in DCCV-20.



Plate 1. Field view of DCCV-15, DCCV-16 and DCCV-17 (*G. hirsutum*) genotypes

4.2.2 *Fibre properties*

Different fibre properties of all twentytwo colour linted cotton genotypes were evaluated at CIRCOT Unit, Dharwad and are presented below (Table 6). The lint samples of Dharwad colour cotton genotypes are presented in Plate 2 & 3.

4.2.2.1 2.5 per cent span length (mm)

The 2.5 per cent span length of colour linted cotton genotypes under evaluation ranged from 18.5 (DCCV-18) to 26.4 mm (DCCV-10) with an average value of 22.55 mm. The number of genotypes belonging to different categories were as follows.

Category	No.of Genotypes	Genotypes
Short B	5	DCCV-3, DCCV-4, DCCV-15, DCCV-17, DCCV-18.
Short A	11	DCCV-1, DCCV-2, DCCV-9, DCCV-12, DCCV-13, DCCV-14, DCCV-16, DCCV-19, DCCV-20, DCCV-21, DCCV-22.
Medium	6	DCCV-5, DCCV-6, DCCV-7, DCCV-8, DCCV-10, DCCV-11.

4.2.2.2 Uniformity ration

The uniformity ratio ranged from 42 (DCCV-19) to 50 (DCCV-2 and DCCV-6) with an average value of 47.36. The uniformity categories to which different genotypes belong are ;

Table 6. Fibre quality parameters of twenty two Dharwad colour cotton genotypes

Sl. No.	Genotypes	2.5% Span length (mm)	Uniformity ratio (%)	Fibre Fineness (Micronaire)	Maturity Coefficient	Fibre Strength 3.2 mm gauage g/tex	Fibre Quality Index (FQI)	Count (C)	Count Strength Product (CSP)	Fibre Colour
1	DCCV-1	20.7	47	3.9	0.77	14.2	149	13	1876	DDB
2.	DCCV-2	20.4	50	4.4	0.76	16.5	161	15	1897	DDB
3.	DCCV-3	18.5	49	3.7	0.79	12.2	117	7	1821	MB
4.	DCCV-4	18.8	47	5.6	0.81	14.8	118	7	1822	MB
5.	DCCV-5	24.8	49	3.8	0.79	14.9	190	21	1948	LB
6.	DCCV-6	26.0	50	4.3	0.81	15.8	198	23	1962	LB
7.	DCCV-7	24.9	48	4.0	0.80	15.6	194	22	1955	LB
8.	DCCV-8	25.1	47	4.1	0.82	15.8	196	22	1958	MB
9.	DCCV-9	23.7	49	3.8	0.81	16.9	206	24	1975	MB
10.	DCCV-10	26.4	46	3.9	0.80	16.2	217	26	1995	VLB
11.	DCCV-11	24.8	46	3.8	0.80	15.6	199	23	1963	MB
12.	DCCV-12	24.1	46	3.2	0.69	13.1	177	18	1925	MB
13.	DCCV-13	22.7	49	4.8	0.80	15.2	158	15	1892	MB
14.	DCCV-14	21.7	48	4.8	0.80	13.1	130	9	1843	DDB
15.	DCCV-15	19.6	48	5.4	0.85	11.9	100	3	1791	DDB
16.	DCCV-16	22.1	47	3.9	0.81	11.8	132	10	1847	DB
17.	DCCV-17	19.8	46	5.3	0.83	13.6	117	7	1821	DB
18.	DCCV-18	18.5	49	5.4	0.85	13.4	107	5	1803	MB
19.	DCCV-19	23.3	42	6.5	*	14.8	135	10	1852	LB
20.	DCCV-20	24.0	44	6.5	*	13.8	130	9	1843	MB
21.	DCCV-21	22.2	49	2.6	0.61	14.2	196	22	1958	BG
22.	DCCV-22	24.2	46	2.9	0.67	15.0	213	25	1988	BG
	Range (Min)	18.5	42	2.6	0.61	11.8	100	3	1791	
	(Max)	26.4	50	6.5	0.85	16.9	217	26	1995	
	Mean	22.55	47.36	4.39	0.78	14.47	160.9	15.3	1897	
	Variance	6.20	3.86	1.09	0.0036	2.16	1488.8	56.3	4514.9	
	S.D.	2.49	1.97	1.04	0.06	1.47	38.58	7.50	67.2	
	S.Em±	10.53	0.42	0.22	0.013	0.31	8.22	1.6	14.33	
	CD at 1%	1.10	0.87	0.46	0.027	0.64	23.3	4.5	40.55	
	CD at 5%	1.50	1.19	0.62	0.04	0.88	17.1	3.3	29.81	

DDB - Deep dark brown; MB - Medium brown; LB - Light brown; VLB - Very light brown;
BG - Brownish green;

Category	No.of Genotypes	Genotypes
Poor	1	DCCV-19.
Average	1	DCCV-20.
Good	9	DCCV-1, DCCV-4, DCCV-8, DCCV-10, DCCV-11, DCCV-12, DCCV-16, DCCV-17, DCCV-22.
Excellent	11	DCCV-2, DCCV-3, DCCV-5, DCCV-6, DCCV-7, DCCV-9, DCCV-13, DCCV-14, DCCV-15, DCCV-18, DCCV-21.

4.2.2.3 Fibre fineness

The micronaire value ranged from 2.6 in DCCV-21 to 6.5 in diploid genotypes DCCV-19 and DCCV-20. The mean micronaire value 4.39 indicated average fineness. The genotypes were classified as below ;

Category	No.of Genotypes	Genotypes
Very fine	2	DCCV-21 DCCV-22.
Fine	8	DCCV-1, DCCV-3, DCCV-5, DCCV-9, DCCV-10, DCCV-11 DCCV-12, DCCV-16.
Average	6	DCCV-2, DCCV-7, DCCV-8, DCCV-13, DCCV-14, DCCV-6.
Coarse	4	DCCV-4, DCCV-15, DCCV-17, DCCV-18.
Very coarse	2	DCCV-19, DCCV-20, (*G. arboreum*)



Plate 2. Lint of samples of DCCV-1, DCCV-2, DCCV-3, DCCV-4, DCCV-5, DCCV-6, DCCV-7, DCCV-8, DCCV-9, DCCV-10, DCCV-11, DCCV-12 (*G. hirsutum*) genotypes

4.2.2.4 Maturity coefficient

The maturity coefficient of these 22 genotypes varied from 0.61 (DCCV-21) to 0.85 (DCCV-18) with a mean maturity of 0.78. The maturity coefficient of diploid genotypes could not be estimated due to high micronaire value. The maturity categories are as follows;

Category	No.of Genotypes	Genotypes
Very immature	NIL	NIL
Immature	NIL	NIL
Average maturity	2	DCCV-21, DCCV-22.
Good maturity	16	DCCV-1, DCCV-2, DCCV-3, DCCV-4, DCCV-5, DCCV-6, DCCV-7, DCCV-8, DCCV-9, DCCV-10, DCCV-11, DCCV-12 DCCV-13, DCCV-14, DCCV-16, DCCV-17.
Very high maturity	2	DCCV-15, DCCV-18.

4.2.2.5 Fibre strength (Tenacity g/tex)

The fibre strength of these genotypes varied from 11.8 (DCCV-16) to 16.9 g per tex (DCCV-9). The average strength was 14.47 g per tex. All genotypes belonged to very low tenacity category as they had tenacity less than 17 g per tex.

4.2.2.6 Fibre quality index (FQI)

The variation observed was very high for FQI among the Dharwad colour cotton genotypes. It ranged from 100 (DCCV-15) to 217 (DCCV-10) with a mean FQI of 160.9. Nearly half of the total genotypes were having FQI lower than average value.

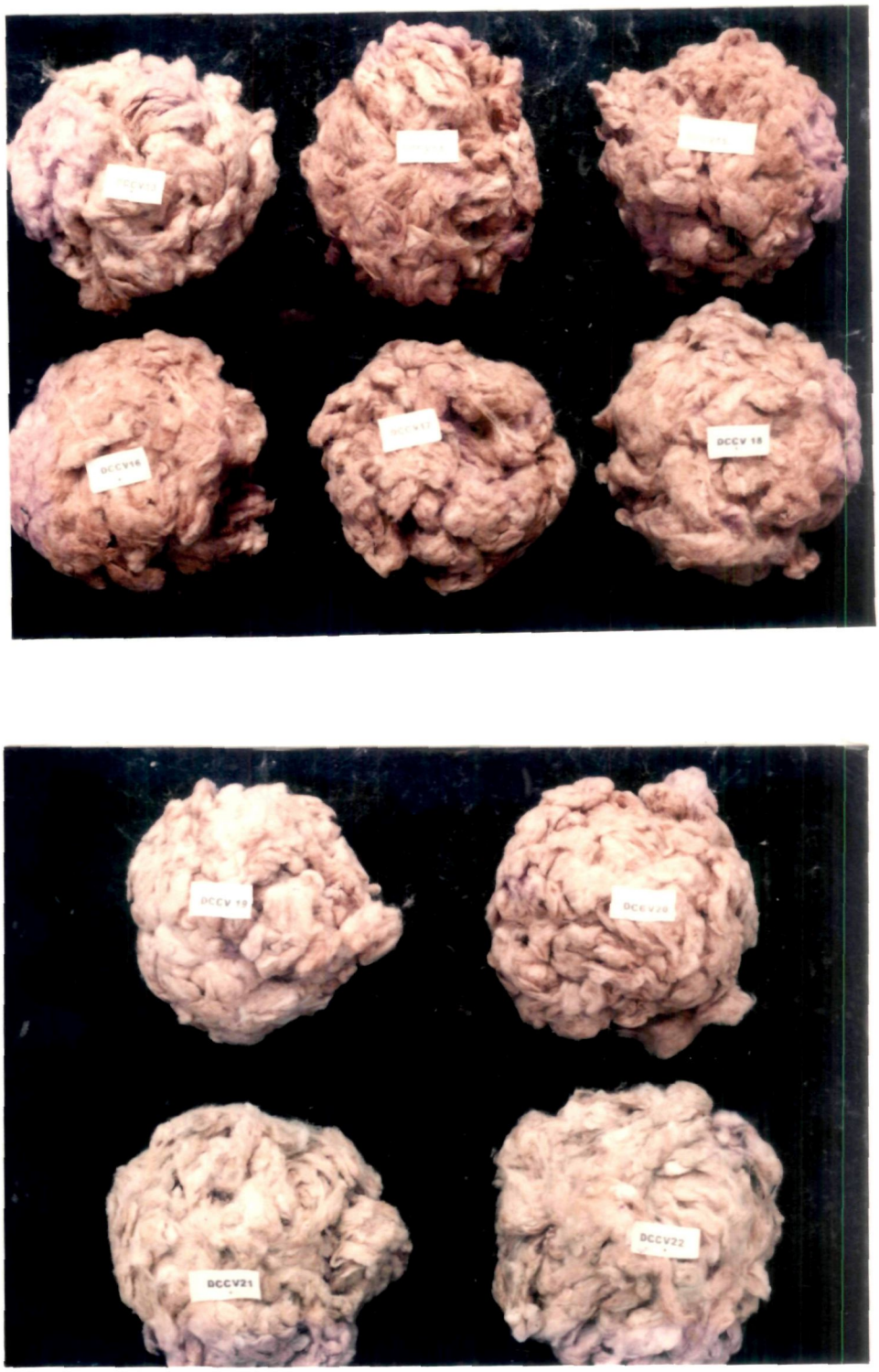


Plate 3. Lint samples of DCCV-13, DCCV-14, DCCV-15, DCCV-16, DCCV-17 DCCV-18, DCCV-21, DCCV-22 (*G. hirsutum*) and DCCV-19, DCCV-20 (*G. arboreum*) genotypes

4.2.2.7 Counts

The variation observed for counts was very high and it ranged from 3 in DCCV-15 to 26 in DCCV-10, with an average value of 15.3. About half of the twenty two genotype were having counts less than mean.

4.2.2.8 Count strength product (CSP)

The count strength product ranged from 1791 (DCCV-15) to 1995 (DCCV-10) with a mean CSP of 1897.

4.3 *Per se* performance of Dharwad colour cotton hybrids and their parents

4.3.1 Growth and yield parameters

The mean height of both diploid and *hirsutum* hybrids was better than that of their parents and checks. The hybrids DCCH-7 had minimum height (121.93 cm) whereas, diploid hybrid DCCH-9 recorded maximum height of 189.6 cm (Table 7).

The average number of monopodia in hybrids was 2.53 and it was slightly lower than average monopodial number in their parents (2.68). Both *hirsutum* hybrids and their parents had low number of monopodia but they were on par with each other. The diploid hybrids had higher, number of monopodia (5.3) than their parents (4.34) and checks. The range varied from 1.30 in DBH-95 to 5.93 in DCCH-10.

In general hybrids recorded less number of sympodia (18.01) than their parents (19.38) but were superior to checks (17.47). The diploid hybrids had more sympodia than the *hirsutum* hybrids. It was observed that in both crosses parents were better than their respective hybrids. The hybrid DCCH-1 had lowest number of sympodia (15.73) whereas,

Table 7. Mean performance of Dharwad colour cotton hybrids, parents and white cotton checks for various growth and yield parameters

Hybrids	Plant height (cm)	No.of Mono-podia	No.of Symp-odia	Days to first boll burst	No.of bolls	Boll weight (g)	Seed Index (g)	Lint Index (g)	Ginning Outturn (%)	Seed Cotton Yield kg/ha	Lint Yield kg/ha
DCCH-1	134.93	1.47	15.73	124.00	12.00	5.13	10.00	6.57	39.83	1741	685.6
DCCH-2	127.93	2.20	17.27	127.67	12.47	5.10	10.00	6.32	37.96	1446	548.0
DCCH-3	129.27	1.50	17.80	130.67	15.90	4.77	10.00	6.10	37.65	1950	734.2
DCCH-4	130.53	2.13	17.27	122.00	14.03	5.33	10.67	6.24	39.20	1574	614.2
DCCH-5	128.53	1.87	16.60	124.67	9.70	5.20	10.33	5.95	36.51	1040	380.5
DCCH-6	137.53	2.00	17.20	128.00	10.30	5.13	9.67	6.35	38.39	1403	498.1
DCCH-7	121.93	1.90	16.20	125.67	12.27	4.30	10.33	6.14	37.29	1371	512.14
DCCH-8	137.13	1.60	17.53	114.33	13.73	4.57	11.33	6.31	35.72	1257	448.1
DCCH-9	189.60	4.67	23.67	133.00	19.90	2.43	7.33	4.54	39.83	1578	618.8
DCCH-10	161.27	5.93	20.80	136.67	22.00	2.17	7.00	5.14	41.56	1295	537.2
DBH-95	115.87	1.30	16.07	128.33	11.83	4.40	10.00	4.73	42.21	907	294.9
DGH-95	115.20	1.53	18.00	115.00	5.63	3.10	10.33	3.10	23.01	300	69.3
DS 28	121.93	1.87	17.67	122.31	10.07	5.93	10.33	8.62	45.46	1144	518.0
Abadhita	134.33	2.73	17.67	119.33	14.33	4.23	9.33	6.70	41.58	1677	698.3
DBA-95	165.20	3.67	23.73	130.67	18.67	2.33	7.00	4.40	38.61	862	331.6
A-82-1-1	149.93	5.00	23.13	136.33	19.13	2.23	7.33	4.96	40.32	1021	410.8
DHH-11	128.00	2.00	17.13	128.00	14.83	5.03	8.67	6.12	42.92	1712	739.4
NHH-44	124.87	1.93	17.80	125.67	11.29	4.17	9.33	5.43	36.82	1438	529.3
Mean	136.31	2.52	18.40	126.24	13.78	4.20	9.39	5.77	38.05	1312	509.13
Hy Mean	139.83	2.53	18.01	126.67	14.23	4.41	9.67	5.97	38.39	1466	557.3
Pa. Mean	133.74	2.68	19.38	125.33	13.28	3.70	9.05	5.42	38.53	986	387.18
HH mean	130.93	1.83	16.95	124.63	12.55	4.94	10.29	6.25	37.82	1473	552.0
HP Mean	121.83	1.86	17.35	121.24	10.47	4.42	10.00	5.79	38.07	1007	220.62
DH mean	175.44	5.3	22.24	134.84	20.95	2.3	7.17	4.84	40.70	1437	577.38
DP mean	157.57	4.34	23.43	133.50	18.90	2.28	7.17	4.68	39.47	942	371.18
C Mean	126.44	1.97	17.47	126.84	13.06	4.6	9.00	5.78	39.87	1575	634.39
CD at 1%	25.38	1.06	5.02	7.79	8.05	1.04	1.71	1.67	5.62	509	191.02
CD at 5%	18.85	0.79	3.73	5.79	5.97	0.77	1.27	1.24	4.17	377	142.32

HH – Hirsutum x Hisrutum hybrids; HP – Hirsutum parent; DH – Diploid hybrids;
DP – Diploid parents; C – Checks mean; HY-Hybrid; PA - Parent

DBA-95 had highest number of sympodia (23.73). The field view of DCCH-1, DCCH-3 and DCCH-10 is presented in Plate 4.

DCCH-8 showed early bursting of first boll (114.33 days) whereas, A-82-1-1 was last to open (136.33 days). The diploid hybrids and their parents were comparatively late than *hirsutum* hybrids and their parents.

In general hybrids were significantly superior to their parents for yield. Both diploid and *hirsutum* hybrids had significantly higher mean yield than their parents. But the mean hybrid yield was lower than the mean of checks. The yield ranged from 1040 kg per ha in DCCH-5 to 1950 kgs per ha in DCCH-3 under rainfed condition. The hybrids DCCH-3 (1950 kg/ha) and DCCH-1 (1741 kg/ha) were on par with white linted check hybrid DHH-11 (1712 kg/ha). These two hybrids along with other hybrids like DCCH-4 (1574 kg/ha) and DCCH-9 (1578 kg/ha) were superior to another white linted check NHH-44.

In general hybrids were superior to their colour linted parents in lint yield. The lint yield of hybrids ranged from 380.5 kg per ha in DCCH-5 to 734.0 kg per ha in DCCH-3, with a mean of 557.3 kg per ha.

The average number of bolls in both hybrids i.e., *hirsutum* (12.5) and diploid (20.95) was higher than that of the parents and checks. The hybrid DCCH-5 had lowest boll number (9.7) among hybrids and parent DGH95 showed minimum number of bolls (5.63) among parents. The maximum number of bolls were seen in DCCH-10 (22) and in parent A82-1-1 (19.13).

The overall mean boll weight of hybrids (4.41 g) was higher than parents (3.7 g) but lower than check mean (4.6 g). The *hirsutum* hybrids were better than parents whereas



Plate 4. Field view of DCCH-1, DCCH-3 (intra *hirsutum*) and DCCH-10 (intra *arboreum*) hybrids

diploid hybrids were on par with their parents. Lowest boll weight was observed in DCCH-10 (2.17 g) and highest was in DCCH-4 (5.33 g). All *hirsutum* hybrids were better than white linted national check NHH-44. The boll weight in parents ranged from 2.23 (A-82-1-1) to 5.93 g (DS-28).

The mean seed index of hybrids (9.67 g) was higher than their parents (9.05 g) and checks (9.00 g). The diploid hybrids were on par with their parents, but *hirsutum* hybrids were better than their parents and checks. The lowest seed index was noticed in diploid hybrids DCCH-10 (7.00 g) and highest in DCCH-8 (11.33 g) intra *hirsutum* hybrid.

The average lint index in hybrids (5.97 g) was higher than parents. Similarly diploid hybrids (4.84 g) and *hirsutum* hybrids (6.25 g) were also superior to their parents. Both checks were inferior to *hirsutum* hybrids. The lint index was least in DCCH-9 (4.54 g) whereas it was highest in DCCH-1 (6.57 g).

The mean ginning out-turn of the checks (39.87%) and parents (38.53%) were higher than *hirsutum* hybrids. The diploid hybrids (40.7%) were better than their parents (39.47%). The ginning out-turn ranged from 35.72 per cent in DCCH-8 to 41.56 per cent in diploid hybrid DCCH-10.

4.3.2 Fibre properties

The hybrids, their parents and checks were evaluated for different fibre characters. The results are presented below (Table 8). The lint samples of hybrids with their parents are presented in Plate 5, 6 and 7.

Table 8. Fibre quality parameters of Dharwad colour cotton hybrids, parents and white cotton checks

Genotypes	2.5% Span length (mm)	Uniformly Ratio (%)	Fibre Fineness (Micro-naire)	Maturity Coeff. (%)	Fibre Strength 3.2 mm guage (g/tex)	Fibre Quality Index (FQI)	Count (C)	Count Strength Product (CSP)	Fibre Colour
DCCH-1	26.7	46	3.8	0.73	18.1	248	32	1867	VLB
DCCH-2	29.2	44	3.5	0.71	17.6	275	38	2096	VLB
DCCH-3	25.2	46	3.9	0.78	19.0	243	32	2040	VLB
DCCH-4	25.2	46	3.7	0.74	19.1	250	33	2052	VLB
DCCH-5	27.1	47	3.8	0.78	19.0	264	35	2076	LBG
DCCH-6	28.4	42	3.9	0.78	18.8	271	37	2089	LBG
DCCH-7	24.1	47	3.7	0.74	18.9	237	30	2029	BG
DCCH-8	25.9	45	4.1	0.78	19.8	253	33	2057	BG
DCCH-9	22.4	44	7.0	-	16.3	137	11	1855	LB
DCCH-10	22.1	44	7.1	-	15.2	126	8	1836	MB
DBH-95	23.0	48	4.5	0.66	16.8	182	19	1934	MB
DGH-95	23.0	47	3.8	0.62	15.8	186	20	1941	BG
DS-28	28.2	41	4.1	0.78	15.7	219	27	1998	W
Abadhita	27.1	46	4.2	0.80	17.8	235	30	2026	W
DBA 95	23.5	42	6.4	-	14.3	133	10	1848	MB
A-82-1-1	19.5	43	7.4	-	16.4	118	7	1832	W
DHH-11	26.6	43	4.4	0.81	16.7	212	25	1986	W
NHH-44	25.2	45	3.9	0.78	14.6	186	20	1941	W
Range (Min)	22.1	42	3.5	0.71	15.2	126	8	1832	
(Max)	29.2	47	7.1	0.78	19.8	271	38	2096	
Mean	25.13	44.78	4.62	0.75	17.22	209.72	24.83	1972.38	
Hybrid mean	25.63	45.1	4.45	0.76	18.18	230.40	28.9	1999.7	
Parent mean	24.05	44.5	5.07	0.72	16.13	178.83	18.83	1929.83	
HH Mean	26.48	45.38	3.8	0.76	18.79	255.13	37.88	2038.25	
HP Mean	25.33	45.5	4.15	0.72	16.53	205.5	18.83	1974.75	
Desi hybrid	22.25	44.0	7.05	-	15.75	131.5	9.5	1845.50	
Desi parent	21.5	42.5	6.9	-	15.35	125.5	8.5	1840.00	
Check	25.9	44.4	4.15	0.80	15.65	199	22.5	1963.50	
Variance	6.52	4.1	1.77	0.103	2.89	2764.66	106.71	8630.41	
S.D.	2.55	2.02	1.33	0.32	1.70	52.58	10.33	92.90	
S.Em±	0.60	0.48	0.31	0.01	0.40	12.39	2.43	21.89	
CD at 1%	1.26	1.01	0.65	0.02	0.84	35.56	6.97	62.82	
CD at 5%	1.74	1.39	0.89	0.03	1.16	26.02	5.10	45.97	

HH – Hirsutum x Hisrutum hybrids. HP – Hirsutum parent
VLB - very light brown; LBG - Light brownish green; BG - Brownish green; LB - Light brown;
MB - Medium brown; W - White

4.3.2.1 2.5 per cent Span length (mm)

The 2.5 span length of hybrids ranged from 22.1 mm in diploid hybrid (DCCH-10) to 29.2 mm in DCCH-2. The mean span length of the hybrids (25.63 mm) was more than their parents mean. Both *hirsutum* and *arboreum* hybrids had higher mean span length than their respective parents. The hybrids DCCH-1 (26.7 mm), DCCH-2 (29.2 mm), DCCH-5 (27.1 mm) and DCCH-6 (28.4 mm) were superior over both white linted checks, whereas DCCH-8 (25.9 mm) was better than check NHH-44. Based on the 2.5 per cent span length, the categories to which hybrids belong are given below;

Category	No.of Genotypes	Genotypes
Short B	NIL	NIL
Short A	3	DCCH-7, DCCH-9, DCCH-10.
Medium	7	DCCH-1, DCCH-2, DCCH-3, DCCH-4, DCCH-5, DCCH-6, DCCH-8.
Long	NIL	NIL
Extra	NIL	NIL

4.3.2.2 Uniformity ratio (UR)

The uniformity ratio of hybrids varied from 42 (DCCH-6) to 47 (DCCH-5 and DCCH—7). The mean uniformity ratio of hybrids (45.1) was on par with their parents (44.5). The *hirsutum* hybrids were having slightly lower uniformity ratio than their parents, whereas diploid hybrids were superior to their parents. Most of the hybrids were superior than both white linted checks. The hybrids belong to different uniformity categories are given below.

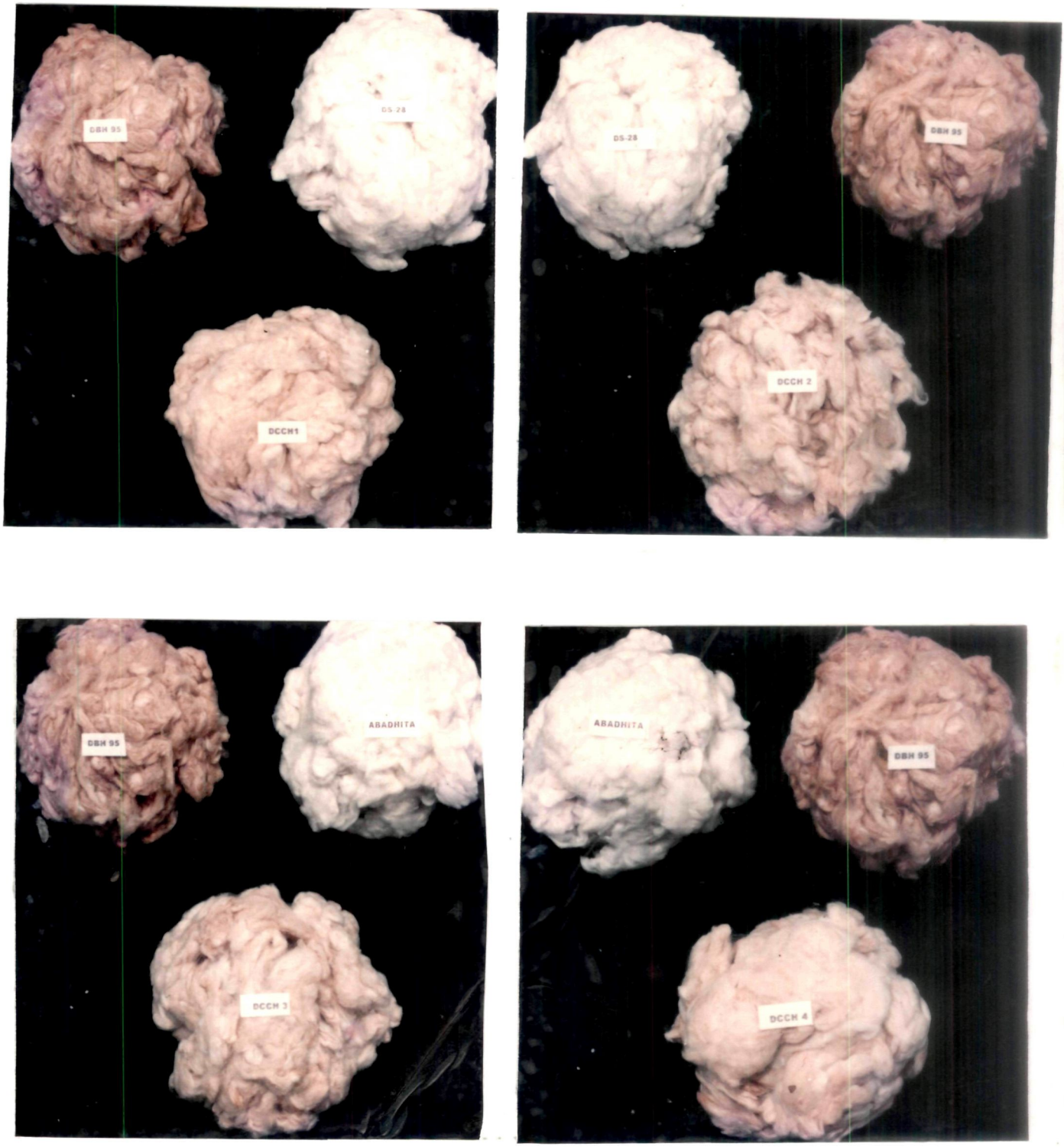


Plate 5. Lint samples of DCCH-1, DCCH-2, DCCH-3, DCCH-4 (intra *hirsutum*) hybrids and their parents

Category	No.of Genotypes	Genotypes
Poor	NIL	NIL
Fair	1	DCCH-6.
Average	4	DCCH-2, DCCH-8, DCCH-9, DCCH-10.
Good	5	DCCH-1, DCCH-3, DCCH-4, DCCH-5, DCCH-7.
Excellent	NIL	NIL

4.3.2.3 Fibre fineness

The micronaire value which indicates fibre fineness varied from 3.5 (DCCH-2) to 7.1 (diploid hybrid DCCH-10). The mean micronaire value of hybrids (4.45) was less than their parents mean (5.07). The *hirsutum* hybrids, were having low micronaire than their parents, whereas it was vice versa for diploid hybrids, which had high micronaire value. Both white linted checks had higher micronaire than all *hirsutum* hybrids. The hybrids could be classified as follows.

Category	**No.of Genotypes**	**Genotypes**
Very fine	NIL	NIL
Fine	7	DCCH-1, DCCH-2, DCCH-3, DCCH-4, DCCH-5, DCCH-6, DCCH-7.
Average	1	DCCH-8.
Coarse	NIL	NIL
Very coarse	1	DCCH-9, DCCH-10.

4.3.2.4 Maturity coefficient

The maturity of the hybrids varied from 0.71 (DCCH-2) to 0.78 (DCCH-3, DCCH-5, DCCH-6, DCCH-8). The average maturity of *hirsutum* hybrids was 0.76 which was slightly higher than mean maturity of their parents. The maturity coefficient of diploid



Plate 6. Lint samples of DCCH-5, DCCH-6, DCCH-7, DCCH-8 (intra *hirsutum*) hybrids and their parents

hybrids could not be estimated as they had high micronaire values. All hybrids evaluated were having good maturity.

4.3.2.5 Fibre strength (at 3.2 mm guage g/tex)

The fibre strength of hybrids ranged from 15.2 (DCCH-10) to 19.8 g per tex (DCCH-8). Overall, hybrids had more stronger fiber than their parents. Diploid hybrids were on par with their parents, whereas *hirsutum* hybrids were superior to their parents for fibre strength. The hybrids fall in following categories;

Category	No.of Genotypes	Genotypes
Very low	2	DCCH-9, DCCH-10.
Low	7	DCCH-1, DCCH-2, DCCH-3, DCCH-4, DCCH-5, DCCH-6, DCCH-7.
Average	1	DCCH-8.
Good	NIL	NIL
Very good	NIL	NIL

4.3.2.6 Fibre quality index (FQI)

The mean FQI of hybrids was 230 with a range of 126 (DCCH-10) to 275 (DCCH-2), whereas mean FQI of parents was 179. The *hirsutum* hybrids (255) were superior than their parents (206). The diploid hybrids were on par with their parents. All *hirsutum* hybrids were superior to white linted checks.

4.3.2.7 Counts

The hybrids varied from 8 counts in DCCH-10 to 38 counts in DCCH-2, with a mean of 28.9 counts. The *hirsutum* hybrids had a mean of 37.88 counts which was higher

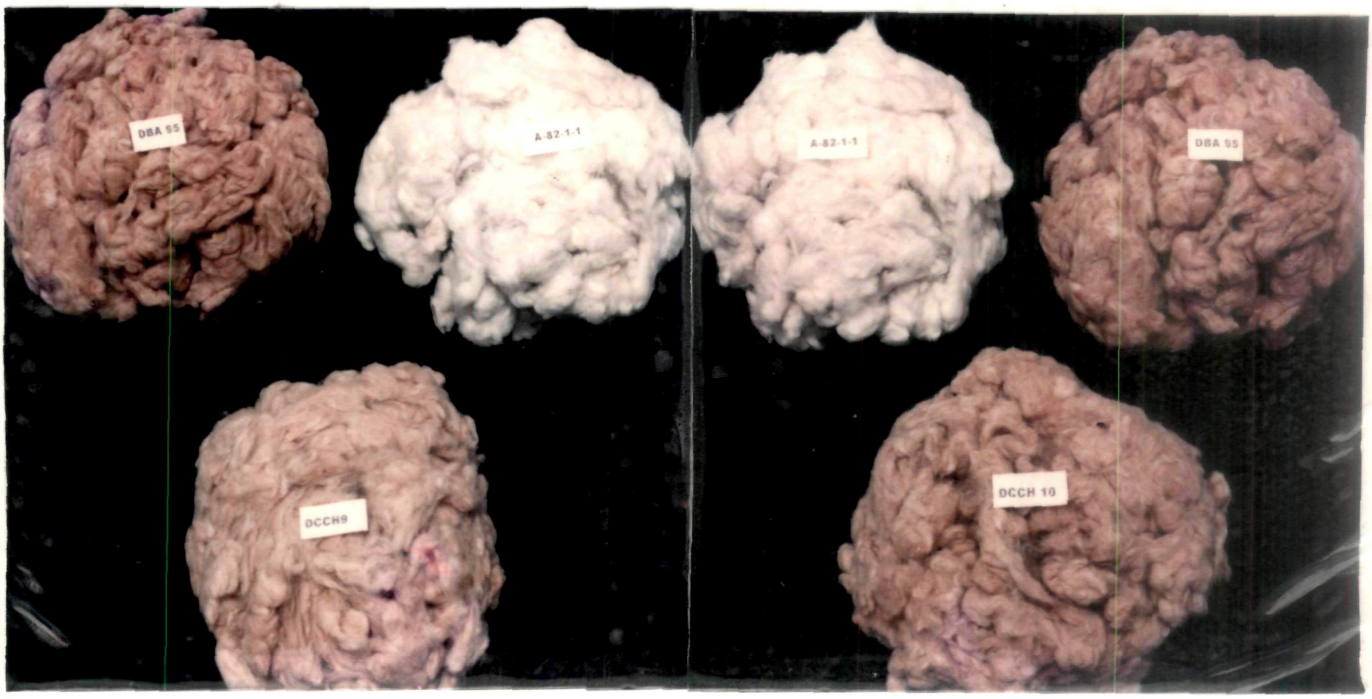


Plate 7a. Lint samples of DCCH-9 and DCCH-10 (intra *arboreum*) hybrids and their parents



Plate 7b. Bolls of DCCH-1, DCCH-2, DCCH-3, DCCH-4 (intra *hirsutum*) and DCCH-9 and DCCH-10 (intra *arboreum*) hybrids

than *hirsutum* parents mean of 18.83 counts, whereas diploid hybrids mean was on par with their parents. It was also observed that overall hybrids mean (28.9 counts) was higher than mean of two checks (22.5 counts).

4.3.2.8 Count strength product (CSP)

The count strength product of hybrids varied from 1836 in DCCH-10 to 2096 in DCCH-2. The hybrids mean (1999.7) was less than their parents mean (1929.83). The *hirsutum* hybrids mean (2038) was higher than *hirsutum* parents (1975), but desi hybrids mean (1845) was less than its parents.

4.4 Genetic variability

Different components of genetic variability studied in Dharwad colour cotton genotypes and Dharwad colour cotton hybrids includes variances, phenotypic and genotypic coefficient of variations, broad sense heritability, genetic advance and genetic advance of mean (Table 9 and 10).

4.4.1 Variances

All three i.e., genotypic, environmental and phenotypic variances were computed for Dharwd colour cotton genotypes and hybrids. It was observed that for all characters studied except plant height in genotypes and number of sympodia in both genotypes and hybrids, the genotypic variance was higher than environmental variance. For plant height in genotype, the genotypic variance was slightly higher than environmental variance. It was noticed that for number of sympodia both genotypic and environmental variances were on par (Table 9). Number of monopodia in genotypes showed lower genetic variance than environmental variance.

Table 9. Components of variability in twenty two Dharwad colour cotton genotypes for different growth and yield components

Sl. No.	Characters	Environ Variance σ^2e	Genotypic variance σ^2g	Phenotypic Variance σ^2p	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)
1.	Plant height (cm)	91.2004	96.8125	188.0129	14.41	11.55	64.2	21.10	19.05
2.	No.of monopodia	0.2405	0.1256	0.3661	31.98	18.73	34.3	0.43	22.73
3.	No.of sympodia	3.8537	3.8004	7.6545	14.83	10.45	49.7	2.83	15.17
4.	Days to first boll burst	6.1925	19.6984	25.8909	3.81	3.32	76.1	7.97	5.94
5.	No of bolls	9.1881	14.5983	23.78864	46.61	36.51	61.41	6.17	58.99
6.	Boll weight (g)	0.1710	0.4884	0.6594	21.47	18.47	74.1	1.24	32.78
7.	Seed index (g)	0.2107	1.2843	1.4950	13.10	12.14	85.9	2.16	23.14
8.	Lint index (g)	0.3277	0.9005	1.2342	22.53	19.31	73.4	1.68	34.07
9.	Ginning out turn (%)	6.855	21.7482	27.9337	15.36	13.56	77.9	8.48	24.65
10	Seed yield	35294.15	102202.1	137496.25	42.19	36.38	74.3	567.78	64.60
11.	Lint yield	5163.2	20 133.93	25297.13	45.21	50.68	79.6	260.77	83.90

PCV – Phenotypic coefficient of variation; GCV – Genotypic coefficient of variation
h^2 – Broad sense heritability; GA – Genetic advance; GAM – Genetic advance of mean

4.4.2 Coefficient of variations

In genotypes, phenotypic coefficient of variance was more than genotypic coefficient of variation for all traits except lint yield. Low GCV and PCV were observed for days to first boll burst (3.32 and 3.81%). The characters plant height (11.55 and 14.14%), number of sympodia(14.83 and 10.45%), seed index (13.10 and 12.14%) and ginning per cent (15.36 and 13.56%) had moderate PCV and GCV, respectively. The characters like number of bolls (46.61 and 36.51%), seed cotton yield (42.19 and 36.38%) and lint yield (45.21 and 50.68%) possessed high PCV and GCV. The traits like number of monopodia (31.98 and 18.73%), boll weight (21.47 and 18.47%) and lint index (22.53 and 19.31%) had high PCV and moderate GCV (Table 9).

In Dharwad colour cotton hybrids, the PCV and GCV were low for days to first boll burst (5.4 and 4.69), monopodia, plant height (15.54 and 13.14%), number of sympodia (17.18 and 12.15%), seed index (15.82 and 13.59%), ginning out-turn (13.64 and 11.95%), boll weight (30.19 and 28.09%), seed cotton yield (33.19 and 28.34%) and lint yield (32.09 and 36.23). In case of lint index PCV was high (23.07%) and GCV was moderate (19.15%) (Table 10).

4.4.3 Heritability, genetic advance and genetic advance of mean

In Dharwad colour cotton varietal genotypes high heritability and moderate GAM were observed for plant height (64.2 and 19.05%), whereas for number of monopodia moderate heritability and high GAM (34.3 and 22.73%) were noticed. For number of sympodia both heritability and GAM were moderate (49.7 and 15.17%). In case of days to first boll burst heritability was very high (76.1%) whereas, GAM was very low (5.94%). High heritability coupled with high GAM was reported for number of bolls (61.41 and 58.99%), boll weight (74.1 and 32.78%), seed index (85.9 and 23.14%), lint index (73.4 and

Table 10. Components of genetic variability in Dharwad colour cotton hybrids for various growth and yield components

Characters	Genotypic variance $\sigma^2 g$	Environmental Variance $\sigma^2 e$	Phenotypic Variance $\sigma^2 p$	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Broad sense heritability h^2	Genetic advance (GA)	Genetic advance of mean (GAM)
PH	320.98	127.77	448.75	15.54	13.14	71.5	31.21	22.90
NM	1.78	0.22	2.00	56.31	53.08	88.8	2.59	102.91
NS	4.99	4.99	9.99	17.18	12.15	50.0	3.26	17.71
FB	35.11	12.05	47.16	5.40	4.69	74.5	10.53	8.34
NB	14.87	6.56	21.44	33.61	27.99	69.4	6.62	48.05
BW	1.39	0.21	1.60	30.19	28.09	86.6	2.26	53.83
SI	1.62	0.57	2.20	15.82	13.59	73.8	2.26	24.07
LI	1.21	0.54	1.76	23.07	19.15	68.9	1.89	32.79
GOT	20.67	6.26	26.94	13.64	11.95	76.7	8.21	21.58
SCY	41.48	5.12	46.61	33.19	28.34	72.9	6.54	49.85
LY	226687.24	7342.72	34029.96	32.09	36.23	78.4	298.20	58.87

PH - Plant height; NM - No.of Monopodia; NS - No.of Sympodia; FB - Days to first boll burst;
NB - No.of bolls; BW - Boll weight; SI - Seed index; LI - Lint index;
GOT - Ginning out-turn; SCY - Seed cotton yield; LY - Lint yield

34.07%), ginning per cent (77.9 and 24.65%), seed cotton yield (74.3 and 64.6%) and lint yield (79.6 and 83.90), respectively (Table 9).

In Dharwad colour cotton hybrids, high heritability was coupled with high GAM for plant height (71.5 and 22.9%), number of monopodia (88.8 and 102.9%), number of bolls (69.4 and 48.05%), boll weight (86.6 and 53.83%), seed index (73.8 and 24.07%), ginning out-turn (76.7 and 21.58%), seed cotton yield (72.9 and 49.85%), lint yield (78.4 and 58.87%) and lint index (68.90 and 32.79%). For number of sympodia heritability (50.0%) and GAM (17.7%) were moderate. Days to first boll burst showed high heritability (74.5%) and low GAM (8.34%) (Table 10).

4.5 Genetics of fibre colour

4.5.1 Genetics of fibre colour in *G. hirsutum* colour cottons

To study the genetics of fibre colour a cross between white linted DS 28 and brown linted *hirsutum* genotype was effected. The F_1 obtained had intermediate fibre colour. The F_2 seeds were obtained from selfing F_1 and was raised with normal cultivation practices. Totally three hundred and three plants were evaluated for fibre colour visually. The variation observed in the F_2 was very high. The colour range observed was from white to dark brown. The F_2 population could be classified in seven different categories, of this seven categories, one was white, whereas all remaining six were pigmented. The pigmented or colour category also showed wide variation and it ranged from off white to dark brown. These classes showed gradual increase in fibre colour from off white to dark brown. The lightest colour category was off white, followed by light cream, cream, light brown, medium brown and dark brown, respectively. The number of plants in each category also varied. The dark brown colour linted category had minimum number of plants (15), followed by medium

Table 11. The F_2 behaviour of *G. hirsutum* (white x brown) colour cotton for fibre colour

Colour classes	No.of F_2 plants
Dark brown	15
Medium brown	30
Light brown	35
Cream	36
Light cream	48
Off white	73
White	66
Total	303

brown (30), light brown (35), cream (36), light cream (48), off white (73) and white (66) (Table 11) (Plate 8a).

The number of plants in each category indicated that one fourth of the plants were white and colour linted plants comprised of three fourth of the population. The segregation ratio of 3:1 was confirmed with χ^2 test.

On further observation of colour classes it was found that they can be broadly categorised as brown and cream. As F_1 was intermediate, it was thought that incomplete dominance is prevailing. The F_2 ratio of 1:2:1 was tried. The calculated χ^2 value was less than table value at two degrees of freedom and 0.05 probability. Thus the ratio 1:2:1 holds good for this segregation.

Further analysis of both these colour classes indicated that they can be further categorised. The brown class could be categorized into dark brown, medium brown and light brown, whereas the cream class could be divided into cream, light cream and off white.

4.5.2 Genetics of fibre colour in *G. arboreum* colour linted cotton

In order to work out genetics of fibre colour a cross between a brown *arboreum* having medium brown and a white genotype, A-82-1-1 was effected. The female parent was having colour fibre, whereas male was white. The F_1 obtained had intermediate colour. This F_1 was selfed to obtain F_2 seeds. The F_2 were raised with normal cultural practices. Three hundred and ninety six plants were evaluated for their fibre colour. It was observed that large variability was created in F_2. The colour of fibres ranged from white to medium brown. As the fibre colour could not be quantified, visual classification was done. The F_2 plants could be categorised into seven separate classes, of which one category was white and all others were having varying shades of fibre colour (Table 12) (Plate 8b).

Table 12. The F_2 behaviour of *G. arboreum* (brown x white) colour cotton for fibre colour

Colour classes	No.of F_2 plants
Medium brown	62
Light brown	65
Very lignt brown	81
Almond	41
Light cream	50
Off white	63
White	34
Total	396



Plate 8a. Fibre colour classes of *G. hirsutum* (white x brown) F_2



Plate 8b. Fibre colour classes of *G. arboreum* (brown x white) F_2

The colour classes were categorised in seven classes and they were off white with very little colour in fibres, followed by light cream wherein pigment in fibre had increased. Third category was almond, fourth class was of very light brown shade, fifth category was light brown, sixth class was medium brown fibre colour which was deepest colour class in this study. The last class was of white linted plants. The number of plants in each category differed and varied from 34 in white to 81 in very light brown. The number of plants in other colour categories were, 63 plants in off white, 50 in light cream, 41 plants in almond, 65 in light brown class and 62 in medium brown class.

The $\chi 2$ studies indicated that present segregation was in 15:1 ratio. The 15 parts out of 16 had colour linted plants whereas only one part was having white linted plants. As explained above the broad class of colour types was having within it another six classes which were showing gradual increase in the colour of fibre. The colour was very light in first class i.e, off white and it increased gradually till it reached maximum i.e., medium brown in this case. The increase in colour was so gradual and minute, that it was very difficult to grade. These classes were overlapping over each other.

As colour class showed further variation it was studied in detail. It was observed that these classes were in the ratio of 3:2:2:3:3:2:1. The last class was that of white linted plant.

4.6 Character association

All three correlation coefficients viz., genotypic, environmental and phenotypic were computed for Dharwad colour cotton genotypes (Table 13) and Dharwad colour cotton hybrids (Table 14). These results are presented below.

4.6.1 Dharwad colour cotton genotypes

The plant height was positively related to number of sympodia singificantly, both at genotypic (0.763) and phenotypic levels (0.562). The number of monopodia was associated positively with number of sympodia (0.518) and days to first boll burst (0.462), only at genotypic level. The genotypic correlation of number of sympodia was positive and significant with days to first boll burst (0.556), number of bolls (0.533), ginning out-turn (0.546), seed cotton yield (0.572) and lint yield (0.623), whereas it had negative relation with boll weight (-0.665) and seed index (-0.672). It was also correlated at phenotypic level with number of bolls positively (0.424) and seed index negatively (-0.448).

Days to first boll burst was significantly and positively correlated to number of bolls (0.518), lint index (0.503), seed cotton (0.510), ginning out-turn (0.727) and lint yield (0.741), but was negatively correlated with boll weight (-0.461) and seed index (-0.411).

The seed cotton yield was having highly significant genotypic level genetic association with number of sympodia (0.572), days to first boll burst (0.510), number of boll (0.803), ginning out-turn (0.729) and lint yield (0..980). The characters number of sympodia (0.468), number of bolls (0.601), seed index (-0.512), ginning out-turn (0.591) and lint yield (0.974) were related phenotypically with seed cotton yield (Table 13).

Number of bolls was related genotypically and phenotypically with boll weight (–0.852** and -0.565**), seed index (–0.821** and -0.565**) and ginning out-turn (0.631** and 0.491*), respectively. Boll weight had positive and significant relation with seed index for all three levels, viz. genotypic, phenotypic and environmental (0.987**, 0.868**, and 0.423*), and it was related with seed cotton yield (-0.573**) and lint yield (-0.551) genotypically. Seed index was associated phenotypically and genotypically with

Table 13. Correlation coefficients among different growth and yield characters in Dharwad colour cotton genotypes at environmental, genotypic and phenotypic levels

Character		PH	NM	NS	FB	NB	BW	SI	LI	GP	SCY	LY
Plant Height	re	**1.000**	0.141	0.310	-0.020	0.048	-0.051	-0.050	0.103	0.100	0.185	0.142
	rg	**1.000**	0.076	0.763**	-0.022	0.024	-0.111	-0.261	-0.087	0.098	0.284	0.309
	rp	**1.000**	0.104	0.562**	-0.021	0.033	-0.092	-0.205	-0.028	0.097	0.252	0.260
No.of Monopodia	re		**1.000**	-0.334	-0.130	-0.161	0.104	0.058	-0.074	-0.178	-0.258	-0.284
	rg		**1.000**	0.518*	0.462*	0.013	-0.378	-0.357	-0.201	-0.022	-0.064	-0.068
	rp		**1.000**	0.021	0.185	-0.075	-0.147	-0.176	-0.132	-0.057	-0.138	-0.140
No.of Sympodia	re			**1.000**	0.066	0.294	0.019	-0.034	0.104	0.189*	0.334	0.372
	rg			**1.000**	0.556**	0.533*	-0.665**	-0.672**	0.092	0.546**	0.572**	0.623**
	rp			**1.000**	0.365	0.424*	-0.396	-0.448*	0.094	0.403	0.468*	0.511*
Days to first boll burst	re				**1.000**	-0.080	-0.295	-0.205	-0.336	-0.267	-0.015	0.160
	rg				**1.000**	0.518*	-0.461*	-0.411	0.503*	0.727**	0.510*	0.741**
	rp				**1.000**	0.329	-0.419	-0.369	0.291	0.498*	0.380	0.286
No.of bolls	re					**1.000**	0.032	0.133	0.310	0.188	0.188	0.231
	rg					**1.000**	-0.852**	-0.821**	0.063	0.631**	0.803**	0.797**
	rp					**1.000**	-0.565**	-0.565**	0.142	0.491*	0.601**	0.622**
Boll weight	re						**1.000**	0.423**	0.282	0.043	0.058	0.048
	rg						**1.000**	0.987**	0.297	-0.352	-0.573**	-0.551*
	rp						**1.000**	0.868**	0.293	-0.257	-0.410	-0.412
Seed index	re							**1.000**	0.383	-0.107	0.131	0.097
	rg							**1.000**	0.308	-0.349	-0.672**	-0.639**
	rp							**1.000**	0.319	-0.304	-0.512*	-0.512**
Lint index	re								**1.000**	0.733**	0.181	0.324
	rg								**1.000**	0.786**	0.305	0.436*
	rp								**1.000**	0.772**	0.272	0.409
Ginning Out-turn	re									**1.000**	0.153	0.372
	rg									**1.000**	0.729**	0.835**
	rp									**1.000**	0.591**	0.737**
Seed cotton Yield	re										**1.000**	0.963**
	rg										**1.000**	0.980**
	rp										**1.000**	0.974**
Lint yield	re											**1.000**
	rg											**1.000**
	rp											**1.000**

re – Environmental correlation , rg – Genotypic correlation , rp – Phenotypic correlation , * - Significant at 5% , ** - Significant at 1% level of significance

seed cotton yield (-0.512 and -0.672) and lint yield (-0.512 and -0.639). The lint index was correlated with ginning out-turn positively and significantly at all three correlation coefficient levels (0.772, 0.786 and 0.733) and at genotypic level with lint yield (0.436). The ginning out-turn was related positively and significantly with lint yield at both phenotypic and genotypic levels (0.737 and 0.835), respectively.

4.6.2 Dharwad colour cotton hybrids

The plant height had positive, significant genotypic and phenotypic correlations with number of monopodia (0.869 and 0.723), number of sympodia (0.855 and 0.819) and number of bolls (0.910 and 0.657) respectively, whereas days to first boll burst had only significant genotypic correlation. Similarly, significant negative genetic and phenotypic associations were observed with boll weight (-0.751 and –0.563) and seed index (-0.870 and –0.655), respectively (Table 14).

The number of monopodia was positively related at genotypic and phenotypic levels with number of sympodia (0.992 and 0.655), days to first boll burst (0.770 and 0.555) and number of bolls (0.911 and 0.707) respectively, whereas characters boll weight (-0.818 and –0.753) and seed index (-0.942 and –0.772) were negatively correlated.

The number of sympodia was having positive and significant genetic association with days to first boll burst (0.693), number of bolls (0.875), whereas lint index was related negatively(-0.556). Similarly, negative phenotypic correlation of number of sympodia was observed with boll weight (-0.635) and seed index (-0.638).

The days to first boll burst was at genotypic level significantly related to number of bolls (0.826), boll weight (-0.520), seed index (-0.869) and phenotypic association was seen with number of bolls (0.569) and seed index (-0.648).

Table 14. Correlation coefficients among different growth and yield characters in Dharwad colour cotton hybrids at environmental, genotypic and phenotypic levels

Character		PH	NM	NS	FB	NB	BW	SI	LI	GP	SCY	LY
Plant Height	re	**1.000**	0.170	0.769**	-0.148	0.056	0.141	-0.084	-0.125	-0.287	0.311	0.238
	rg	**1.000**	0.869**	0.855**	0.649**	0.910**	-0.751**	-0.870**	-0.314	0.425	0.109	0.160
	rp	**1.000**	0.723**	0.819**	0.434	0.657**	-0.563*	-0.655**	-0.257	0.241	0.165	0.179
No.of Monopodia	re		**1.000**	-0.045	-0.419	-0.042	-0.290	-0.056	-0.109	0.028	-0.074	-0.084
	rg		**1.000**	0.992**	0.770**	0.911**	-0.818**	-0.942**	-0.340	0.383	-0.040	0.049
	rp		**1.000**	0.655**	0.555**	0.707**	-0.753**	-0.772**	-0.286	0.320	-0.045	0.028
No.of Sympodia	re			**1.000**	-0.010	0.152	0.094	-0.024	-0.093	-0.270	0.255	0.195
	rg			**1.000**	0.693**	0.875**	-0.103	-1.036	-0.556	0.270	-0.289	-0.198
	rp			**1.000**	0.426	0.575*	-0.635**	-0.638**	-0.363	0.075	-0.081	-0.060
Days to first boll burst	re				**1.000**	-0.089	0.089	-0.017	-0.109	-0.065	-0.079	-0.091
	rg				**1.000**	0.826**	-0.520*	-0.869**	-0.213	0.459	0.222	0.246
	rp				**1.000**	0.569*	-0.412	-0.648**	-0.183	0.331	0.143	0.167
No.of bolls	re					**1.000**	-0.190	-0.032	-0.205	-0.289	0.538*	0.425
	rg					**1.000**	-0.668**	-0.887**	-0.153	0.619**	0.305	0.367
	rp					**1.000**	-0.556*	-0.644**	-0.169	0.375	0.372	0.380
Boll weight	re						**1.000**	0.631**	0.505*	0.009	-0.171	-0.150
	rg						**1.000**	0.812**	0.789**	0.187	0.409	0.380
	rp						**1.000**	0.768**	0.712**	0.154	0.292	0.288
Seed index	re							**1.000**	0.672**	0.352	-0.086	0.089
	rg							**1.000**	0.389	-0.412	0.041	-0.072
	rp							**1.000**	0.469	-0.223	0.007	-0.033
Lint index	re								**1.000**	0.713**	-0.206	0.075
	rg								**1.000**	0.685**	0.642**	0.662**
	rp								**1.000**	0.689**	0.395	0.506*
Ginning outturn	re									**1.000**	-0.278	0.107
	rg									**1.000**	0.734**	0.809**
	rp									**1.000**	0.479*	0.651**
Seed cotton yield	re										**1.000**	0.913**
	rg										**1.000**	0.986**
	rp										**1.000**	0.966**
Lint yield	re											**1.000**
	rg											**1.000**
	rp											**1.000**

re – Environmental correlation ; rg – Genotypic correlation ; rp – Phenotypic correlation ; * - Significant at 5% ; ** - Significant at 1% level of significance

The number of bolls had significant genetic and phenotypic association with boll weight (-0.668 and –0.556) and seed index (-0.887 and –0.644) whereas ginning out-turn was having only genetic correlation (0.619).

Boll weight had positive and highly significant genotypic, phenotypic and environmental correlations with seed index (0.812, 0.768 and 0.651) and lint index (0.789, 0.712 and 0.505). Lint index also had significant genotypic, phenotyipc and environmental correlation coefficients with GOT (0.685 , 0.689 and 0.713), respectively and both genetic and phenotypic correlation with lint yield (0.662 and 0.506), repsectively and only genetic relation with seed cotton yield (0.642).

Seed cotton yield was significantly related with number of boll at phenotypic level (0.538), lint index at genotypic level (0.642), ginning out-turn at both phenotypic and genotypic level (0.479 and 0.734) and with lint yield at genotypic, phenotypic and environmental level (0.986, 0.966 and 0.913), respectively.

Lint yield also had significant and positive relation with lint index (0.662 and 0.506), ginning out-turn (0.809 and 0.651) at genotypic and phenotypic levels, whereas it was related to seed cotton yield at all three levels i.e,. genotypic, phenotypic and environmental.

4.6.3 Correlation coefficient among fibre quality parameters in Dharwad colour cotton genotypes

Simple correlation coefficients were computed among different fibre quality parameters and results are presented below (Table 15).

Table 15. Correlation coefficient among different fibre quality characters in Dharwad colour cotton genotypes

Characters	FL	UR	Mic	MC	FS	FQI	C	CSP
FL	1.000	-0.215	-0.306	-0.187	0.554**	0.826**	0.824**	0.827**
UR		1.000	-0.411	-0.728**	0.106	0.109	0.115	0.109
Mic			1.000	-0.521*	-0.150	-0.675**	-0.677**	-0.675**
MC				1.000	0.023	0.143	0.153	0.143
FS					1.000	0.724**	0.723	0.722**
FQI						1.000	0.999**	0.999**
C							1.000	0.999**
CSP								1.000

*, ** - Significant at 5% and 1% level of significance

FL - 2.5% Span length ; UR - Uniformity ratio ; Mic - Micronaire value MC - Maturity coefficient ;
FS - Fibre strength ; FQI - Fibre quality index; C - Counts ; CSP - Count Strength Product

The parameters like fibre strength (0.554), FQI (0.826), counts (0.824) and CSP (0.827) had highly significant association with 2.5 per cent span length. Uniformity ratio was negatively correlated with maturity coefficient (-0.728). Fibre fineness was negatively and significantly associated with maturity coefficient (-0.521), FQI (-0.675), counts (-0.677), and CSP (-0.675). Fibre strength was having positive and significant relation with FQI (0.724), counts (0.723) and CSP (0.722). FQI had highly significant correlations with counts (0.99) and CSP (0.999). Similarly counts and CSP were highly correlated (0.999).

4.6.4 Correlation coefficient studies on fibre properties in Dharwad coloured cotton hybrids

Simple correlations were computed among eight different fibre quality parameters. The results are presented below (Table 16).

Highly significant and positive correlations were observed between 2.5 per cent span length and maturity coefficient (0.748), fibre quality index (FQI) (0.844), counts (0.847) and count strength produced CSP (0.749). Fibre fineness (micronaire) was significantly and negatively related with span length (-0.741), Fibre strength (-0.537), FQI (-0.884), counts (-0.880), CSP (-0.788) and positively with maturity coefficient (0.959). Maturity coefficient had positive significant relation with fibre strength (0.563), highly significant positive association with FQI (0.783), counts (0.782) and CSP (0.795). FQI also reported highly significant positive correlation with counts (0.999) and CSP (0.891), Counts and CSP were highly significantly and positively related (0.895).

Table 16. Correlation coefficient among different fibre quality characters in Dharwad colour cotton hybrids

Characters	FL	UR	Mic	MC	FS	FQI	C	CSP
FL	**1.000**	-0.1402	-0.741**	0.748**	0.402	0.844**	0.847**	0.749**
UR		**1.000**	-0.402	0.347	0.400	0.249	0.236	0.170
Mic			**1.000**	0.959**	-0.537*	-0.884**	-0.880**	-0.788*
MC				**1.000**	0.563*	0.870**	0.864**	0.795**
FS					**1.000**	0.783**	0.782**	0.718**
FQI						**1.000**	0.999**	0.891**
C							**1.000**	0.895**
CSP								**1.000**

*, ** - Significant at 5% and 1% level of significance

FL - 2.5% Span length ; UR - Uniformity ratio ; Mic - Micronaire value; MC - Maturity coefficient ;
FS - Fibre strength ; FQI - Fibre quality index; C - Counts ; CSP - Count Strength Product

4.7 Path analysis

4.7.1 Genotypic path analysis for seed cotton yield in Dharwad colour cotton genotypes

The genotypic paths for seed cotton yield was computed. The results obtained are outlined here under. The characters used for path were seed cotton yield as dependent variable with number of monopodia, number of sympodia, number of bolls, boll weight, seed index, lint index and ginning percentage as independent variables.

The partitioning of genotypic correlations into direct and indirect effects is given in Table 17. The direct effect of number of monopodia (0.182) was very low, but it had higher positive indirect effect through seed index (0.792) and lint index (0.834). It also had high negative indirect effect through boll weight (-1.858).

The number of sympodia had low negative direct effect (-0.237), but it indirectly influenced through seed index (1.490) and ginning out-turn (2.559). So also through boll weight it showed high negative indirect effect (-3.273).

The number of bolls per plant had direct moderate influence (0.602), whereas its indirect influence through seed index (1.822), ginning out-turn (2.959) and boll weight (-4.195) were high.

The boll weight on its own had very high direct effect (4.921). But its negative indirect effects through number of bolls (-0.513), seed index (-2.190), lint index (-1.230) and ginning out-turn (-1.650) has resulted in its negative correlation with yield (-0.573).

Table 17. Genotypic path analysis of seed cotton yield in Dharwad colour cotton genotypes

Characters	NM	NS	NB	BW	SI	LI	GOT	rg with SCY
NM	**0.182**	-0.123	0.008	-1.858	0.792	0.834	0.102	-0.064
NS	0.094	**-0.237**	0.320	-3.273	1.490	-0.382	2.559	0.572**
NB	0.002	-0.126	**0.602**	-4.195	1.822	-0.260	2.959	0.803**
BW	-0.069	0.158	-0.513	**4.921**	-2.190	-1.230	-1.650	-0.573**
SI	-0.065	0.159	-0.494	4.857	**-2.219**	-1.274	-1.636	-0.673**
LI	-0.037	-0.022	0.038	1.463	-0.683	**-4.139**	3.685	0.305
GOT	0.004	-0.129	0.380	-1.732	0.775	-3.254	**4.687**	0.729**

Direct effects on main diagonal
Residual effect = -0.1664
NM - No.of Monopodia; NS - No.of Sympodia; NB - Number of bolls; BW - Boll weight; SI - Seed index;
LI - Lint index; GOT - Ginning out-turn; SCY - Seed cotton yield

The seed index showed high negative direct influence (-2.219) and also had indirect effect through number of bolls (-0.494), lint index (-1.274) and ginning out-turn (-1.636). Its cumulative negative effect through all these characters as being reduced by its high indirect positive influence through boll weight (4.857).

The lint index had a high direct negative effect (-4.139) on yield, but indirect positive influence through boll weight (1.463) and ginning percentage (3.685) resulted in its positive correlation with yield (0.305).

High direct positive effect (4.687) of ginning out-turn is coupled with moderate indirect effects of number of bolls (0.380) and seed index (0.775). High negative influence through boll weight (-1.732) and lint index (-3.254) was also observed. The residual effect observed was negative and low.

4.7.2 Genotypic path analysis of seed cotton yield in Dharwad colour cotton hybrids

The path was computed with number of monopodia, number of sympodia, days to first boll burst, number of bolls, boll weight, seed index, lint index and ginning out-turn as independent traits and seed cotton yield as dependent character (Table 18).

The number of monopodia had high negative direct effect (-0.766) on seed cotton yield. Its indirect effect through number of bolls was very high and positive (1.394), whereas it was negative through boll weight (-0.292) and seed index (-0.783). The trait number of sympodia had very low positive direct effect (0.158). But its indirect effects were high and negative through number of sympodia (-0.760), boll weight (-0.357) and seed index (-0.862), whereas it was positive through numbe r of bolls (1.340).

Table 18. Genotypic path analysis of seed cotton yield in Dharwad colour cotton hybrids

Characters	NM	NS	FB	NB	BW	SI	LI	GP	rg With SCY
NM	**-0.766**	0.157	0.250	1.394	-0.292	-0.783	-0.035	0.035	0.040
NS	-0.760	**0.158**	0.225	1.340	-0.357	-0.862	-0.058	0.025	-0.289
FB	-0.590	0.110	**0.325**	1.264	-0.185	-0.723	-0.022	0.042	0.222
NB	-0.698	0.138	0.269	**1.531**	-0.238	-0.738	-0.016	0.057	0.305
BW	-0.627	-0.159	-0.169	-1.022	**0.356**	0.676	0.082	0.017	0.409
SI	0.722	-0.164	-0.283	-1.358	0.290	**0.832**	0.041	-0.038	0.041
LI	0.260	-0.088	-0.069	-0.234	0.281	0.324	**0.104**	0.063	0.642**
GOT	-0.293	0.043	0.149	0.948	0.067	-0.343	0.071	**0.092**	0.734**

Direct effects on main diagonal
Residual effect = 0.1614
NM - No.of Monopodia; NS - No.of Sympodia; NB - Number of bolls; BW - Boll weight;
FB - Days to first boll burst; SI - Seed index; LI - Lint index; GOT - Ginning out-turn;
SCY - Seed cotton yield

The character days to first boll burst had moderate direct effect (0.325). Its indirect effects through number of monopodia (-0.590), number of bolls (1.264) and seed index (-0.723) were high. The number of bolls had very high direct effect (1.531), but most of its indirect effect was through number of monopodia (-0.698), seed index (-0.738), boll weight (-0.238) and days to boll burst (0.269).

Boll weight had moderate positive direct effect (0.356) on seed cotton yield. Its indirect effects through number of monopodia (-0.627) and number of bolls (-1.022) was negative and high. Its indirect effect through seed index was positive (0.676). Seed index had high positive direct effect (0.832) on seed cotton yield. Its indirect effects through number of bolls and number of monopodia were -1.358 and 0.722, respectively.

Lint index had very less direct effect (0.104) on seed cotton yield. Its indirect effect through boll weight (0.281), seed index (0.324), number of monopodia (0.260) and number of bolls (-0.234) were moderate. Ginning out-turn had very low positive direct effect (0.092). Its indirect effect through number of bolls was positive and high (0.948), whereas indirect effects were moderate and negative through number of monopodia (-0.293) and seed index (-0.343). The residual effect observed was low and negative (-0.1614).

4.7.3 Genotypic path analysis for lint yield in Dharwad colour cotton genotypes

Genotypic path for lint yield was computed by using characters like days to first boll burst, number of bolls, seed index, lint index, seed cotton yield and GOT (Table 19).

The direct effects of seed cotton yield (0.737) and lint index (0.288) were positive and high, whereas, direct effect of days to first boll burst was very less (0.055). The characters like number of bolls (0.592), lint index (0.225), GOT (0.538) and days to first boll

Table 19. Genotypic path analysis of lint yield in Dharwad coloured cotton genotypes

Characters	NB	SI	LI	GOT	SCY	FB	rg With LY
NB	**-0.083**	0.211	0.018	0.005	0.592	0.053	0.797 **
SI	0.068	**-0.257**	0.089	-0.003	-0.496	-0.041	-0.639 * *
LI	-0.005	-0.079	**0.288**	0.007	0.225	0.001	0.436 *
GOT	-0.052	0.090	0.227	**0.009**	0.538	0.025	0.835 * *
SCY	-0.066	0.173	0.088	0.006	**0.737**	0.042	0.980 * *
FB	-0.081	0.183	0.005	0.004	0.569	**0.055**	0.741 * *

Direct effects on main diagonal
Residual effect = 0.0056
NB - No.of bolls; SI - Seed index; LI - Lint index; LY - Lint yield; GOT - Ginning out turn;
SCY - Seed cotton yield; FB - Days to first boll burst

burst (0.569) had indirect positive influence on lint yield through seed cotton yield, whereas seed index had high negative indirect influence (-0.496) on lint yield through seed cotton yield, and it also had direct negative effect (-0.257). Ginning out-turn had less direct influence on lint, but it indirectly influenced through lint index (0.227) and seed cotton yield (0.538) to a large extent. The residual effect observed was very low (0.0056).

4.7.4 Genotypic path analysis of lint yield in Dharwad colour cotton hybrids

Genotypic path for lint yield was computed by utilizing characters like number of monopodia, number of sympodia, days to first boll burst, number of bolls, boll weight, seed index, lint index, ginning out-turn and seed cotton yield (Table 20).

The number of monopodia had high positive direct effect (0.652) on lint yield, but its indirect effect through number of bolls was negative (-0.811) and very high. Similarly negative indirect effect was seen through boll weight (-0.272) and days to first boll burst (-0.160). The indirect effect was positive through characters like number of sympodia (0.190), lint index (0.209), ginning out-turn (0.232).

Number of sympodia had very low but positive direct effect but it had high indirect effects through characters like number of monopodia (0.647), number of bolls (-0.779), boll weight (-0.333), seed cotton yield (-0.347) and lint index (0.342). Days to first boll burst had negative direct effect (-0.207) on lint yield. Its indirect influence through characters like number of monopodia (0.502), number of bolls (-0.735) and seed cotton yield (0.233) ranged from moderate to high.

Number of bolls had very high negative direct effect (-0.890) on lint yield. Its indirect effects through other characters were 0.594 (number of monopodia), 0.376 (ginning out-turn), 0.366 (seed cotton yield), -0.222 (boll weight) and –0.171 (days to first boll burst).

Table 20. Genoypic path analysis of lint yield in Dharwad coloured cotton hybrids

Characters	NM	NS	FB	NB	BW	SI	LI	GP	SCY	rg With LY
NM	**0.652**	0.190	-0.160	-0.811	-0.272	0.055	0.209	0.232	-0.048	-0.049
NS	0.647	**0.191**	-0.144	-0.779	-0.333	0.060	0.342	0.164	-0.347	-0.198
FB	0.502	0.133	**-0.207**	-0.735	-0.172	0.051	0.131	0.279	0.233	0.246
NB	0.594	0.168	-0.171	**-0.890**	-0.222	0.0502	0.094	0.376	0.366	0.367
BW	-0.534	-0.192	0.108	0.594	**0.322**	-0.047	-0.485	0.114	0.491	0.380
SI	-0.614	-0.198	0.180	0.789	0.270	**-0.058**	-0.240	-0.250	0.050	-0.072
LI	-0.222	-0.107	0.044	0.136	0.262	-0.023	**-0.615**	0.416	0.771	0.662**
GOT	0.250	0.052	-0.095	0.551	0.062	0.024	-0.421	**0.607**	0.882	0.809**
SCY	-0.026	-0.055	-0.046	-0.272	0.136	-0.002	-0.395	0.446	**1.201**	0.986**

Direct effects on main diagonal
Residual = 0.0147
NM - No.of Monpodia; NS - No.of Sympodia; NB - No.of bolls; SI - Seed index; LI - Lint index; LY - Lint yield;
GOT - Ginning out turn; SCY - Seed cotton yield; FB - Days to first boll burst; BW - Boll weight

Boll weight also had moderate positive direct effect (0.332), but its indirect effects through other characters were on higher side. The indirect effects through number of monopodia (-0.534), number of bolls (0.594), lint index (-0.485) and seed cotton yield (0.491) were important.

Seed index had very low direct effect (-0.058) on lint yield but it had high positive indirect effect through number of bolls (0.789), whereas through number of monopodia indirect effect was negative and high (-0.614). Moderate indirect effect through boll weight (0.270), lint index (-0.240) and ginning out-turn (-0.250) were also observed.

Lint index had high negative direct effect (-0.615) on lint yield. Its indirect effects through characters like ginning out-turn (0.416) and seed cotton yield (0.771) were high, and positive. Moderate indirect effects were also observed through number of monopodia (-0.222) and boll weight (0.262). Ginning out-turn had positive direct effect (0.607) and high indirect effect through seed cotton yield (0.882). Seed cotton yield had very high positive direct effect (1.201) on lint yield. Its indirect effects through other characters were 0.446 (ginning out-turn), -0.395 (lint index) and -0.272 (number of bolls). The residual effect observed was low and negative (-0.147).

4.7.5 Path analysis for fibre length in Dharwad colour cotton genotypes

The path analysis was performed with uniformity ratio, micronaire, maturity coefficient and strength as independent variables having influence on fibre length. The direct effect of uniformity ratio was negative (-0.299) but its indirect effect through fibre fineness (0.193) and fibre strength (0.055) was positive, whereas indirect effect through maturity coefficient was negative (-0.164) (Table 21).

Table 21. Path analysis of fibre length in Dharwad colour cotton genotypes

Characters	UR	Mic	MC	FS	Correlation With FL
UR	**-0.299**	0.193	-0.164	0.055	-0.215
Mic	0.123	**-0.468**	0.117	-0.078	-0.306
MC	-0.217	0.244	**-0.225**	0.012	-0.186
FS	-0.032	0.070	-0.005	**0.520**	0.554**

Direct effects on main diagonal
Residual effect = 0.4627
UR - Uniformity ratio; Mic - Micronaire value; MC - Maturity coefficient;
FS - Fibre strength; FL - 2.5% Span length

The direct effect of fibre fineness (micronaire) was negative and high (-0.468). Its indirect effects through uniformity ratio (0.123) and maturity coefficient (0.117) was positive but through fibre strength negative indirect effect (-0.078) was observed.

Maturity coefficient also had moderate negative direct effect (-0.225). Its indirect effect through uniformity ratio was negative (-0.217), whereas it was positive through fibre fineness (0.244). The fibre strength had high positive direct effect (0.52) on fibre length. It had low indirect through uniformity ratio (-0.032) and maturity coefficient (-0.005), whereas its indirect effect through micronaire was positive but low. The residual effect observed was high (0.463).

4.7.6 Path analysis for fibre length in Dharwad colour cotton hybrids

Path for fibre length was computed by taking fibre length as dependent variable and uniformity ratio, micronaire, maturity coefficient as independent variable. The direct effects of uniformity ratio was negative and high (-0.548), whereas its indirect effects through other characters were positive and high through micronaire value (0.311), and low through maturity coefficient (0.041) and fibre strength (0.056). The direct effect of micronaire value of fibre length was negative and high (-0.772), whereas its indirect effects through other characters were uniformity ratio (0.220), maturity coefficient (-0.114) and fibre strength (-0.075) were low. The direct effect of maturity coefficient was low (0.119) whereas its indirect effect through micronaire was very high (0.740), and through uniformity ratio it was moderate and negative (-0.190). In case of fibre strength direct effect on fibre length was low (0.14) but its indirect effect through micronaire was high (0.415) and through uniformity ratio it was negative (-0.219) and moderate (Table 22).

Table 22. Path analysis of fibre length in Dharwad colour cotton hybrids

Characters	UR	Mic	MC	FS	Correlation With FL
UR	**-0.548**	0.311	0.041	0.056	-0.140
Mic	0.220	**-0.772**	-0.114	-0.075	-0.741**
MC	-0.190	0.740	**0.119**	0.079	0.748**
FS	-0.219	0.415	0.067	**0.140**	0.403

Direct effects on main diagonal
Residual = 0.2054
UR - Uniformity ratio; Mic - Micronaire value; MC - Maturity coefficient;
FS - Fibre strength; FL - 2.5% Span length

4.7.7 Path for fibre quality index (FQI) in Dharwad colour cotton hybrids

Fibre length had high positive direct effect on FQI. Its indirect effects through different fibre parameters was positive viz., through micronaire (0.394) and fibre strength (0.180), whereas it was negative through maturity coefficienty (-0.146). Uniformity ratio reported very low negtive direct effect on FQI. Its indirect effect through micronaire and strength were 0.214 and 0.180 respectively. Fibre fineness had very high direct negative effect (-0.532) and also indirect effects through fibre length (0.307) and strength (-0.241), but it was positive (0.187) through maturity coefficient (Table 23).

Maturity coefficient had negative direct effect (-0.196) on FQI but its indirect effects was positive through fibre length (0.309). Fibre strength had high direct effect (0.449) on fibre quality index. Its indirect effect through fibre length was 0.166 and fibre fineness (0.285). In Dharwad colour cotton genotypes the residual effect in the path for fibre quality index was very high therefore, it has not been presented.

4.7.8 Path analysis for count strength product (CSP) in Dharwad colour cotton hybrids

The direct effect of fibre length on count strength product (CSP) was negative (-0.167) whereas its indirect effect through FQI was very high (0.733) and it was low through maturity coefficient (0.164). Uniformity ratio had negative direct effect (-0.153) on CSP, whereas its indirect effect through FQI was 0.216. Direct effect of micronaire was very less but it had high negative indirect effect through FQI (-0.768) and maturity coefficient (-0.210). Indirect effect through fibre length was low (0.124). Maturity coefficient had direct positive effect on CSP, so also its indirect effect through FQI (0.755). Its indirect effect through fibre length was negative (-0.125). Fibre strength had very little direct effect

Table 23. Path analysis of fibre quality index (FQI) in Dharwad colour cotton hybrids

Characters	FL	UR	Mic	MC	FS	Correlation With FQI
FL	**0.414**	0.003	0.394	-0.146	0.180	0.845**
UR	-0.058	**-0.019**	0.214	-0.068	0.180	0.249
Mic	-0.307	0.008	**-0.532**	0.187	-0.241	-0.884**
MC	0.309	-0.007	0.600	**-0.196**	0.253	0.870**
FS	0.166	-0.008	0.285	-0.110	**0.449**	0.783**

Direct effects on main diagonal
Residual = 0.0040
UR - Uniformity ratio; Mic - Micronaire value; MC - Maturity coefficient;
FS - Fibre strength; FL - 2.5% Span length

Table 24. Path analysis of counts strength product (CSP) in Dharwad coloured cotton hybrids

Characters	FL	UR	Mic	MC	FS	FQI	Correlation With CSP
FL	**-0.167**	0.021	-0.023	0.164	0.020	0.733	0.748**
UR	0.023	**-0.153**	-0.013	0.076	0.020	0.216	0.169
Mic	0.124	0.061	**0.031**	-0.210	-0.027	-0.768	-0.789**
MC	-0.125	-0.053	-0.030	**0.219**	0.028	0.755	0.794**
FS	-0.067	-0.060	-0.017	0.124	**0.050**	0.680	0.710**
FQI	-0.141	-0.038	-0.028	0.191	0.039	**0.868**	0.891**

Direct effects on main diagonal
Residual = 0.1920
UR - Uniformity ratio; Mic - Micronaire value; MC - Maturity coefficient;
FS - Fibre strength; FL - 2.5% Span length; FQI - Fibre quality index

on CSP but its indirect effect through FQI was very high (0.680), which was followed by indirect effect through maturity coefficient (0.124). Fibre quality index had very high positive direct effect (0.868) on CSP. Its indirect effect through maturity coefficient and fibre length were 0.191 and –0.141, respectively (Table 24). In Dharwad colour cotton genotypes the residual effect in the path for count strength product was very high therefore, it has not been presented.

4.8 Heterosis

Heterosis was computed over Mid Parent (MP), Better Parent (BP), Colour linted parent (CP), White linted parent (WP) and two white linted hybrid checks viz., DHH-11 and NHH-44.

4.8.1 Growth and yield paraeters

4.8.1.1 Plant height

The diploid hybrid DCCH-9 showed significant heterosis over MP (20.31%), BP (14.76%), CP (14.77%), WP (26.46%) and both checks (48.92 and 51.83%), whereas another diploid hybrid DCCH-10 was significantly superior over both checks (25.99 and 29.15%). DCCH-6 intra *hirsutum* hybrid had significant heterosis over mid parent (15.72%). Similarly DCCH-1 (16.45%), DCCH-6 (19.11%), DCCH-8 (19.04%) showed significant positive heterosis over colour linted parents (Table 25).

4.8.1.2 Number of monopodia

Intra *hirsutum* hybrids DCCH-3 (-45.05%) and DCCH-8 (-41.39%) had highly significant whereas, DCCH-7 was having only significant negative heterosis over BP (-30.40%). The diploid hybrid DCCH-10 had significant positive heterosis over mid parent (36.79%), better parent (18.60%), colour linted parent (61.58%), white linted parent (18.6%),

Table 25. Estimates of heterosis for plant height

Hybrids	Heterosis over					
	Mid parent	Better Parent	Colour Parent	White Parent	DHH-11	NHH-44
DCCH-1	13.48	10.66	16.45*	10.66	5.41	8.05
DCCH-2	7.59	4.92	10.41	4.90	-0.05	2.45
DCCH-3	3.33	-3.77	11.56	3.77	0.99	3.52
DCCH-4	4.34	-2.82	12.65	-2.83	1.97	4.53
DCCH-5	8.40	5.41	11.57	5.41	0.41	2.93
DCCH-6	15.72*	12.52	19.1*	12.52	7.18	9.87
DCCH-7	-2.27	0.00	5.84	9.23	-4.74	-2.35
DCCH-8	9.91	12.46*	19.04*	2.08	-7.13	9.81
DCCH-9	20.31**	14.76*	14.77*	26.46**	48.42**	51.83**
DCCH-10	2.35	-2.37	-2.38	7.56	25.99**	29.15**
CD at 1%	a 21.98	b 25.38				
CD at 5%	16.32	18.84				

*,** - Significant at 5% and 1% level
a – Significance for mid parent; b – significant for all others

Table 26. Estimates of heterosis for number of monopodia

Hybrids	Heterosis over					
	Mid parent	Better parent	Colour parent	White parent	DHH-11	NHH-44
DCCH-1	-7.25	-21.39	13.08	-21.39	-26.50	-23.83
DCCH-2	38.80	17.65	69.23*	17.65	10.00	13.98
DCCH-3	-25.55	-45.05**	15.38	-45.05**	-25.50	-22.27
DCCH-4	5.70	21.97	63.85*	-21.98	6.50	10.36
DCCH-5	10.00	0.00	22.22	-	-6.50	-3.10
DCCH-6	17.65	6.95	30.72	6.95	0.00	3.62
DCCH-7	-10.79	-30.40*	24.18	-30.40*	-5.00	-1.55
DCCH-8	-24.88	-41.39**	4.5	-41.39**	-20.00	-17.09
DCCH-9	7.72	-6.60	27.25*	-6.60	133.50**	141.96**
DCCH-10	36.79**	18.60*	61.58**	18.6*	196.50**	207.25**
CD at 1%	a 0.92	b 1.06				
CD at 5%	0.68	0.92				

*,** - Significant at 5% and 1% level
(a) – Significance over mid parent; (b) – Significance over all others

checks DHH-11 (196.5%) and NHH-44 (207.25%). The hybrids DCCH-2 (69.23%), DCCH-4 (63.85%) and DCCH-9 (27.25%) registered significant positive heterosis over colour linted parents, whereas DCCH-3 (-45.05), DCCH-7 (-30.40%) and DCCH-9 (-41.39%) reported significant negative heterosis over white linted parent (Table 26).

4.8.1.3 Number of sympodia

Only diploid hybrid DCCH-10 showed highly significant positive heterosis over checks DHH-11 (21.42%) and NHH-44 (16.85%). No hybrid had significant heterosis over MP, BP, CP and WP (Table 27).

4.8.1.4 Days to first boll burst

The hybrid DCCH-4 showed significant negative heterosis over better parent (-4.93%), colour linted parent (-4.93%) and check DHH-11 (-4.69%). DCCH-8 reported negative heterosis over both checks. Highly significant and positive heterosis for days to first boll burst was observed in DCCH-3 (5.23%), DCCH-5 (5.06%), DCCH-7 (7.25%) and DCCH-6 (7.87%) over their mid parental values. DCCH-7 also had positive heterosis over BP (5.31%), CP (9.28%) and WP (5.31%). The diploid hybrid DCCH-10 had highly significant positive heterosis over both checks DHH-11 (6.77%) and NHH-44 (8.75%), whereas DCCH-9 possessed significant heterosis over NHH-44 (5.83%). The hybrids DCCH-5 and DCCH-6 had significant positive heterosis over CP. The intra *hirsutum* hybrids DCCH-2 (4.38%), DCCH-3 (9.5%), DCCH-6 (4.65%), reported significant positive heterosis over white linted parent (Table 28).

4.8.1.5 Number of bolls

Diploid hybrids DCCH-9 and DCCH-10 were having significant positive heterosis over DHH-11 (34.19 and 48.35%) and NHH-44 (77.68 and 96.43%, respectively).

Table 27. Estimates of heterosis for number of sympodia

Hybrids	Heterosis over					
	Mid parent	Better parent	Colour parent	White parent	DHH-11	NHH-44
DCCH-1	-6.75	-10.97	2.12	-10.98	-8.17	-11.62
DCCH-2	2.37	-2.26	7.46	-2.26	0.81	-2.97
DCCH-3	3.57	0.73	10.76	1.13	3.91	0.00
DCCH-4	0.49	-2.26	7.47	-2.27	0.81	-2.97
DCCH-5	-6.92	-7.77	7.77	-6.06	-3.09	-6.74
DCCH-6	-3.56	-4.44	-4.44	-2.65	02.40	-3.37
DCCH-7	-9.16	-10.00	-10.00	-8.32	-5.42	-8.98
DCCH-8	-1.17	-2.61	-2.61	0.79	2.33	-1.51
DCCH-9	17.58	-0.25	-0.25	2.33	38.17	32.97
DCCH-10	3.32	-12.47	12.35	10.07	21.42**	16.85**
CD at 1%	a 4.35	b 5.02				
CD at 5%	3.23	4.35				

*,** - Significant at 5% and 1% level
(a) – Significance over mid parent; (b) – Significance over all others

Table 28. Estimates of heterosis for number of days to first boll burst

Hybrids	Heterosis over					
	Mid parent	Better parent	Colour Parent	White parent	DHH-11	NHH-44
DCCH-1	-1.61	-3.37	-3.37	1.38	-3.12	-1.33
DCCH-2	1.87	-0.51	-5.14	4.38*	-0.258	1.59
DCCH-3	5.23**	1.82	1.82	9.50**	2.08	3.98
DCCH-4	-1.48	-4.93*	-4.93*	2.24	-4.69*	2.92
DCCH-5	5.06*	1.91	8.41**	1.92	-2.60	-0.796
DCCH-6	7.87**	4.63	11.30**	4.65*	0.00	1.85
DCCH-7	7.25**	5.31*	9.28**	5.31*	-1.82	0.00
DCCH-8	-2.42	-4.19	0.58	-4.19	-10.68**	-9.02**
DCCH-9	-0.37	-2.44	1.78	-2.44	3.91	5.83**
DCCH-10	2.37	0.249	4.59*	0.25	6.77**	8.75**
CD at 1%	a 6.75	b 7.79				
CD at 5%	5.01	5.78				

*,** - Significant at 1% and 5% level
(a) – Significance over mid parent; (b) – Significance over all others

The intra *hirsutum* hybrid DCCH-3 reported significant positive heterosis over NHH-44 (33.93%). The hybrids DCCH-5 (-34.59%) and DCCH-6 (-30.55%) had significant negative heterosis over the check DHH-11. The hybrids DCCH-6 (82.95%), DCCH-7 (117.94%) and DCCH-8 (143.87%) had high significant positive heterosis over colour linted parent (Table 29).

4.8.1.6 Boll weight

The hybrids DCCH-4 (23.52%), DCCH-7 (17.33%) and DCCH-8 (24.39%) had highly significant positive heterosis over mid parent. Similarly DCCH-5 had significant heterosis (15.17%) over mid parent. Significant negative heterosis over better parent was observed for hybrids DCCH-1 (-13.49) and DCCH-6 (-13.49), whereas hybrids DCCH-2 (13.99%) and DCCH-4 (21.14%) had significant positive heterosis over BP. DCCH-9 and DCCH-10 showed highly significant negative heterosis over checks DHH-11 (-51.69 and -56.86%), and NHH-44 (-41.73 and -47.96%, respectively). All intra *hirsutum* hybrids except DCCH-3 had significant positive heterosis over white linted check NHH-44 (Table 30).

4.8.1.7 Seed index

No hybrid showed any significant heterosis over BP and MP. The diploid hybrids DCCH-9 and DCCH-10 showed significant negative heterosis over checks DHH-11 (-15.46 and -19.26%) and NHH-44 (-21.44 and 24.97%, respectively). Except DCCH-6 all intra *hirsutum* hybrids had significant positive heterosis over DHH-11, whereas only two intra *hirsutum* hybrids DCCH-4 (14.36%) and DCCH-8 (21.44%) had positive significant heterosis over NHH-44 (Table 31).

Table 29. Estimate of heterosis for number of bolls

Hybrids	Heterosis over					
	Mid parent	Better parent	Colour Parent	White parent	DHH-11	NHH-44
DCCH-1	9.59	1.44	1.44	19.16	-19.83	7.14
DCCH-2	13.88	5.41	5.41	23.83	-15.92	11.34
DCCH-3	21.56	10.96	34.40	10.96	7.22	33.93*
DCCH-4	7.26	-2.09	18.60	2.09	-5.39	25.27
DCCH-5	23.57	-3.67	72.30	-3.67	-34.59*	-13.39
DCCH-6	31.21	2.28	82.98*	2.28	-30.55*	-8.04
DCCH-7	22.95	-14.38	117.94**	-14.38	-17.26	9.55
DCCH-8	37.58	-4.19	143.87**	-4.18	-7.42	22.59
DCCH-9	5.29	-4.03	6.59	4.03	34.19*	77.68**
DCCH-10	16.40	15.00	17.84	15.00	48.35**	96.43**
CD at 1%	a 4.98	b 5.75				
CD at 5%	3.70	4.27				

*,** - Significant at 1% and 5% level
(a) – Significance over mid parent; (b) – Significance over all others

Table 30. Estimates of heterosis for boll weight

Hybrids	Heterosis over					
	Mid parent	Better Parent	Colour Parent	White parent	DHH-11	NHH-44
DCCH-1	-0.67	-13.49*	16.6	-13.49*	1.99	23.02*
DCCH-2	-1.26	13.99*	15.9	-13.99*	1.39	22.30*
DCCH-3	10.54	8.41	8.41	12.76	-5.17	14.39
DCCH-4	23.52**	21.14*	21.14*	26.00**	5.96	24.82**
DCCH-5	15.17*	-12.31	67.74**	-12.31	3.38	24.70*
DCCH-6	13.62	-13.49*	65.48**	-13.49*	1.99	23.02*
DCCH-7	17.33**	1.65	38.70**	1.65	-14.51	3.12
DCCH-8	24.39**	8.04	47.42**	8.03	-9.15	9.59
DCCH-9	6.58	4.29	4.29	8.96	-51.69**	-41.73**
DCCH-10	-4.82	-6.87	-6.87	-2.69	-56.86**	-47.96**
CD at 1%	a 0.90	b 1.04				
CD at 5%	0.67	0.77				

*,** - Significant at 5% and 1% level
(a) – Significance over mid parent; (b) – Significance over all others

Table 31. Estimates of heterosis for seed index

Hybrids	Heterosis over					
	Mid parent	Better Parent	Colour Parent	White Parent	DHH-11	NHH-44
DCCH-1	-1.62	-3.19	0.00	-3.19	15.34*	7.18
DCCH-2	-1.62	-3.19	0.00	-3.19	15.34*	7.18
DCCH-3	3.47	0.00	0.00	7.18	15.34*	7.18
DCCH-4	10.39	6.70	6.70	14.36*	20.07**	14.36*
DCCH-5	0.00	0.00	0.00	0.00	19.15*	10.72
DCCH-6	-6.39	-6.39	-6.38	-6.39	11.53	3.64
DCCH-7	5.09	0.00	0.00	10.72	19.15*	10.72
DCCH-8	15.26	9.68	9.68	21.44**	30.68**	21.44**
DCCH-9	2.30	0.00	4.71	0.00	-15.46*	-21.44**
DCCH-10	-2.30	-4.50	0.00	-4.50	-19.26*	-24.97**
CD at 1%	a 1.48	b 1.71				
CD at 5%	1.20	1.27				

*,** - Significant at 5% and 1% level
a – Significance for mid parent; b – significant for all others

4.8.1.8 Lint index

Highly significant positive heterosis was seen over mid parent for the hybrids DCCH-7 (25.31%) and DCCH-8 (28.77%). The hybrids DCCH-1 (-23.78%), DCCH-2 (-26.68%), DCCH-5 (-30.97%) and DCCH-6 (-26.33%) recorded highly significant negative heterosis over better parent. Only DCCH-9 showed significant negative heterosis over check DHH-11 (-25-82%), whereas other hybrids did not possess significant heterosis over checks (Table 32).

4.8.1.9 Ginning out-turn

The hybrid DCCH-7 had significant positive heterosis over mid parent (15.47%), whereas all intra *hirsutum* hybrids except DCCH-4 had highly significant heterosis over BP. Similarly, hybrids DCCH-2, DCCH-5, DCCH-6, DCCH-7 and DCCH-8 had significant negative heterosis over DHH-11 check (Table 33).

4.8.1.10 Seed cotton yield

Highly significant positive heterosis was observed over mid parent in intra *hirsutum* hybrids DCCH-2 (40.98%), DCCH-5 (44.19%), DCCH-3 (49.84%), DCCH-1 (69.67%), DCCH-6 (80.23%) and in diploid hybrids DCCH-9 (67.71%) and DCCH-10 (38.12%). One each of intra *hirsutum* hybrid DCCH-1 (52.2%) and diploid hybrid DCCH-9 (54.45%) showed significant heterosis over better parent. The hybrids DCCH-5 (-38.9%), DCCH-6 (-23.65%) and DCCH-10 (-24.14%) had highly significant negative heterosis over check DHH-11. Similarly DCCH-3 (34.5%), DCCH-4 (9.3%) had significant positive heterosis over NHH-44, whereas DCCH-7 had significant negative heterosis over NHH-44 (-12.86%). The hybrids DCCH-1 (1.97%) and DCCH-3 (13.3%) recorded positive heterosis over DHH-11 check (Table 34).

Table 32. Estimates of heterosis for lint index

Hybrids	Heterosis over					
	Mid parent	Better Parent	Colour Parent	White Parent	DHH-11	NHH-44
DCCH-1	-1.57	-23.78**	38.98**	-26.78**	7.35	20.99
DCCH-2	-5.32	-26.68**	33.62**	-26.68**	3.27	16.39
DCCH-3	6.74	-8.96	28.96*	-8.96	-0.33	12.34
DCCH-4	9.19	-6.87	31.92*	6.87	1.96	14.92
DCCH-5	38.05	-30.97**	91.94**	-30.97**	-2.78	9.58
DCCH-6	47.33	-26.33**	104.80**	-26.33**	3.76	16.94
DCCH-7	25.31*	-8.36	98.06**	8.36	0.33	13.07
DCCH-8	28.77*	-5.82	103.50**	-5.82	3.10	16.20
DCCH-9	-3.40	-8.47	16.82	-8.47	-25.82*	-16.39
DCCH-10	9.36	3.63	7.50	3.63	-16.01	-5.34
CD at 1%	a 1.44	b 1.67				
CD at 5%	1.07	1.24				

*,** - Significant at 5% and 1% level
a – Significance for mid parent; b – significant for all others

Table 33. Estimates of heterosis for ginning out-turn

Hybrids	Heterosis over					
	Mid parent	Better Parent	Colour Parent	White Parent	DHH-11	NHH-44
DCCH-1	2.56	-12.38**	-3.35	-12.38**	-7.19	8.17
DCCH-2	2.33	-16.56**	-7.96	-16.56**	-11.62	3.01
DCCH-3	2.05	-9.45*	-8.64	-9.45	12.27	2.25
DCCH-4	6.25	-5.72	-4.88	-5.72	-8.67	6.46
DCCH-5	6.64	-19.69**	58.67**	-19.69**	-14.93**	-0.84
DCCH-6	12.14	-15.52**	66.84**	-17.97**	-10.54*	4.26
DCCH-7	15.47*	-10.32*	62.06**	-10.32*	-13.17**	1.27
DCCH-8	10.60	-14.09**	55.24**	-14.09*	-16.75**	-2.98
DCCH-9	0.92	-1.21	3.16	-1.22	-7.19	8.17
DCCH-10	5.31	3.04	7.64	3.00	-3.16	-12.87*
CD at 1%	a 4.87	b 5.62				
CD at 5%	3.61	4.14				

*,** - Significant at 5% and 1% level
a – Significance for mid parent; b – significant for all others

Table 34. Estimates of heterosis for seed cotton yield

Hybrids	Heterosis over					
	Mid parent	Better Parent	Colour Parent	White Parent	DHH-11	NHH-44
DCCH-1	69.67**	52.21**	91.95**	52.19**	1.97	21.05
DCCH-2	40.98**	26.47	59.43**	26.39**	-15.27	0.58
DCCH-3	49.84**	15.58	114.90**	16.28**	13.30	34.50**
DCCH-4	21.82	-6.03	73.54**	-6.01**	-7.82	9.36*
DCCH-5	44.19**	-8.82	246.66**	-9.09**	-38.92**	-27.48
DCCH-6	80.23**	13.97	367.67**	22.64**	-23.65*	-9.36
DCCH-7	26.81	-25.12	357.00**	-18.25**	-26.60*	-12.86*
DCCH-8	38.72*	-18.09	319.00**	-25.04**	-19.70	-4.68
DCCH-9	67.71**	54.45**	83.00**	54.55**	-7.82	-9.36
DCCH-10	38.12*	27.27	50.25**	26.84**	-24.14*	-9.94
CD at 1%	a 0.52	B 0.60				
CD at 5%	0.39	0.45				

*,** - Significant at 5% and 1% level
a – Significance for mid parent; b – significant for all others

4.8.1.11 Lint yield

It was observed that all hybrids had highly significant heterosis over colour linted parent, whereas only DCCH-1 (32.30%) was having significant heterosis over white linted parent and DCCH-7 (-26.60%), DCCH-8 (-33.83%) and DCCH-9 (-50.83%) had negative heterosis. No hybrids had positive heterosis over white check DHH-11 but DCCH-1 (26.53%), DCCH-3 (37.78%) had positive heterosis over NHH-44 (Table 35).

4.8.2 Heterosis for fibre properties

The heterosis was computed for different fibre characters over colour linted parents, white linted parent and both white linted hybrid checks DHH-11 and NHH-44.

4.8.2.1 2.5 per cent span length

No hybrids had significant heterosis over mid parent. All intra *hirsutum* hybrids except DCCH-7 showed significant positive heterosis over colour linted parents, whereas in case of diploid hybrids the heterosis observed was negative. All intra *hirsutum* hybrids except DCCH-2 had negative heterosis over their white linted parents, but in case of diploid hybrids it was vice versa. DCCH-2 had highly significant heterosis over checks DHH-11 (9.77%) and NHH-44 (15.9%). Other hybrids showed negative heterosis over the check DHH-11. Most of the intra *hirsutum* hybrids were having significant positive heterosis over NHH-44, whereas diploid hybrids had negative heterosis over NHH-44 (Table 36).

4.8.2.2 Uniformity ratio

The hybrids DCCH-1 (3.37%), DCCH-5 (6.82%), DCCH-9 (3.5%) and DCCH-10 (3.5%) had significant positive heterosis over mid parent, but DCCH-6 (-4.55%) and DCCH-8 (-3.23%) showed negative heterosis. All intra *hirsutum* hybrids except DCCH-5 and DCCH-7 showed highly significant negative heterosis over colour linted

Table 35. Estimates of heterosis for lint yield

Hybrids	Heterosis over					
	Mid parent	Better Parent	Colour Parent	White Parent	DHH-11	NHH-44
DCCH-1	68.65**	32.33*	132.5**	32.30*	-7.27	29.53*
DCCH-2	34.96*	5.89	86.03**	5.87	-25.80*	3.65
DCCH-3	46.86**	4.44	147.30**	4.44	-1.37	37.78**
DCCH-4	23.68	-12.04	108.30**	-12.04	-16.93	42.45
DCCH-5	29.55	-26.56	449.06**	-26.57	-48.54**	-28.11*
DCCH-6	69.26**	-3.86	618.80**	-3.88	-32.63**	5.89
DCCH-7	33.44	-26.66*	639.00**	-26.66*	-30.74**	-3.24
DCCH-8	16.73	-35.82**	546.61**	-35.83**	-39.39**	-15.34
DCCH-9	66.70**	50.63**	86.61**	-50.63**	-16.31	16.91
DCCH-10	44.71**	30.77	62.00**	30.77	-27.35**	1.49
CD at 1%	a 165.42	b191.02				
CD at 5%	123.24	142.32				

*,** - Significant at 5% and 1% level
a – Significance for mid parent; b – significant for all others

Table 36. Estimates of heterosis for fibre length

Hybrids	Heterosis over				
	Mid parent	Colour parent	White parent	DHH-11	NHH-44
DCCH-1	4.39	16.10**	-5.32**	0.40	5.95*
DCCH-2	14.01	27.02**	3.55	9.77**	15.90**
DCCH-3	0.50	9.57**	-7.01**	-5.30*	0.00
DCCH-4	0.50	9.57**	-7.01**	-5.30*	0.00
DCCH-5	4.10	17.80**	-3.90	1.90	7.54**
DCCH-6	10.90	23.50**	0.71	4.01	12.70**
DCCH-7	-3.80	4.78	-11.10	-9.40**	-4.37
DCCH-8	3.39	12.60**	-4.43	2.63	-2.77
DCCH-9	4.20	-4.70	14.87**	-15.80**	-11.11**
DCCH-10	2.30	-5.96*	13.33**	-16.90**	-12.30**
CD at 1%	1.26				
CD at 5%	1.74				

*,** - Significant at 5% and 1% level

parents, whereas diploid hybrids DCCH-9 (4.76%) and DCCH-10 (4.76%) had highly significant positive heterosis. Except DCCH-8 all other hybrids possessed significant positive heterosis over white linted parents. Highly significant positive heterosis over check DHH-11 was observed in all hybrids except DCCH-6. Except DCCH-4 and DCCH-8 all other hybrids had significant heterosis over another white linted check NHH-44 (Table 37).

4.8.2.3 Fibre fineness

All intra *hirsutum* hybrids except DCCH-8 showed negative heterosis over mid parent and both diploid hybrids recorded positive heterosis. Negative heterosis over colour linted parents was observed in the hybrids DCCH-1 (-15.56%), DCCH-2 (-22.22%), DCCH-3 (-13.33%) and DCCH-4 (-15.56%), whereas positive heterosis was noticed in hybrids DCCH-8, DCCH-9 and DCCH-10 (10.94%). All hybrids showed negative heterosis over their respective white linted parents. All intra *hirsutum* hybrids possessed negative heterosis over white linted check DHH-11, whereas diploid hybrids DCCH-9 and DCCH-10 had positive significant heterosis over DHH-11 and NHH-44 (Table 38).

4.8.2.4 Fibre maturity coefficient

Highly significant positive heterosis over mid parent was observed in hybrids DCCH-3 (6.85%), DCCH-5 (11.43%), DCCH-6 (11.43%), DCCH-7 (4.23%) and DCCH-8 (9.86%). The heterosis over colour linted parents was highly significant and positive in all hybrids. Negative and significant heterosis over white linted parents and checks viz., DHH-11 and NHH-44 was observed in all hybrids, except DCCH-7 which showed positive significant heterosis over NHH-44 (Table 39).

Table 37. Estimates of heterosis for fibre uniformity ratio

Hybrids	Heterosis over				
	Mid parent	Colour parent	White parent	DHH-11	NHH-44
DCCH-1	3.37**	-4.17**	12.20**	6.97**	2.22*
DCCH-2	-1.12	-8.33**	7.30**	2.33*	-2.22*
DCCH-3	-2.13	-4.17**	0.00	6.97**	2.22*
DCCH-4	-2.13	-4.17**	0.00	6.97**	2.22*
DCCH-5	6.82**	0.00	14.63**	9.30**	4.44**
DCCH-6	-4.55**	-10.64**	2.43*	-2.33*	-6.66**
DCCH-7	1.10	0.00	2.17*	9.30**	4.44**
DCCH-8	-3.23**	-4.26**	-2.17*	4.65**	0.00
DCCH-9	3.50**	4.76**	2.32*	2.33*	-2.22*
DCCH-10	3.50**	4.76**	2.32*	2.33*	-2.22*
CD at 1%	1.01				
CD at 5%	1.39				

*,** - Significant at 5% and 1% level

Table 38. Estimates of heterosis for fibre fineness (Micronaire)

Hybrids	Heterosis over				
	Mid parent	Colour parent	White parent	DHH-11	NHH-44
DCCH-1	-11.63	-15.56*	-7.32	-13.64	-2.56
DCCH-2	-18.60*	-22.22**	-14.63	-20.45**	-10.26
DCCH-3	-10.34	-13.33	-7.14	-11.36	0.00
DCCH-4	-14.94*	-15.56*	-11.90	-15.91*	-5.13
DCCH-5	-3.80	0.00	-7.32	-13.64	-2.56
DCCH-6	-1.27	2.63	-4.88	-11.36	0.00
DCCH-7	-7.50	-2.50	-11.90	-15.91*	-5.13
DCCH-8	2.50	7.89	-2.38	-6.82	5.12
DCCH-9	1.45	9.38	-5.40	59.09**	79.49**
DCCH-10	2.90	10.94*	-4.05	61.36**	82.05**
CD at 1%	0.65				
CD at 5%	0.89				

*,** - Significant at 5% and 1% level

Table 39. Estimates of heterosis for fibre maturity coefficient

Hybrids	Heterosis over				
	Mid parent	Colour parent	White parent	DHH-11	NHH-44
DCCH-1	1.39	10.60**	-6.41**	-9.88**	-6.41**
DCCH-2	-1.39	7.56**	-8.97**	-12.35**	-8.97**
DCCH-3	6.85**	18.18**	-2.50*	-3.70**	0.00
DCCH-4	1.39	12.12**	-7.50**	-8.64**	-5.13**
DCCH-5	11.43**	25.81**	0.00	-3.70**	0.00
DCCH-6	11.43**	25.81**	0.00	-3.70**	0.00
DCCH-7	4.23**	19.35**	-7.50**	-8.64**	5.13**
DCCH-8	9.86**	25.81**	-2.50*	-3.70**	0.00
DCCH-9	0.00	0.00	0.00	0.00	0.00
DCCH-10	0.00	0.00	0.00	0.00	0.00
CD at 1%	0.02				
CD at 5%	0.03				

*,** - Significant at 5% and 1% level

4.8.2.5 Fibre strength (Tenacity)

All intra *hirsutum* hybrids had highly significant positive heterosis over mid, colour linted parents, white linted parents and check hybrids DHH-11 and NHH-44. The diploid hybrid DCCH-9 had significant positive heterosis over mid parent (6.19%), colour linted parents (13.99%) and check NHH-44 (11.64%). Another diploid hybrid DCCH-10 reported significant positive heterosis over colour linted parents (6.3%), white linted parents (7.32%) and significant negative heterosis over DHH-11 (-8.98%) (Table 40).

4.8.2.6 Fibre quality index (FQI)

No significant heterosis over mid parent was observed, but all intra *hirsutum* hybrids had highly significant positive heterosis over respective colour linted parents and checks DHH-11 and NHH-44. The hybrids DCCH-1 (13.36%), DCCH-2 (25.6%), DCCH-5 (20.76%) and DCCH-6 (23.62%) showed significant positive heterosis over white linted parents. Diploid hybrids DCCH-9 and DCCH-10 had highly significant negative heterosis over both checks DHH-11 (-35.30 and 40.48% respectively) and NHH-44 (-26.45 and -32.33% respectively) (Table 41).

4.8.2.7 Counts (C)

All hybrids except DCCH-7 and DCCH-9 and DCCH-10 had highly significant positive heterosis over mid parent and highest heterosis was observed in DCCH-2 (63.34%) and lowest in DCCH-10 (1.80%). All intra *hirsutum* hybrids possessed highly significant positive heterosis over colour linted parents and highest being 93.42 per cent in DCCH-2. Only four hybrids viz., DCCH-1 (21.54%), DCCH-2 (41.35%), DCCH-5 (33.46%) and DCCH-6 (38.08%) had significant heterosis over white linted parent. All intra *hirsutum* hybrids showed significant heterosis over NHH-44 and DHH-11, except DCCH-7 over DHH-11. Significant negative heterosis over both checks was observed in two diploid

Table 40. Estimates of heterosis for fibre strength

Hybrids	Heterosis over				
	Mid parent	Colour parent	White parent	DHH-11	NHH-44
DCCH-1	11.38**	7.74**	15.29**	8.38**	23.97**
DCCH-2	8.31**	4.76	12.10**	5.39**	20.55**
DCCH-3	9.83**	13.10**	6.74**	13.77**	30.14**
DCCH-4	10.40**	13.70**	7.30**	14.37**	30.82**
DCCH-5	20.63**	20.25**	21.02**	13.77**	30.14**
DCCH-6	19.37**	18.99**	19.75**	12.57**	28.77**
DCCH-7	12.50**	19.62**	6.18*	13.17**	29.45**
DCCH-8	17.86**	25.32**	11.24**	18.56**	35.62**
DCCH-9	6.19*	13.99**	-0.61	-2.40	11.64**
DCCH-10	-0.98	6.30*	7.32**	-8.98**	4.11
CD at 1%	0.84				
CD at 5%q	1.16				

*,** - Significant at 5% and 1% level

Table 41. Estimates of heterosis for fibre quality index (FQI)

Hybrids	Heterosis over				
	Mid parent	Colour parent	White parent	DHH-11	NHH-44
DCCH-1	23.69**	36.10**	13.36*	17.05**	33.07**
DCCH-2	37.06**	50.81**	25.61**	29.70**	47.45**
DCCH-3	16.13*	33.10**	2.99	15.89**	30.14**
DCCH-4	19.84**	37.36**	6.29	18.13**	34.30**
DCCH-5	30.39**	41.68**	20.76**	24.69**	41.76**
DCCH-6	33.47**	45.04**	23.62**	27.65**	45.12**
DCCH-7	12.28	27.03**	0.59	11.80**	27.11**
DCCH-8	20.01**	35.87**	7.59	19.58**	35.94**
DCCH-9	9.45	3.19	16.52	-35.30**	-26.45**
DCCH-10	0.69	-5.06	7.20	-40.48**	-32.33**
CD at 1%	35.56				
CD at 5%	26.02				

*,** - Significant at 5% and 1% level

Table 42. Estimates of heterosis for Counts

Hybrids	Heterosis over				
	Mid parent	Colour parent	White parent	DHH-11	NHH-44
DCCH-1	40.44**	66.31**	21.54*	28.29*	59.65**
DCCH-2	63.34**	93.42**	41.35**	49.21**	85.68**
DCCH-3	27.16*	61.00**	4.68	24.21*	54.57**
DCCH-4	33.25**	68.72**	9.69	30.16**	61.98**
DCCH-5	51.39**	74.88**	33.46**	40.87**	75.31*
DCCH-6	56.63**	80.94**	38.08**	45.75**	81.38**
DCCH-7	20.12	48.52**	0.84	19.64	48.89**
DCCH-8	33.07**	64.53**	11.71	32.54**	63.65**
DCCH-9	27.71	8.16	55.88	-57.94**	-47.65**
DCCH-10	1.80	-13.78	24.26	-66.47**	-58.27**
CD at 1%	6.97				
CD at 5%	5.10				

*,** - Significant at 5% and 1% level

hybrids viz., DCCH-9 (-57.94% and –47.65%) and DCCH-10 (-66.47% and -58.27%) (Table 42).

4.8.2.8 Count strength product (CSP)

All intra *hirsutum* hybrids recorded significant heterosis over mid parent and colour linted parent. DCCH-1 (2.50%), DCCH-2 (4.85%), DCCH-4 (3.35%), DCCH-5 (3.95%) and DCCH-7 (4.45%) showed significant heterosis over white linted parent. All intra *hirsutum* hybrids possessed significant positive heterosis over both checks DHH-11 and NHH-11, whereas diploid hybrids DCCH-9 (-6.60 and –4.43), DCCH-10 (-7.55 and –5.41%) had significant negative heterosis over both checks DHH-11 and NHH-44 (Table 43).

4.9 Generation mean analysis

4.9.1 Mean performance of six generations

4.9.1.1 Cross I - DS-28 x DGH 95

Growth parameters

The generations like F_1 (1.8, 14.4), F_2 (1.58, 13.29), B_1 (2.01, 10.88) and B_2 (1.53, 11.51) were having lower number of monpoodia and sympodia respectively than their parents. The F_1 was also superior to segregating generations like F_2 (1.58) and B_2 (1.53) for number of monopodia, whereas all segregating generations had lower number of sympodia than F_1. For days to first boll burst all six generations were on par. Both parents were superior to F_1 and all segregating generations for plant height (Table 44).

Yield and fibre parameter

The mean yield of F_1 (35 g/plant), B_1 (29.7 g) and B_2 (29.73 g) was higher than the colour linted parent (27.3 g) but less than white linted parent DS-28 (40.9 g). The F_2 yield was on par with the colour linted parent. The average number of bolls per plant in F_1

Table 43. Estimates of heterosis for Counts strength product (CSP)

Hybrids	Heterosis over				
	Mid parent	Colour parent	White parent	DHH-11	NHH-44
DCCH-1	4.17**	5.89**	2.50*	3.12*	5.51**
DCCH-2	6.56**	8.32**	4.85**	5.49**	7.93**
DCCH-3	2.95*	5.43**	1.04	2.67*	5.05**
DCCH-4	3.61*	6.10**	3.35**	3.32**	5.72**
DCCH-5	5.46**	7.00**	3.95**	4.58**	7.00**
DCCH-6	5.97**	7.52**	4.45**	5.09**	7.52**
DCCH-7	2.27**	4.53**	0.09	2.17	4.53**
DCCH-8	3.73**	6.03**	1.53	3.62**	6.03**
DCCH-9	1.09	0.38	1.81	-6.60**	-4.43**
DCCH-10	0.05	-0.65	0.77	-7.55**	-5.41**
CD at 1%	62.82				
CD a 5%	45.97				

*,** - Significant at 5% and 1% level

Table 44. Mean performance of six generations for growth parameters in five crosses of Naturally Coloured Cotton

Cross/Char.	Generations					
	P_1	P_2	F_1	F_2	B_1	B_2
DS-28xDGH95						
PH	118.60±6.50	117.50±8.81	109.90±7.07	98.39±1.33	79.37±2.27	96.42±1.83
NM	2.40±0.29	2.10±0.22	1.80±0.20	1.58±0.05	2.01±0.09	1.53±0.09
NS	16.80±0.85	15.40±0.67	14.40±1.06	13.29±0.21	10.88±0.37	11.51±0.34
FB	143.90±0.29	144.50±0.41	144.70±0.25	141.92±0.26	141.70±0.42	141.03±0.55
DS-28xDBH95						
PH	89.00±8.82	83.90±3.85	102.20±7.78	84.74±1.44	94.84±2.35	96.73±2.35
NM	2.20±0.22	1.60±0.19	1.60±0.22	2.91±0.56	1.55±0.10	1.53±0.09
NS	14.80±0.71	10.80±0.63	13.00±1.48	11.01±0.20	11.81±0.33	11.46±0.33
FB	145.00±0.52	144.90±0.37	143.80±0.12	140.92±0.71	141.99±0.51	140.80±0.60
AbadhitaxDGH 95						
PH	105.20±5.67	110.90±6.56	98.80±5.31	100.95±1.34	95.46±4.01	92.73±2.85
NM	1.10±0.29	2.10±0.32	1.70±0.26	1.74±0.05	2.20±0.27	1.52±0.09
NS	12.50±0.74	14.10±1.08	13.20±0.96	12.67±0.19	13.37±1.19	11.17±0.36
FB	144.20±0.25	143.90±0.42	129.80±0.68	145.59±0.44	147.82±4.64	142.10±0.55
DBH95x DGH 95						
PH	96.00±8.27	87.70±4.26	82.30±7.15	92.66±4.53	82.47±2.75	92.15±2.73
NM	1.70±0.20	1.20±0.20	2.00±0.14	1.33±0.05	1.44±0.16	1.58±0.20
NS	11.60±0.88	10.50±0.92	11.40±0.97	10.90±0.21	10.58±0.40	10.85±0.41
FB	143.50±0.17	144.40±0.16	143.60±0.17	14.40±0.62	143.32±0.44	140.14±2.35
DBA95xA-82-1-1						
PH	98.40±6.96	110.00±8.83	142.90±9.45	122.11±1.83	130.36±4.89	128.94±3.85
NM	3.20±0.22	2.20±0.32	3.20±0.57	2.79±0.07	2.68±0.16	2.54±0.18
NS	11.00±1.60	14.40±1.13	19.00±1.94	16.92±0.31	15.38±0.80	16.03±0.61
FB	146.80±0.32	144.70±0.12	147.00±0.16	148.28±0.25	149.03±0.58	146.77±1.78

PH – Plant height (cm); NM – Number of monopodia;
NS – Number of sympodia; FB – Days to first boll burst (days);

Table 45. Performance of six generations for yield parameters and fibre length in five crosses of naturally coloured cotton

Cross/Char.	Generations					
	P_1	P_2	F_1	F_2	B_1	B_2
DS-28 x DGH-95						
NB	10.80±0.49	8.20±1.26	10.20±1.76	7.74±0.24	8.27±0.47	8.67±0.50
SCY	40.90±3.31	27.30±2.45	35.00±4.37	26.45±1.05	29.70±1.89	29.73±1.90
BW	3.68±0.23	3.71±0.35	4.01±0.34	3.44±0.07	3.60±0.09	3.52±0.10
FL	26.97±0.47	25.29±0.31	27.54±0.65	24.03±0.14	25.66±0.25	25.98±0.23
DS-28 x DBH-95						
NB	6.50±1.32	6.50±0.95	9.20±1.19	7.55±0.26	6.30±0.44	7.33±0.42
SCY	28.40±3.46	25.10±0.39	35.10±3.55	26.39±1.08	23.50±2.01	26.77±1.61
BW	4.82±0.41	3.69±0.37	3.89±0.28	3.47±0.07	3.69±0.11	3.77±0.12
FL	28.80±0.51	19.93±0.39	27.20±0.62	24.14±0.17	23.94±0.28	23.34±0.23
AbadhitaxDGH-95						
NB	8.50±1.08	11.60±1.38	9.10±1.47	8.43±0.27	11.43±0.88	8.61±0.52
SCY	27.00±3.69	33.10±3.02	28.60±4.90	28.45±0.99	39.41±3.27	29.38±1.64
BW	3.33±0.24	3.02±0.21	3.14±0.32	3.46±0.06	3.51±0.15	3.66±0.14
FL	23.90±0.51	22.90±0.22	21.20±0.59	22.45±0.11	26.00±2.14	21.85±0.27
DBH-95 x DGH-95						
NB	7.60±1.05	6.60±0.60	13.30±1.16	8.50±0.25	6.73±0.49	10.21±0.61
SCY	28.55±3.93	21.70±2.96	52.30±1.20	33.03±1.20	24.67±1.80	38.76±2.55
BW	3.86±0.21	3.29±0.38	3.94±0.21	3.90±0.06	3.76±0.14	3.83±0.12
FL	19.46±0.47	21.00±0.54	21.97±0.97	20.27±0.07	19.14±0.22	22.99±0.79
DBA-95 x A-81-1-1						
NB	9.00±1.10	12.30±1.47	22.00±1.58	12.32±0.33	10.54±0.68	13.14±0.77
SCY	17.70±2.31	27.80±3.51	45.60±4.59	23.79±0.71	20.94±1.32	26.36±1.51
BW	2.02±0.14	2.47±0.13	2.09±0.18	2.08±0.05	2.26±0.13	2.25±0.13
FL	19.10±0.17	15.99±0.42	19.70±0.37	18.44±0.09	18.04±0.23	17.27±0.20

NB – Number of bolls; BW – Boll weight (g);
SCY – Seed cotton yield/plant (g); FL – Fibre length (mm);

(10.2) was higher than colour linted parent DGH 95 (8.2), F_2 (7.74), B_1 (8.27) and B_2 (8.67), but it was less than DS-28 (10.8). Similarly F_1 had highest mean boll weight (4.01 g) and fibre length (27.54 mm) than any other generations viz., P_1 (3.68 g, 26.97 mm), P_2 (3.71 g, 25.29 mm), F_2 (3.44 g, 24.03 mm), B_1 (3.6 g, 25.66 mm) and B_2 (3.5 g, 25.98 mm) (Table 45).

4.9.1.2 Cross II - DS-28 x DBH 95

Growth parameters

The mean height of the F_1 (102.20 cm) was more than all other generations. The F_1 (1.6), B_1 (1.55) and B_2 (1.53) were on par for number of monopodia with the colour linted parent DBH 95 (1.60), but significantly less than P_1 DS-28 (2.2) and F_2 (2.9). The F_1 had more mean number of sympodia (13.0) than P_2 (10.8), F_2 (11.01), B_1 (11.81) and B_2 (11.46). All segregating generations did not vary significantly for sympodial number. The segregating generations like F_2 (140.9 days), B_1 (141.99) and B_2 (140.8) required less number of days to first boll burst than F_1 (143.8 days), P_1 (145 days) and P_2 (144.9 days) (Table 44). The field view of different generations of this cross is presented Plate 9 and 10.

Yield and fibre parameters

The mean yield per plant of F_1 (35.1 g) was higher than all other generations. The F_2 (26.39 g) and B_2 (26.77 g) showed higher mean yield per plant than P_2 (26.10 g) but were lower than P_1 (28.40). Backcross generation B_1 recorded lower mean yield (23.56 g) per plant than P_2 (Table 45).

The average number of bolls observed in F_1 (9.2), F_2 (7.55) and B_2 (7.33) were higher than P_1 (6.50), P_2 (6.5) and B_1 (6.30). The F_2 had lowest boll weight (3.47 g), whereas B_1 (3.69 g) and B_2 (3.77 g) were on par with P_2 but were less than F_1 (3.89 g) and P_1 (4.82 g).





Plate 9. Field view of different generations (P_1, P_2 F_1 and F_2) of DS-28 (white) x DBH-95 (brown) Intra *hirsutum* cross

Fibre length of F_1 (27.2 mm), F_2 (24.14 mm), B_1 (23.94 mm) and B_2 (23.34 mm) was longer than P_2 (19.9 mm), but shorter than that of P_1 (28.8 mm).

4.9.1.3 Cross III - Abadhita x DGH 95

Growth parameters

The mean plant height in F_1 (98.8 cm), F_2 (100.95 cm), B_1 (95.46 cm) and B_2 (92.73 cm) was less than both parents. The F_1 ,F_2 and B_2 generations had more number of monopodia than P_1 (Abadhita), whereas P_2 (2.1) was on par with B_1 generation mean. In case of number of sympodia, P_2 was having more sympodia than any other generations. The F_1 required significantly less number of days for first boll burst (129.8 days) than both parents and segregating generations. The F_2 (145.49 days) and B_1 (147.87 days) needed slightly more number of days than their parents, whereas B_2 required less number of days than parents (Table 44).

Yield and fibre parameters

The average yield per plant of B_1 generation was highest (39.41 g) followed by P_2 (33.10 g), B_2 (29.38 g), F_1 (28.60 g), F_2 (28.45 g) and P_1 (27.0 g). The mean boll number was maximum in P_2 (11.6), which was followed by B_1 (11.43), F_1 (9.1), B_2 (8.61), P_1 (8.5) and F_2 (8.43). The boll weight was highest in B_2 generation (3.66 g) and followed by B_1 (3.50 g), F_2 (3.46). P_1 (3.33 g), F_1 (3.14 g) and P_2 (3.02 g). The back cross B_1 possessed longest fibre (26.0 mm). The F_1 (21.2 mm), F_2 (22.45 mm) and B_2 (21.85 mm) had shorter fibre than both parents (Table 45).

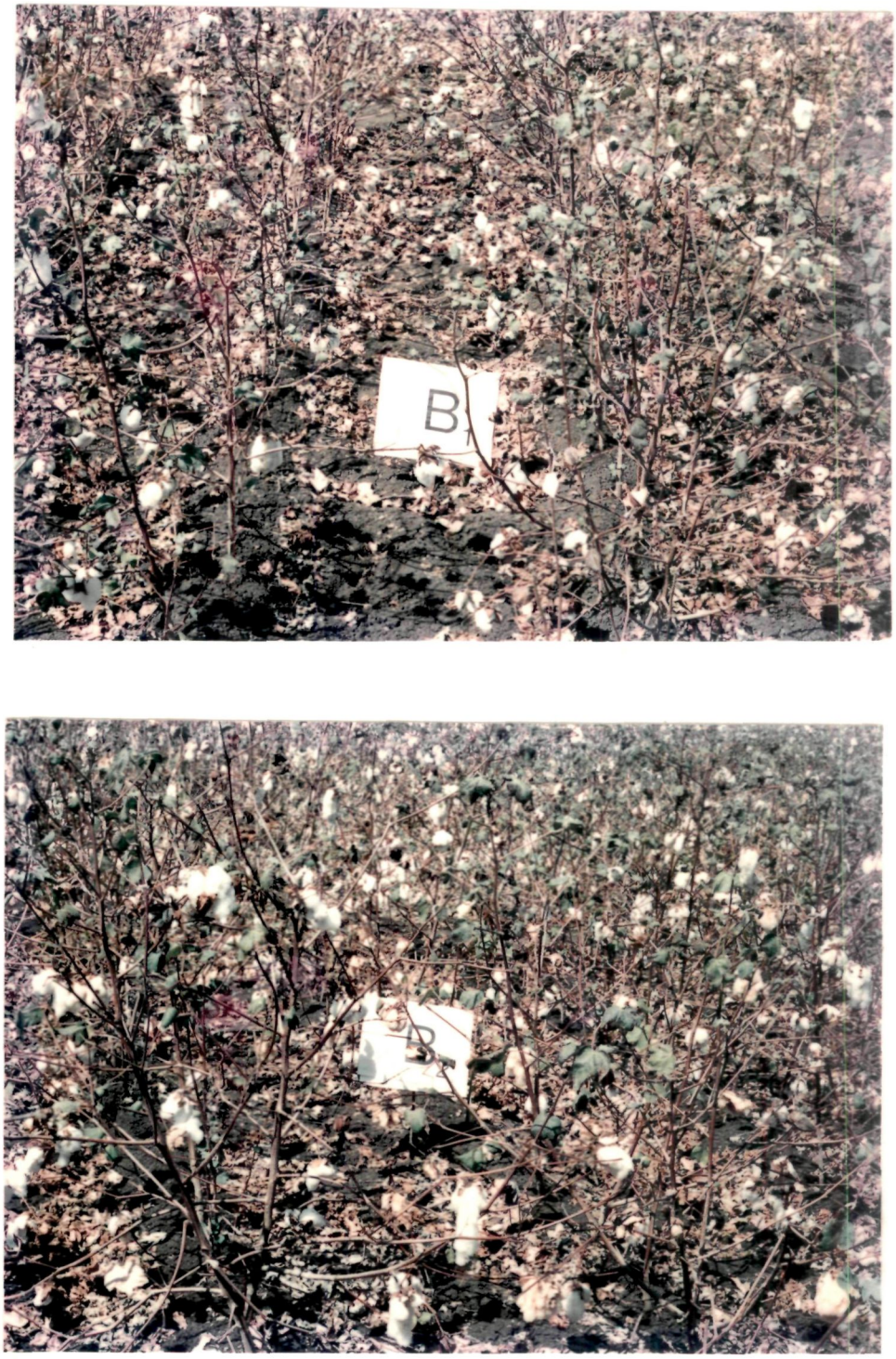


Plate 10. Field view of backcross generations (B_1 and B_2) of DS-28 (white) x DBH-95 (brown) intra *hirsutum* cross

4.9.1.4 Cross IV - DBH 95 x DGH 95

Growth parameters

The parent P_1 (96.00 cm) was tallest followed by F_2 (92.66), B_2 (92.15), P_2 (87.70 cm), B_1 (82.47 cm) and F_1 (82.30 cm) in that order. The F_1 (82.30 cm) and B_1 were on par, so also F_2 (92.66 cm) and B_2 (92.15 cm) The number of monopodia was highest in F_1 (2.00) than both parents and segregating generations, which were having higher mean than P_2. The number of sympodia were on par in all segregating generations, wherein P_1 had maximum (11.6) and followed by F_1 (11.4), F_2 (10.9), B_2 (10.85), B_1 (10.58) and P_2 (10.5). No much variation was observed for mean days for first boll burst in all six generations (Table 44).

Yield and fibre parameters

The F_1 (52.3 g), B_2 (38.8 g) and F_2 (33.03 g) were significantly superior over both P_1 (28.55 g) and P_2 (21.70 g) for seed cotton yield per plant. The F_1 reported highest number of bolls (13.3) than parents (7.6 and 6.6), F_2 (8.5), B_1 (6.73) and B_2 (10.21). Similarly it had heaviest boll (3.94 g) followed by F_2 (3.90 g), P_1 (3.86 g), B_2 (3.83 g), B_1 (3.76 g) and P_2 (3.29 g). The mean fibre length of B_2 (22.99 mm) was more than both parents (19.46 mm and 21.00 mm), F_1 (21.97 mm), F_2 (20.27 mm) and B_1 (19.14 mm) (Table 45).

4.9.1.5 Cross V - DBA 95 x A-82-1-1

Growth parameters

The mean height of F_1 (142.90 cm), B_1 (130.36 cm), B_2 (128.94 cm), F_2 (122.11 cm) was significantly higher than both P_1 (98.40 cm) and P_2 (110.00 cm). The F_1 was on par with P_1, but it had more number of monopodia than P_2, so also other generations like F_2, B_1 and B_2. Highest number of sympodia were observed in F_1 (19.00) followed by F_2



Plate 11. Field view of different generations (P_1, P_2, F_1 and F_2) of DBA-95 (brown) x A-82-1-1 (white) intra *arboreum* cross

(16.92), B_2 (16.03), B_1 (15.38), P_2 (14.40) and P_1 (11.00). All generations were on par for days to first boll burst, wherein B_1 generation required maximum days for number of boll burst (149.0 days) and whereas P_1 required minimum number of days (144.7 days) (Table 44). The field view of different generations of this cross is presented Plate 11 and 12.

Yield and fibre parameters

The mean yield per plant of F_1 (45.60 g) was significantly higher than both parents and segregating generations. The F_2 (23.79 g), B_1 (20.94 g) and B_2 (26.36 g) yielded better than colour linted parent. The boll load was also high in F_1 (22.00) followed by B_2 (13.14), F_2 (12.32), P_2 (12.30), B_1 (10.54) and P_1 (9.00). The boll weight of F_1 (2.09 g), F_2(2.08 g), B_1 (2.28)and B_2 (2.25 g) was more than colour linted parent but less than that of white linted parent. All segregating generations had longer fibre length than P_2 (white linted), but were shorter than F_1, which was superior to colour linted parent (P_1) and white linted parent (P_2) (Table 45).

4.9.2 Gene effects

The gene effects in five different crosses between colour and white linted parents for growth, yield and fibre parameters are presented in Table 46 and 47.

4.9.2.1 Cross I - DS-28 x DGH 95

Growth parameters

For plant height, additive [d], dominance [h] and their interaction effects like i (add x add), j (add x dom) and l (dom x dom) were found highly significant. Except [l] and [m] all other gene effects were negative. The magnitude of dominance x dominance effect was highest. The dominance [h] and its interaction effects [l] had opposite signs, indicating duplicate type of gene interaction.

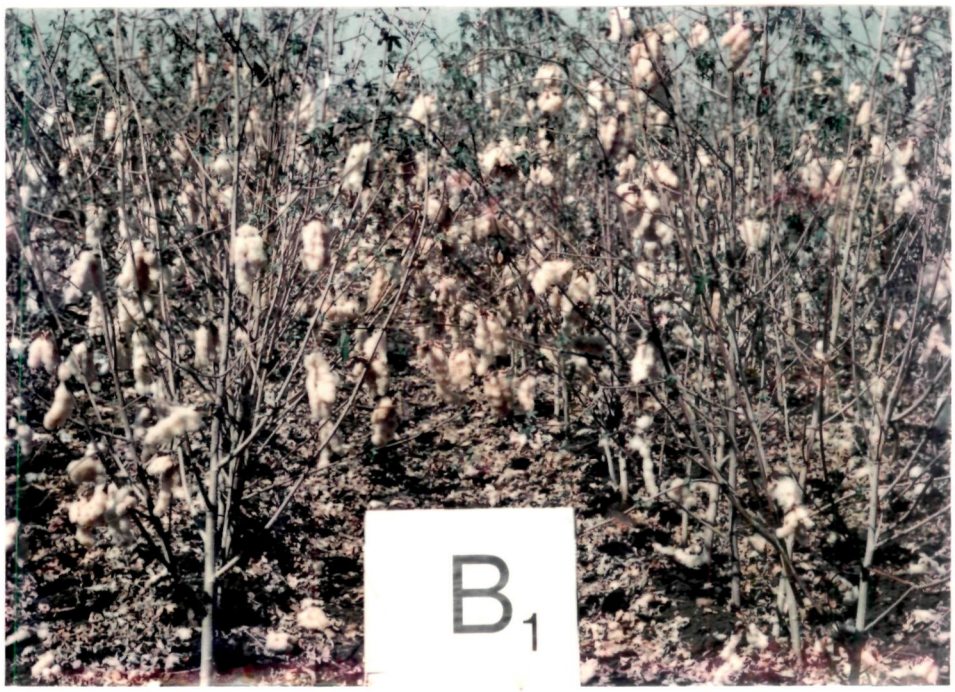




Plate 12. Field view of backcross generation of (B_1 and B_2) of DBA-95 (brown) x A-82-1-1 (white) intra *arboreum* cross

Table 46. Gene effects for growth parameters in five crosses of Naturally coloured cotton

Cross/Char.	Gene effects						
	[m]	[d]	[h]	[i]	[j]	[l]	E
DS-28xDGH95							
PH	98.39±1.33	-17.05**±2.92	-50.12**±11.94	-41.97**±7.91	-17.60**±6.20	146.30**±22.02	D
NM	1.58±0.05	0.48**±0.13	0.32±0.42	0.77**±0.32	0.33±0.22	0.26±0.77	C
NS	13.29±0.21	-0.63±0.50	-10.08**±1.76	-8.38**±1.29	-1.33±0.73	24.60**±3.21	D
FB	141.97±0.26	0.67±0.69	-1.90±1.78	-2.40±1.74	0.97±0.73	14.73**±3.04	D
DS-28XdBH95							
PH	84.74**±1.44	-1.91±3.37	59.92**±12.74	44.17**±8.87	-4.46±5.89	-49.99*±23.45	D
NM	2.91**±0.56	0.02±0.73	-5.80**±2.26	-5.50±2.24	-0.28±0.20	6.35**±2.35	D
NS	11.01**±0.20	0.35±0.47	2.71±1.98	2.51*±1.22	-1.65*±0.66	2.54±3.71	C
FB	140.92**±0.71	1.19**±0.79	0.75±3.27	1.90*±3.25	1.14±0.85	10.02*±4.30	C
AbadhitaxDGH 95							
PH	100.95**±1.34	2.74±4.92	-36.66**±13.13	-27.41**±11.20	5.59±6.60	64.73**±24.58	D
NM	1.74**±0.52	0.68*±0.29	0.60±0.70	0.50±0.61	1.18**±0.36	-1.36±1.36	D
NS	12.67**±0.19	2.20±1.24	-1.70±2.60	-1.60±2.60	3.00±1.41	5.53±5.55	D
FB	145.60**±0.44	5.78±4.70	-16.69±15.85	-2.44±9.50	5.63±4.67	-29.79±31.55	C
DBH95 x DGH 95							
PH	92.66**±1.53	-9.69*±3.88	-30.96*±13.06	-21.41*±9.88	-13.84*±6.06	20.47±0.24	D
NM	1.33**±0.05	-0.15±0.26	1.27±0.59	0.72±0.55	-0.40±0.30	0.14±0.11	C
NS	10.90**±0.21	-0.27±0.57	-0.39±1.82	-0.78±1.41	-0.82±0.86	2.78±3.36	D
FB	141.41**±0.63	3.18±2.39	0.99±5.39	1.34±5.39	3.63±2.39	6.84±9.89	C
DBA95 x A-82-1-1							
PH	122.11**±1.83	1.42±6.22	68.83**±18.16	30.13*±14.46	7.22±8.39	-54.52±34.03	D
NM	2.80**±0.07	0.14±0.24	-0.23±0.83	-0.73±0.56	-0.36±0.33	2.10±1.59	D
NS	16.92**±0.31	-0.64±1.00	1.43±3.21	-4.87*±2.36	1.06±1.40	5.45±6.04	C
FB	148.28**±0.25	2.26±1.87	-0.27±3.87	-1.52±3.87	1.21±1.88	-4.57±7.55	C

*,** - Significant at 5% and 1% level

PH – Plant height (cm); NM – Number of monopodia; NS – Number of sympodia;

FB – Days to first boll burst; E - Epistasis; D – Duplicate; C – Complimentary;



Plate 13a. Fibre colour variation in bolls of backcross generations (B_1 and B_2) of DS-28 (white) x DBH-95 (brown) intra *hirsutum* cross



Plate 13b. Fibre colour variation in bolls of backcross generation (B_1 and B_2) of DBA-95 (brown) x A-82-1-1 (white) intra *arboreum* cross

The analysis revealed that only additive [d] and additive x additive [i] gene effects were significant for number of monopodia, both [h] and [l] had same sign indicating complementary gene interaction. In case of sympodia number, dominance [h] and interaction with additive x additive effect [i] and dominance x dominance [l] were highly significant. The magnitude of [l] was very high than other effects and it also had opposite sign that of dominance effect.

The dominance x dominance [l] was highly significant for days to first boll burst whereas all other effects were non-significant. The dominance effect [h] and its interaction [l] were in opposite direction thus indicating complementary gene action. The magnitude of interaction [l] was also comparatively high (Table 46).

Yield and fibre parameters

The gene effects for yield per plant were not significant except additive x dominance effect. For other two yield parameters viz., number of bolls and boll weight none of the gene effects were significant. All three characters viz., yield per plant, number of bolls and boll weight showed complementary epistasis. In case of fibre length, dominance [h], dominance x additive [j] and dominance x dominance [l] effects were highly significant. The interaction observed was duplicate (Table 47).

4.9.2.2 Cross II - DS-28 x DBH 95

Growth parameters

The plant height in this cross was governed by dominance [h], additive x additive [i] and dominance x dominance [l] gene effects which were statistically significant. The interaction observed was duplicate. The number of monopodia was governed by only dominance x dominance effects. These were significant with duplicate gene interaction. The

Table 47. Gene effects for yield parameters and fibre length in five crosses of Naturally coloured cotton

Cross/Char.	Gene effects						E
	[m]	[d]	[h]	[i]	[j]	[l]	
DS-28xDGH95							
NB	7.74**±0.24	-0.40±0.69	3.62±2.52	2.92±1.68	-1.71±0.97	2.61±4.80	C
SCY	26.45**±1.05	-0.03±2.70	13.93±8.35	13.03±6.80	-6.83*±3.38	6.32±15.02	C
BW	3.44**±0.08	0.09±0.14	0.78±0.56	0.47±0.40	0.11±0.25	0.70±1.00	C
FL	24.03**±0.14	-0.31±0.34	8.56**±1.12	7.15**±0.87	-1.15**±0.44	-3.10±2.03	D
DS-28xDBH95							
NB	7.55**±0.26	-1.02±0.61	-0.47±2.15	2.92±1.60	-0.77±1.02	7.57±1.02	D
SCY	26.39**±1.08	-3.21±2.58	3.45±7.99	-4.90±6.73	-4.86±3.54	27.95*±14.11	C
BW	3.47**±0.06	-0.08±0.16	0.69±0.57	1.05*±0.42	-0.64*±0.32	0.32±1.05	C
FL	24.14**±0.17	0.58±0.37	0.87±1.22	-1.97*±1.00	-3.86**±0.49	10.49**±2.14	C
AbadhitaxDGH95							
NB	8.43**±0.27	2.82**±1.02	5.39±2.87	6.34**±2.30	4.37**±1.34	-8.10±5.43	D
SCY	28.45**±0.99	10.03**±3.66	22.34*±9.94	23.80**±8.30	13.08**±4.36	-44.08**±18.66	D
BW	3.46**±0.06	-0.15±0.20	0.48±0.59	0.51±0.47	-0.31±0.26	-2.22*±1.11	D
FL	22.45**±0.11	4.15±2.15	3.69±4.38	5.89±4.33	3.65±2.17	-12.39±8.70	D
DBH95 x DGH95							
NB	8.50**±0.25	-3.48**±0.78	6.06**±2.27	-1.44±1.85	-3.98**±0.99	7.08±4.19	C
SCY	33.03**±12.01	-14.09**±3.13	21.92*±9.96	-5.26±7.88	-17.52**±3.99	33.25±18.1	C
BW	3.90**±0.06	-0.07±0.18	-0.06±0.54	-0.42±0.44	-0.36±0.29	0.25±0.98	D
FL	20.27**±0.08	-3.85**±0.82	4.93*±1.96	3.19**±1.66	-3.08**±0.89	-3.07±3.89	D
DBA95 x A-82-1-1							
NB	12.32**±0.36	-2.60*±1.02	9.41**±3.03	-1.94±2.42	-0.95±1.37	19.88**±5.64	C
SCY	23.79**±0.71	-5.42**±2.00	22.27**±7.05	-0.58±4.92	-0.37±2.90	42.69**±13.20	C
BW	2.08**±0.05	0.01±0.18	0.54±0.47	0.69±0.42	0.24±0.21	-1.05±0.87	D
FL	18.44**±0.09	0.77*±0.30	-0.99±0.84	-3.15**±0.72	-0.78*±0.38	7.01**±1.54	D

*,** - Significant at 5% and 1% level

NB – Number of bolls; BW – Boll weight (g); SCY – Seed cotton yield/plant (g);
FL – Fibre length (mm); E – Epistasis. D – Duplicate; C – Complimentary;

interaction effects like additive x additive [i] and additive x dominance [j] were significant for number of sympodia. The gene interaction observed was complementary. In case of days to first boll burst the additive, additive x additive and dominance x dominance effects were significant and it expressed complementary type of epistasis (Table 46).

Yield and fibre parameters

The dominance x dominance [l] effect was significant with high magnitude for yield per plant. The [h] and [l] had same signs and indicated presence of complementary type of epistasis. No gene effect was significant for number of bolls and the interaction observed was duplicate. The interaction effects viz., additive x additive, additive x dominance were significant for boll weight. The epistasis present was complementary. All three interaction effects via., additive x additive [i], additive x dominance [j] and dominance x dominance [l] were significant for fibre length, which also showed complementary type of epistasis (Table 47).

4.9.2.3 Cross III - Abadhita x DGH 95

Growth parameters

The estimates of dominance, additive x additive and dominance x dominance gene effects were significant for plant height. As the values of [h] and [l] were having opposite signs the interaction observed was duplicate. The values of additive and additive x dominance effects were significant for number of monopodia. The interaction noticed was duplicate. In case of sympodial number only additive x dominance effect showed significant with duplicate gene interaction. No gene effects were significant for days to first boll burst and the epistasis found was complementary in nature (Table 46).

Yield and fibre parameters

All gene effects were highly significant for seed cotton yield per plant with dominance x dominance effects showing highest magnitude than other effects. For number of bolls, additive effect was important along with its interactions viz., additive x additive and additive x dominance effects and the epistasis was duplicate. Only dominance x dominance [l] gene effect was significant for boll weight. No gene effect was significant for fibre length. As the estimates of [h] and [l] were having opposite signs for above four characters and the epistasis observed was duplicate type (Table 47).

4.9.2.4 Cross IV - DBH 95 x DGH 95

Growth parameters

The estimates, additive, dominance, additive x additive and additive x dominance were significant for plant height. The epistasis observed was duplicate. Only dominance effect was important for number of monopodia which showed complementary gene action. No gene effect was significant for number of sympodia which had duplicate epistasis. Similarly, for days to first boll burst no gene effect was found significant but complementary genetic interaction was noticed (Table 46).

Yield and fibre parameters

The additive, dominance and additive x dominance effects were found significant for yield and number of bolls per plant. The magnitude of [h] was higher than [d] but less than [l] for both characters. Similarly epistasis observed was complementary type. No gene effect was observed significant for boll weight. In case of fibre length the estimates additive, dominance, additive x additive, additive x dominance effects were significant. For both the characters duplicate gene interaction was observed (Table 47).

4.9.2.5 Cross V - DBA 95 x A-82-1-1

Growth parameters

Only dominance and additive x additive gene effects were significant for plant height. Magnitude of dominance effect was higher. In case of number of monopodia none of the gene effects were significant. Both these characters displayed duplicate epistasis. For sympodial number, only additive x additive interaction effect was significant, whereas for days to first boll burst no gene effect was significant. Both these characters had complementary gene interaction (Table 46).

Yield and fibre parameters

The yield per plant and number of bolls per plant were governed by additive ,dominance gene effects. In both characters magnitude of dominance x dominance was higher than both additive and dominance effects. The epistasis observed was complementary. No gene effects were significant for boll weight. In case of fibre length additive, additive x additive, additive x dominance and dominance x dominance gene effects significantly influenced the expression of the trait. The gene interaction dominance x dominance [l] was highest for this trait. The gene interaction observed for both these characters was duplicate (Table 47).

4.10 Mutation studies

The results of mutation studies are presented under two headings.

4.10:1 Performanc of brown *G. hirsutum* M_2 generations

The M_2 generation of brown *hirsutum* were evaluated for yield per plant and fibre length, both these characters showed wide range (Table 48).

Table 48. Mean performance of brown *G. hirsutum* M_2 mutant lines for yield and halo length during 1995-96

Treatment Ems%	No.of Lines	Yield (g/pl)				Halo length (mm)				No.of plants advan-ced to M_3
		Range	Mean	S.D.	Variance	Range	Mean	S.D.	Variance	
0.2	23	2.0-104.5	23.5	6.99	48.87	13.3-25.0	19.4	0.40	0.16	31
0.3	24	1.5-96.5	24.9	7.20	51.84	12.0-25.0	20.2	0.64	0.41	71
0.4	13	2.5-131.0	22.7	7.91	62.50	12.7-24.0	20.0	0.98	0.96	38
BH Control							21.0			

4.10.1.1 Yield

The M_2 lines with 0.4 per cent EMS treatment had highest range for yield per plant (2.5-131.0 g/plant), which was followed by M_2 lines with 0.2 per cent EMS treatment (2.0-104.5 g/plant), and 0.3 per cent EMS treatment (2.54-96.5 g/plant). Even though variation was more in M_2 lines with treatment 0.4 per cent EMS the overall mean was higher in M_2 with 0.3 per cent EMS treatment (24.92 g/plant) which was followed by 0.2 per cent EMS treatment M_2 (23.5 g/plant) and 0.4 per cent EMS treated M_2 (22.7 g/plant). The lowest variance was observed in M_2 with 0.2 per cent, EMS treatment (48.67) and was in increasing order in 0.3 (51.84) and 0.4 (62.5) per cent EMS treatment (62.50).

4.10.1.2 Fibre length

The fibre length observed varied from 12.0-25.0 mm in M_2 generation obtained from 0.3 per cent EMS, followed by 12.7-24.0 mm in M_2 plants from 0.4 per cent EMS treatment and 13.3-25.0 mm in M_2 lines of 0.2 per cent EMS treatment. The mean fibre length was 19.42 mm (0.2% EMS treatment), 20.00 mm (0.4% EMS treatment) and 20.2 mm (0.3% EMS treatment). The variance ranged from 0.16 in 0.2 per cent EMS treatment to 0.96 in 0.4 per cent EMS treatment.

Based on yield per plant (g), fibre length (mm) and fibre colour outstanding individual plants were selected for advancing to M_3 generation. The number of plants selected in different treatments were 31, 71 and 38 in 0.2, 0.3 and 0.4 per cent EMS treatments, respectively.

4.10.2 Performance of brown *G. arboreum* M_2 generation

The M_2 lines derived from different mutagen treatments were evaluated for yield per plant and fibre length (Table 49). The field view of M_2 generations of different treatments are presented in Plate 13.

4.10.2.1 Yield per plant

The variation observed for yield was very high and it ranged from 2.0-284.0 g per plant in the mutagen treatment of 0.3 per cent EMS, which was followed by 5.0-190.0 g per plant (0.2% EMS), 2.0-141.0 g per plant (20 kr gamma irradiated) and 2.0-118.0 g per plant (0.4% EMS). Even though range was high in M_2 lines derived from the treatment 0.3 per cent EMS, the mean yield per plant was highest in the M_2 individual drawn from the 0.2 per cent EMS treatment (42.00 g/plant), followed by 0.4 per cent EMS (25.70 g/plant), 0.3 per cent EMS (25.08 g/plant) and 20 kr gamma irradiated (20.93 g/plant). The variance was highest in M_2 lines derived from 0.2 per cent EMS treatment (84.89). It was followed by treatments like 0.4 per cent EMS (69.41), 0.3 per cent EMS (46.70) and the least variance (41.94) was observed in the irradiated M_2 lines.

4.10.2.2 Fibre length

The variation observed for fibre length was moderate in M_2 generations derived from different mutation treatments. The fibre length ranged from 15.3-26.3 mm in the M_2 lines obtained from the treatment 0.3 per cent EMS, which was followed by 15.3-25.0 mm (0.2% EMS), 16.0-25.3 mm (0.4% EMS) and 16.7-25.3 mm (irradiated). The mean fibre length of M_2 lines was 21.4 mm (0.3% EMS), 21.3 mm (0.4% EMS), 20.8 (0.2% EMS) and 20.8 mm (irradiated). The variance observed was highest in M_2 generations derived from the treatment 0.3 per cent EMS (2.73) followed by the treatments 0.4 per cent EMS (1.31), 0.2 per cent EMS (0.69) and irradiated (0.19).

Table 49. Mean performance of brown *G. arboreum* M_2 mutant lines for yield and halo length during 1995-96

Treatment Ems%	No.of Lines	Yield (g/pl)				Halo length (mm)				No.of plants advanced to M_3
		Range	Mean	S.D.	Variance	Range	Mean	S.D.	Variance	
0.2	27	5-190.0	42.00	13.60	184.89	15.3-25.0	20.82	0.83	0.69	77
0.3	26	2-284.0	25.08	6.83	46.70	15.3-26.3	21.40	1.65	2.73	69
0.4	20	2-118.0	25.70	8.33	69.41	16.0-25.3	21.30	1.14	1.31	29
Irradiated (20 kr)	31	2-141.0	20.93	6.48	41.94	16.7-25.3	20.80	0.43	0.19	66
BA Control							22.90			

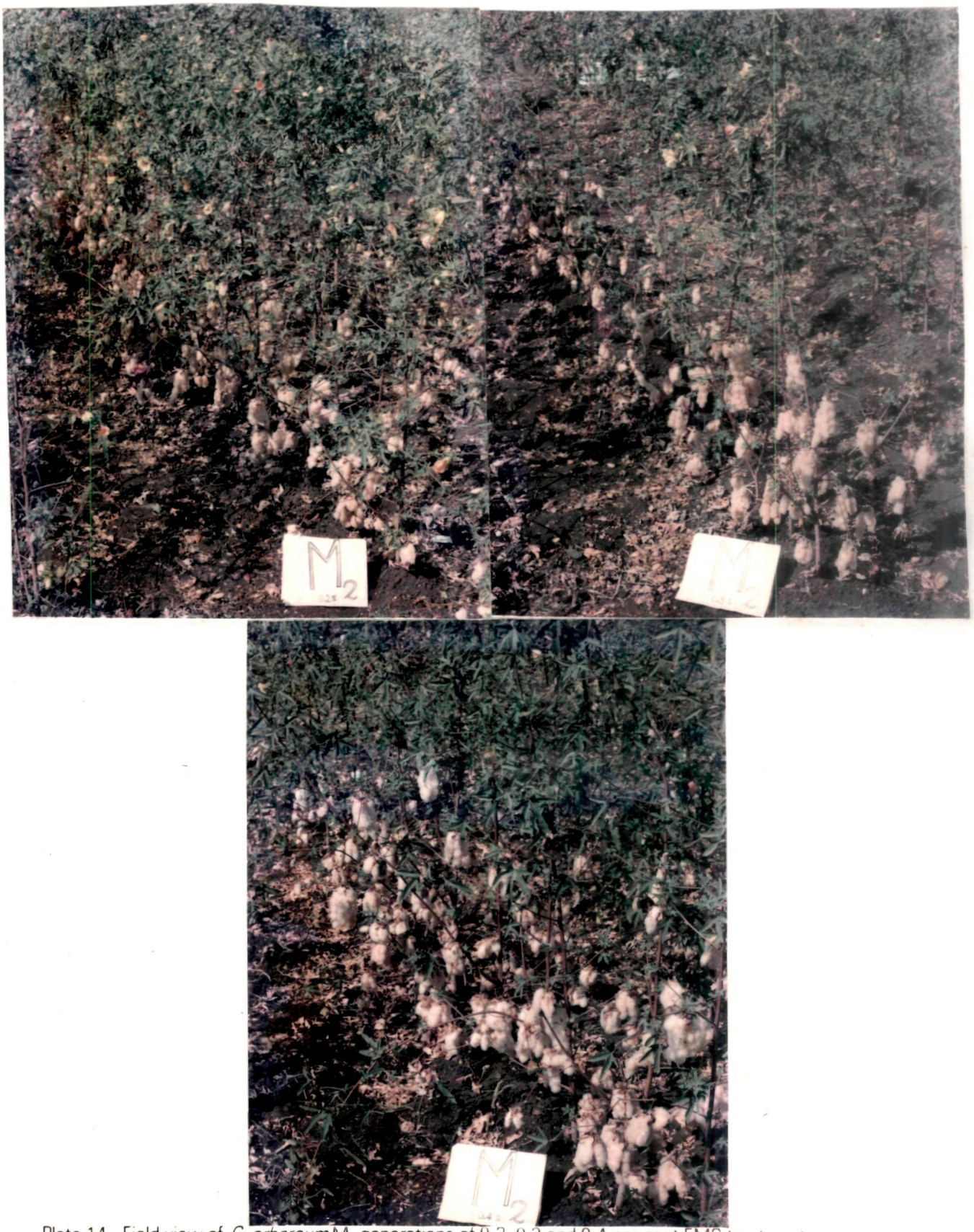


Plate 14. Field view of *G. arboreum* M_2 generations of 0.2, 0.3 and 0.4 per cent EMS treatment

Based on the yield per plant, fibre length and fibre colour, individual plants were selected and advanced to M_3 generation. The number of plants selected and advanced in different treatments were as follows.

0.2 per cent EMS	77 plants
0.3 per cent EMS	69 plants
0.4 per cent EMS	29 plants
20 kr gamma irradiated	66 plants

4.10.3 Performance of M_3 generation of brown *G. hirsutum* during 1996-97

M_3 generations of *G. hirsutum* lines were evaluated for yield, ginning per cent, seed index, lint index and fibre length, details of which are presented below (Table 50).

4.10.3.1 Yield

A wide range and highest mean yield (q/ha) were observed in M_3 generations from 0.4 per cent EMS treatment, whereas M_3 lines obtained from 0.3 per cent EMS and 0.2 per cent EMS followed in that order. The variance was also highest in 0.4 per cent EMS M_3, which was followed by M_3's of 0.2 per cent and 0.3 per cent EMS, respectively. The number of families above the mean yield of untreated check were very less.

4.10.3.2 Ginning out-turn

The highest range, mean and variance was observed in the M_3's of 0.4 per cent EMS, followed by 0.2 per cent and 0.3 per cent EMS treatments, respectively. The number of families above untreated check were highest in 0.4 per cent EMS (65.8%), followed by 0.2 per cent EMS (58.1%) and 0.3 per cent EMS (50.7%).

4.10.3.3 Seed index

The range was maximum in 0.3 per cent EMS treatment, whereas mean was highest in 0.4 per cent EMS M_3 and variance was more in 0.2 per cent EMS treatment. Number of families above check control were 47.44 (0.4% EMS), 29.2 (0.2% EMS) and 23.94 (0.3% EMS).

4.10.3.4 Lint index

The range observed in 0.4 per cent EMS and 0.2 per cent EMS M_3 was on par. The mean lint index was more in 0.4 per cent EMS (5.03 g) followed by other two treatments 0.2 per cent EMS (4.86 g) and 0.3 per cent EMS (4.67 g). Number of families above untreated check were highest in 0.4 per cent EMS (60.5%), 0.2 per cent EMS (45.2%) and 0.3 per cent EMS (39.4%).

4.10.3.5 Fibre length

Maximum range was noticed for fibre length in 0.2 per cent EMS, which also had higher variance than other two treatments. The mean fibre length was more in 0.4 per cent EMS than 0.2 and 0.3 per cent treatments. Number of families having more fibre length than check, were 38.7 (0.2% EMS), 34.2 (0.4% EMS) and 26.8 per cent (0.3% EMS).

4.10.4 Performance of brown *G. arboreum* in M_3 families

M_3 generations of *G. arboreum* lines were evaluated for yield, ginning per cent, seed index, lint index and fibre length, details of which are presented below (Table 51).

4.10.4.1 Yield

Maximum range of seed cotton yield (5.58-16.98 q/ha) and highest mean yield (10.88 q/ha) was observed in 0.2 per cent EMS M_3's families which also had highest variance among all three dosages of chemical mutagen, but was less than irradiated M_3 families. Only

Table 50. Mean performance of M_3 mutant lines of Brown *G. hirsutum* (BH) for different characters

Treatment	No.of Lines	Yield q/ha	Ginning outturn (%)	Seed Index (g)	Lint Index (g)	Fibre length (mm)
0.2% Ems BH	31					
Range		6.72-15.40	28.57-39.02	8.00-11.00	3.90-6.40	15.00-26.33
Mean		10.72	32.54	10.03	4.86	21.04
S.D.		2.62	2.25	0.78	0.57	1.77
Variance		6.86	5.07	0.61	0.32	3.12
0.3% Ems BH	71					
Range		6.04-15.45	27.27-36.59	8.00-12.00	3.44-5.89	18.67-24.33
Mean		11.55	31.57	10.11	4.67	20.90
S.D.		2.37	1.86	0.72	0.45	1.07
Variance		5.64	3.46	0.52	0.20	1.16
0.4% Ems BH	38					
Range		2.70-18.69	26.83-38.24	9.00-11.00	3.67-6.16	19.33-24.33
Mean		12.62	32.55	10.39	5.03	21.21
S.D.		2.95	2.40	0.63	0.57	1.21
Variance		8.72	5.76	0.40	0.32	1.47
BH control		15.28	31.28	10.50	4.80	21.45

in 0.2 and 0.3 per cent EMS treatments number of families above untreated check were more (67.5 and 30.4%, respectively).

4.10.4.2 Ginning out-turn

The range for ginning out-turn was high in 0.2 per cent EMS treatments followed by irradiation and 0.3 per cent EMS. The mean ginning percentage was highest in irradiation treatment, followed by 0.3 per cent EMS, 0.4 per cent EMS and 0.2 EMS. Forty two per cent lines, were above untreated check in 0.3 per cent EMS treatment, similarly thirty four per cent lines were above check in 20 kr gamma irradiation.

4.10.4.3 Seed index

The seed index ranged from 5 to 9 g in 0.4 per cent EMS whereas for other treatments it was (6-8 g). The treatment 0.3 per cent EMS had highest mean seed index (7.13) and variance followed by 0.2 per cent EMS (6.95 g), 20 kr irradiated (6.82) and 0.4 per cent EMS (6.79). Most of the M_3 families in all treatment were having more seed index than untreated check.

4.10.4.4 Lint index

The overall range for lint index was from 2.77-5.83 g. The highest mean lint index was seen in 0.3 per cent EMS (4.13 g) followed by irradiated, 0.4 and 0.3, respectively. About 65 per cent families in 0.3 per cent EMS and 51.5 per cent in irradiated were above untreated check.

4.10.4.5 Fibre length

The fibre length varied from 17.33 to 28.33 mm in 0.3 per cent EMS. But the mean and variance were highest in irradiated (22.41 mm), followed by all chemical mutagen

Table 51. Mean performance of M_3 mutant lines of Brown *G. arboreum* for different characters

Treatment	No.of lines	Yield q/ha	Ginning outturn (%)	Seed Index (g)	Lint Index (g)	Fibre length (mm)
0.2% Ems BA	77					
Range		5.58-16-9	28.57-43.75	6.0-8.0	2.77-4.57	18.67-25.0
Mean		10.88	33.48	6.95	3.49	21.56
S.D.		2.34	2.72	0.55	0.44	1.50
Variance		5.48	7.39	0.31	0.19	2.25
0.3% Ems BA	69					
Range		4.2-13.81	29.41-42.90	6.0-8.0	3.0-5.33	17.33-28.33
Mean		8.09	36.49	7.13	4.13	21.64
S.D.		2.29	3.15	0.16	0.57	1.73
Variance		5.25	9.95	0.37	0.33	2.98
0.4% Ems BA	29					
Range		2.75-11.06	31.25-42.10	5.0-9.0	2.77-5.09	19.0-24.67
Mean		7.17	35.21	6.79	3.71	21.49
S.D.		2.00	2.73	0.49	0.55	1.68
Variance		4.00	7.44	0.24	0.30	2.82
BA Irridiated (20 kr)	66					
Range		1.74-11.84	31.82-45.10	6.0-8.0	3.0-5.83	20.0-27.0
Mean		6.29	36.75	6.82	3.99	22.41
S.D.		2.54	2.86	0.58	0.59	1.87
Variance		6.47	8.17	0.33	0.34	3.49
Control		9.44	37.19	6.50	3.84	20.33

treatments, which were on par with each other. Most of M_3 families were having more fibre length than that of untreated check.

4.11 Studies on fibre colour development

This study was carried out with an objective to know the exact time of colour development in the fibre of naturally coloured cottons. For this an preliminary study was conducted by tagging bolls of green and brown *hirsutum* on the day of pollination (DAP). These bolls were opened on 30th day after pollination (30 DAP) and 40th DAP. It was observed that colour develops between 30 to 40 DAP as fibre in the bolls after 40 DAP had colour whereas, there was no colour in the fibres of 30 DAP bolls (Table 52) (Plate 14).

Based on above results a study was planned to know exact day on which colour development in fibre starts. All three colour linted types viz., brown *hirsutum*, green *hirsutum* and brown *arboreum* were used for the study.

4.11.1 Fibre colour development in the brown *hirsutum*

The result indicated that in brown *hirsutum* at 30 DAP, the fibre had dull white cotton. From 31 DAP to 34 DAP the fibre showed shiny dull white fibre colour. At 35 DAP a light brown tinge was seen near to seed coat. At 36 DAP light brown colour was seen throughout the fibre. From 37 DAP colour intensity started increasing and reached to full brown colour by 39th DAP.

4.11.2 Fibre colour development in green *hirsutum*

It was observed that at 30 DAP green *hirsutum* had shiny white lint. Light green tinge at the top of seed was observed in the fibres of bolls after 32 DAP. At 33 DAP light greenish tinge was observed throughout the fibre. This light green tinge increased on 34

Table 52. Fibre Colour Development Studies in Naturally coloured cottons

Days after Pollination (DAP)	Genotypes		
	Brown *hirsutum*	Green *hirsutum*	Brown *arboreum*
30	Dull white	Shiny white	White
31	Shiny dull white	Shiny white	White
32	Shiny dull white	Light green tinge at the tip of seed	White
33	Shiny dull white	Light greenish tinge in the fibre	White
34	Shiny dull white	Increased light greenish tinge	White
35	Light brown tinge near seeds	Shiny light green tinge throughout the fibre	White
36	Light brown colour in the fibre	Light green colour throughout the fibre	White
37	Increase light brown color in the fibre	Light green colour throughout the fibre	White
38	Full brown colour	Green colour fibre	White
39	Full brown colour		White
40			White
41			White
42			White
43			White
44			White
45			White
46			Dull white
47			Dull white
48			Light brown tinge in the fibre
49			Intensity of colour increased
50			Intensity of colour increased
51			Light brown fibre

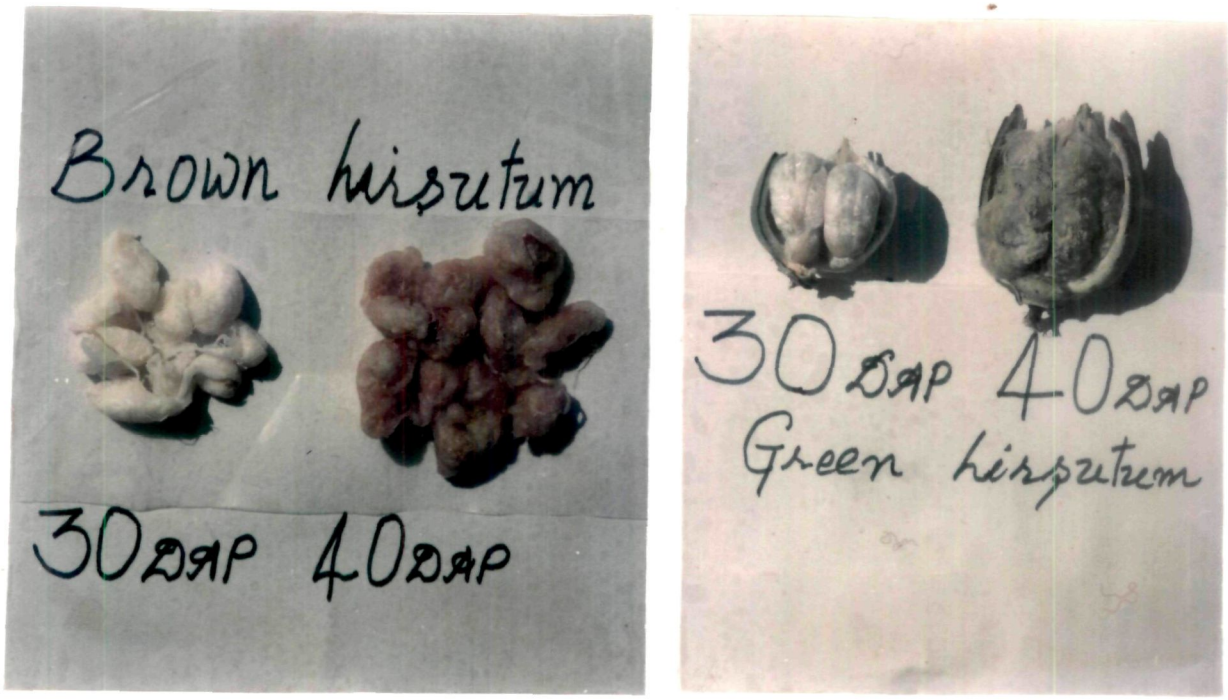


Plate 15a. Fibre colour development between 30 and 40 days after pollination (DAP) in brown and green *G. hirsutum*



Plate 15b. Fibre colour development at 38 days after pollination (DAP) in brown *G. hirsutum* (BH) and green *G. hirsutum* (GH) and brown *G. arboreum* (BA)

DAP and at 35 DAP shiny light green shade was observed throughout the fibre. By 36 DAP light green colour was seen throughout the fibre. By 38 DAP dark green colour fibre was seen throughout.

4.11.3 Fibre colour development in brown *arboreum*

Colour develoopment in the fibres of brown *arboreum* was different than that of *hirsutum* types. It was observed that from 30 DAP to 45 DAP the fibre colour in the bolls was white. Only on 46 DAP the fibre turned dull white and remained so on 47 DAP also. From 48 DAP light brown tinge was observed in the fibre. The intensity of colour increased from 50 DAP-51 DAP and on 52 DAP light brown fibre was seen.

4.12 Characterisation of Naturally Colour Cottons Genotypes through Electrophorosis

Polymorphism of enzyme peroxidase was used to characterise naturally colour cotton genotypes. Eight *hirsutum* genotypes and two *arboreum* genotypes were studied. The *G. hirsutum* genotypes included, four brown shaded genotypes, two green and one each of cream and white (Sahana) colour genotypes. *G. arboreum* genotypes included one colour linted and one white linted (A-82-1-1) genotype. The Rm value for each band in each genotype was calculated and are presented in Table 53. The zymogram of the study is also presented.

The zymogram and Rm value table indicated presence of two bands in all *G. hirsutum* irrespective of their fibre colour. But the behaviour of *G. arboreum* genotypes was different from that of *G. hirsutum*. The colour linted *arboreum* genotype had only one band whereas white genotype showed three distinct bands.

Table 53. Characterization of Naturally coloured cotton genotypes through electrophorosis of peroxidase enzyme

Genotypes	No.of bands	Rm values		
		Band 1	Band 2	Band 3
DDBH	2	0.30 (d)	0.5 (L)	-
MBH	2	0.28 (d)	0.5 (L)	-
BH	2	0.30 (d)	0.5 (L)	-
LB	2	0.30 (d)	0.5 (L)	-
Cream	2	0.30 (d)	0.5 (L)	-
Sahana	2	0.30 (d)	0.5 (L)	-
GH-1	2	0.32 (d)	0.5 (L)	-
GH-2	2	0.32 (d)	0.5 (L)	-
BA	1	0.34 (d)	-	-
A-82-1-1	3	0.35 (d)	0.58 (L)	0.75 (d)

It was observed that first band in all genotype was dense whereas second band was light in all genotypes. Third band in diploid A-82-1-1 was also dense. In all the *G. hirsutum* genotypes, second band was at Rm of 0.5, whereas first band was at 0.3 Rm most of the genotypes except for MBH (0.28) and two green genotypes (0.32). The brown *arboreum* had its first band at 0.34 Rm value, whereas three bands of A-82-1-1 were at 0.35, 0.58 and 0.75 Rm distances (Plate 15).

4.13 Studies on extraction and nature of fibre colour in naturally coloured cottons

Among eight solvents tried, for extraction of fibre colour in naturally coloured cotton only NaOH could extract pigments. All other solvents failed to extract pigment from colour cotton fibre. It was observed that except in NaOH there was no extraction of pigment in any other solvent. Maximum extraction was seen when 2 g of colour lint was treated with 20 per cent NaOH for 24 hours. The colour extracted from dark brown *hirsutum* was dark sharbati red colour whereas colour extracted from brown *arboreum* was light yellowish brown. It was noticed that no extraction was possible from green *hirsutum*. All eight solvents tried could not extract pigments from green *hirsutum*. When the extracts was filtered and read at different wave length in spectrophotometer it was observed that both dark brown *hirsutum* and brown *arboreum* differed. Dark brown *hirsutum* had absorption peak at 510 nm. In case of brown *arboreum* absorption peak was between 430 to 480 nm (Table 54).



Plate 16. Peroxidase isozyme banding pattern of Naturally coloured cotton genotypes

Table 54. Absorption peaks in Naturally coloured cottons (*G. hirsutum* and *G. arboreum*)

Wave length (nm)	OD values	
	Dark brown *G. hirsutum*	Brown *G. arboreum*
345	-	0.354
350	-	0.356
360	0.878	0.359
370	0.879	0.361
380	0.881	0.364
390	0.882	0.365
400	0.893	0.367
410	0.916	0.380
420	0.917	0.395
430	0.917	0.400
440	0.918	**0.410**
450	0.918	**0.410**
460	0.919	**0.410**
470	0.919	**0.410**
480	0.919	**0.410**
490	**0.920**	0.409
500	**0.920**	0.406
510	**0.921**	0.402
520	**0.920**	0.393
530	**0.920**	0.377
540	**0.920**	0.347
550	**0.920**	0.309
560	0.918	0.254
570	0.916	0.179
580	0.913	0.105
590	0.906	
600	0.892	
610	0.860	
620	0.825	
630	0.776	
640	0.721	
650	0.654	
660	0.582	
670	0.514	
680	0.435	
690	0.368	
700	0.309	

Discussion

V. DISCUSSION

The basic requirement of men for survival is food, shelter and clothing. Men from pre-historic era used different material like animal skin, tree bark, plant leaves etc. In search of better alternatives he discovered fibres like flax, cotton, jute, wool and silk. He also learnt to make fabric from these fibres. The naturally colour cottons also formed an integral part of this process of civilization world wide. Archeological and historic records showed the use of naturally colour cottons in different civilization spread over different parts of the globe. The cultivation and use of colour cottons did not get the previlage that of its white cousine, thus remained undeveloped. The reasons for this were many like easy dyeability of white cottons, and demand for supply of white cotton which prohibited cultivation of colour cottons either legally or by force as there was a fear of contaminations. Therefore over centuries no systematic effort was made to improve colour cottons either for yield or fibre properties. Thus the cultivation of naturally colour cottons was reduced drastically and it had become nearly extinct, except in some parts of Peru. Recently interest in it was revived because of all together different reasons. The present day white cotton cultivation involves use of huge quantity of different chemicals like fertilizers, pesticides, weedicides, defoliator etc during cultivation. During its journey from fibre to fabric manufacture many hazardous chemicals dyes and other chemicals are also used. Most of these are carcinogenic and the process of dyeing is also most water consuming and polluting one. Because of these reasons the present day cotton cultivation has been termed as environment non-friendly. In this context the revival of interest in colour cottons is important as it is considered as eco-friendly because it avoids process of dyeing. Facbrics manufactured from it do not cause skin diseases, allergies etc., as that of chemically dyed white cotton fabric.

Revival of colour cottons has also brought forth its problem which include low yielding ability, poor fibre quality, susceptibility to insect pests and unstability of colour over locations and seasons.

The need of hour is to overcome all these draw backs. For which the need to study the available variability and devise improvement programmes was felt. Considering all required priorities a series of studies with different objectives were undertaken at Agricultural Research Station, Dharwad. The studies were aimed to evaluate colour cotton genotypes and hybrids, to assess variability, associations, component character analysis, heterosis, gene effect along with basic genetics and mutation effects etc.

5.1 Analysis of variance

The analysis of variance in both Dharwad colour cotton genotypes and hybrids indicated availability of significant variation among different genotypes for different characters. Significant variation in hybrids due to replication was observed for characters like lint index, ginning out-turn, plant height, number of sympodia and seed cotton yield. The presence of high degree of variability indicates to a possible exploitation of variation for different breeding purposes, but at the same time restraint has to be excersized for the characters which showed significant block variation. In case of such characters care should be taken to discount the block effect. It could be observed that in case of hybrids variation due to replication was high for above five characters whereas in the genotypes replication variation was not observed, indicating that genotypes were less influenced by environment, whereas performance of hybrids was highly influenced by environment. Similar results were reported by Bijapur (1996), Singh *et al.* (1996), Khadi *et al.* (1996b) and Amudha and Raveendran (1997).

5.2 *Per se* performance

5.2.1 *Per se* performance of Dharwad colour cotton genotypes

All twenty two genotypes varied significantly for almost all characters, which is evident by the range observed for the different characters viz., plant height (92.2-144.40 cm), number of monopodia (1.08-3.13), number of sympodia (15.33 to 23.8), days to first boll burst (122-140), number of bolls (4.03-18.57), boll weight (2.33-5.13 g), seed index (7-11.33 g), lint index (3.57-6.67 g), ginning out-turn (20.93-43.6%), seed cotton yield (395.34 to 1430.81 kg/ha) and lint yield (93.88 to 571.55 kg/ha).

It was observed that in general *hirsutum* genotypes were having seed cotton yield range from 395 to 1430 kg per ha under rainfed condition, wherein green linted genotypes had very low seed cotton yield as compared to brown linted *hirsutum* genotypes. The diploid genotypes had higher seed cotton yield than others. The growth parameters values were higher in diploid than *hirsutum* cottons. The results indicated that the green linted genotypes were less potential for yield than brown *hirsutum* and brown *arboreum* genotypes. The range indicated extent of available utilizable variation and scope for practicing selection to obtain improved strains.

The perforamnce of different colour linted genotypes indicated that brown linted *hirsutum* genotypes were having varying performance and most of them were above grand mean for different yield and growth parameters. Similarly brown linted *arboreum* genotypes were also found to be above average for most of the characters. But the green linted *hirsutum* genotypes were below normal for most of the characters. Thus the performance of Dharwad colour linted cotton genotypes suggests that more efforts are required to improve green linted genotypes, whereas some brown *arboreum* and *hirsutum* genotypes found better suitability for commercial cultivation.

Most of the genotypes under study were found belong to medium staple category and no genotype possessed long and extra-long staple length (Table 55).

Nearly all genotypes except DCCV 19 and 20 had good uniformity i.e., eleven genotypes belonged to excellent category, nine to good category. Similarly the fibre fineness of these genotypes was well spread. Both diploid genotypes were very coarse, whereas both green genotypes were very fine. The *hirsutum* genotypes were spread over fine (8), average (6) and coarse (4). All DCCV genotypes had above average maturity, most of the genotypes belong to good maturity category (16). Fibre strength was very low in all twenty two genotypes. It can be inferred that these genotypes have average to excellent fibre quality parameters except for fibre strength, which was reported to be low. So the stress has to be given on improving fibre strength. The diploid cotton genotypes reported to possess short A fibre length, poor to average uniformity ratio, very coarse fibre and very low fibre strength. Thus these genotypes had moderate fibre quality index (FQI), less counts and with 1850 CSP value. These genotypes are found to be suitable for manufacturing fabrics like denim, furnishing, dress material, and terry fabric etc.

The green linted genotypes, also had short A, fibre length, good to excellent uniformity ratio, very low micronaire value, average maturity and very low fibre strength. It may be suitable for 20-25 counts spinning but as micronaire value and fibre strength are too low the spinning would be difficult and yarn produced would be weak.

The brown linted *hirsutum* genotypes had short B, short A and medium staple length, similarly they had good to excellent uniformity and their finness varied from fine to coarse. The maturity observed was good to very high maturity. All genotypes were very poor in fibre strength. The FQI varied from 100 to 217, similarly counts ranged from 3s to

Table 55. Categorisation of twenty two Dharwad colour cotton genotypes with respect to fibre quality parameters

2.5% Span length		Uniformity/Ratio		Fibre Fineness		Maturity coefficient		Fibre strength	
Short B	[5]	Poor	[1]	Very fine	[2]	Very immune	[-]	Very low	[22]
Short A	[11]	Fair	[-]	Fine	[8]	Immature	[-]	Low	[]
Mdeium	[6]	Average	[1]	Average	[6]	Average M	[2]	Average	[]
Long	[-]	Good	[9]	Coarse	[4]	Good maturity	[16]	Good	[]
Extra long	[-]	Excellent	[11]	Very coarse	[2]	Very high M	[2]	Very good	[]

26s and CSP value from 1791 to 1995. This obsrvation indicates the possibility of exploitation of these genotypes for manufacturer of mats, denims, beddings, furnishings and dress materials.

5.2.2 *Per se* performance of Dharwad colour cotton hybrids

The performance of hybrids was better than their colour linted parents for most of the characters related to yield. All hybrids were taller than parents but number of monopodia and sympodia were more in *hirsutum* parents than their hybrids, whereas diploid hybrids (DCCH-9 and DCCH-10) were having more monopodia and sympodia than their parents. For days to first boll burst all hybrids were on par with their parents.

It was also observed that all hybrids were significantly superior over both parents for yield but the superiority was greater over colour linted parents as compared to white linted parents. The hybrids with all three colour linted parents viz., DBH, DGH and DBA gave higher yield than their parents. Similarly trend was also observed for lint yield. So it can be inferred that for increasing yield levels in colour linted cottons development of hybrids could be of paramount importance.

For average boll number, lint index and GOT both diploid and *hirsutum* hybrids were slightly superior to their parental means, whereas for boll weight, seed index, the *hirsutum* hybrids were better than parents but diploid hybrids were on par with their parents. It was noted that for almost all characters the hybrids were on par with white linted checks. Thus it can be said that colour linted cotton hybrids are comparable to that of white ones and if good parents are utilised then there is a possibility of developing very high performing hybrids.

The objective of developing hybrids was not only to improve yield but also to explore the possibility of improving fibre quality. The results indicated that this objective has been met partially. One clear observation was that hybrids involving DBH and DGH as colour linted parents and DS-28, Abhadita, as white linted parent were having higher 2.5 per cent span length than their colour linted parents and it was less than white linted parents. Whereas in case of diploid colour cotton hybrids the fibre length was more than white linted parent but less than colour linted parent (Table 56).

All hybrids were on par with their parents and check for uniformity ratio and fibre maturity. In case of fibre finness, all hybrids except DCCH-8 and diploid hybrids had micronaire value in the range of 3.5 to 3.9 which is a positive development. All *hirsutum* colour hybrids had reduced micronaire than their parental mean (4.15) and check mean value (4.15). The *hirsutum* hybrids were better than their parent with respect to the fibre strength, whereas diploid hybrids were on par. Thus it is seen that hybridisation has helped in the improvement of fibre length, micronaire and fibre strength, whereas in case of uniformity ratio and maturity coefficient there was no change.

The hybridisation has helped to develop hybrids with good maturity, fine to very.coarse fibre, very low to average fibre strength, fair to good uniformity and short A to medium fibre length. The areas were more stress needed are to develop long to extra long staple cotton, with excellent maturity and good fibre strength.

Using above fibre parameters, some more fibre quality parameters like FQI, counts and CSP were computed. The results indicated that *hirsutum* hybrids performed better than colour linted parents whereas diploid hybrids were better than white linted parent for all

Table 56. Categorisation of twenty two Dharwad colour cotton hybrids with respect to fibre quality parameters

2.5% Span length		Uniformity/Ratio		Fibre Fineness		Maturity coefficient		Fibre strength	
Short B	[-]	Poor	[-]	Very fine	[-]	Very immune	[-]	Very low	[2]
Short A	[3]	Fair	[1]	Fine	[7]	Immature	[-]	Low	[7]
Mdeium	[7]	Average	[4]	Average	[1]	Average M	[-]	Average	[1]
Long	[-]	Good	[5]	Coarse	[-]	Good maturity	[10]	Good	[-]
Extra long	[-]	Excellent	[-]	Very coarse	[2]	Very high M	[-]	Very good	[-]

characters. Thus indicating and confirming earlier observation of this study that hybridisation helps to improve naturally colour cottons.

5.3 Genetic variability

Improvement of any crop depends on the existence of exploitable variation and the extent of its exploitation by plant breeder. The plant breeder should be able to identify sources of desirable genes, devise and use methods to incorporate them into breeding population and also select for a combinations of desirable traits which might yield a productive and desirable genotype. To achieve these objectives the plant breeder needs to study the extent of available exploitable variation. These can be achieved by evaluating large number of genotypes for the variability. Some of the biometrical parameters that can be used to assess variability include, variances, phenotypic (PCV) and genotypic co-efficient of variations, heritability and genetic advance of mean

In order to assess the existing variability in naturally colour cottons two sets of genotypes were evaluated. The first set consisting of 22 Dharwad colour cotton genotypes (DCCV), whereas second set comprised of ten colour cotton hybrids (DCCH) along with their parents and white linted checks (Fig. 1 and 2).

The variances studied indicated that except for number of monopodia in DCCV and number of sympodia in both DCCV and DCCH all characters had higher component of genotypic variance. Thus, they are stable and would have high response to selections. For number of sympodia, it may be inferred that both genetic and environmental component have equal role in the expression. The number of monopodia showed higher environmental variation indicating that the environmental component is more in its expression. Bijapur (1996) reported similar results in colour cottons studies.

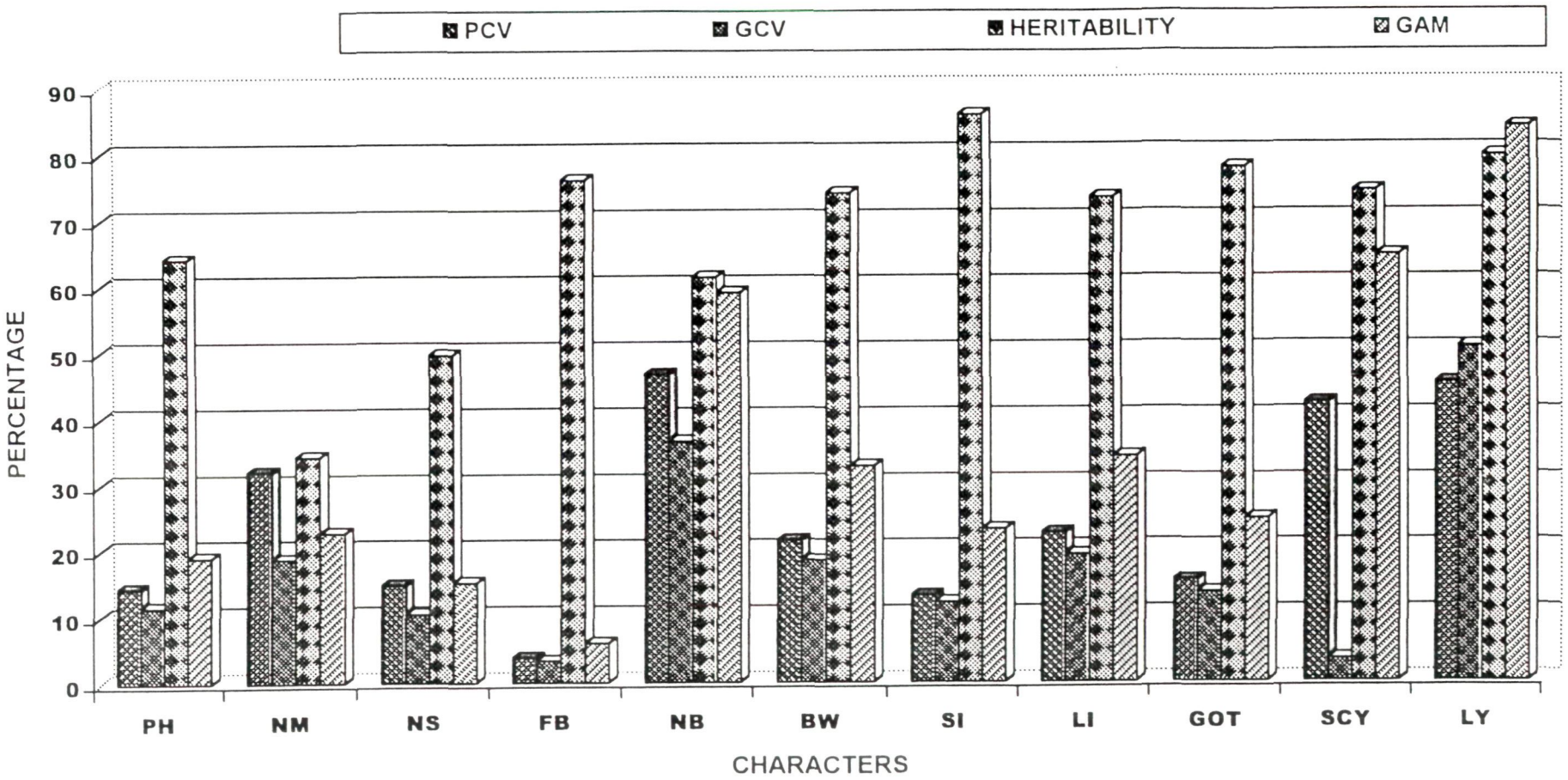


FIG. 1. Components of genetic variability in Dharwad colour cotton genotypes

In both evaluations the coefficients of variation (PCV and GCV) were moderate to high for all characters studied except for days to first boll burst, which indicates moderate to high diversity for the characters. The number of days to first boll burst showed low values of PCV and GCV which indicated low diversity for it. In Dharwad colour cotton genotypes difference between PCV and GCV was low for all characters except number of monopodia and number of bolls. This result indicated that all these characters have low sensitivity to environment, depends on genetic factors and selection practiced for these characters will be more effective. The difference between PCV and GCV were high for number of monopodia and number of bolls which means that these two characters are sensitive to environment, they are also influenced by non-genetic factors.

In Dharwad colour cotton hybrids evaluation, except for number of bolls all characters had low differences between PCV and GCV indicating less influence of environmental factors in expression of these characters.

The selection will be more effective only if it is based not only on PCV and GCV but also on heritability, which indicates the accuracy with which a genotype can be evaluated by its phenotypic expression. Heritability value is an indication of degree of fixable additive variance in the population. The estimate of heritability accompained by estimate of genetic advance of mean are more meaningful from the point of expected genetic gain. The genetic advance of mean is the measure of improvement that can be achieved by practising selection in a population.

In both hybrids and genotypes evaluation studies, high heritability was coupled with high genetic advance of mean for the characters number of bolls, boll weight, seed index, lint index, ginning out-turn, seed cotton yield and lint yield and plant height,

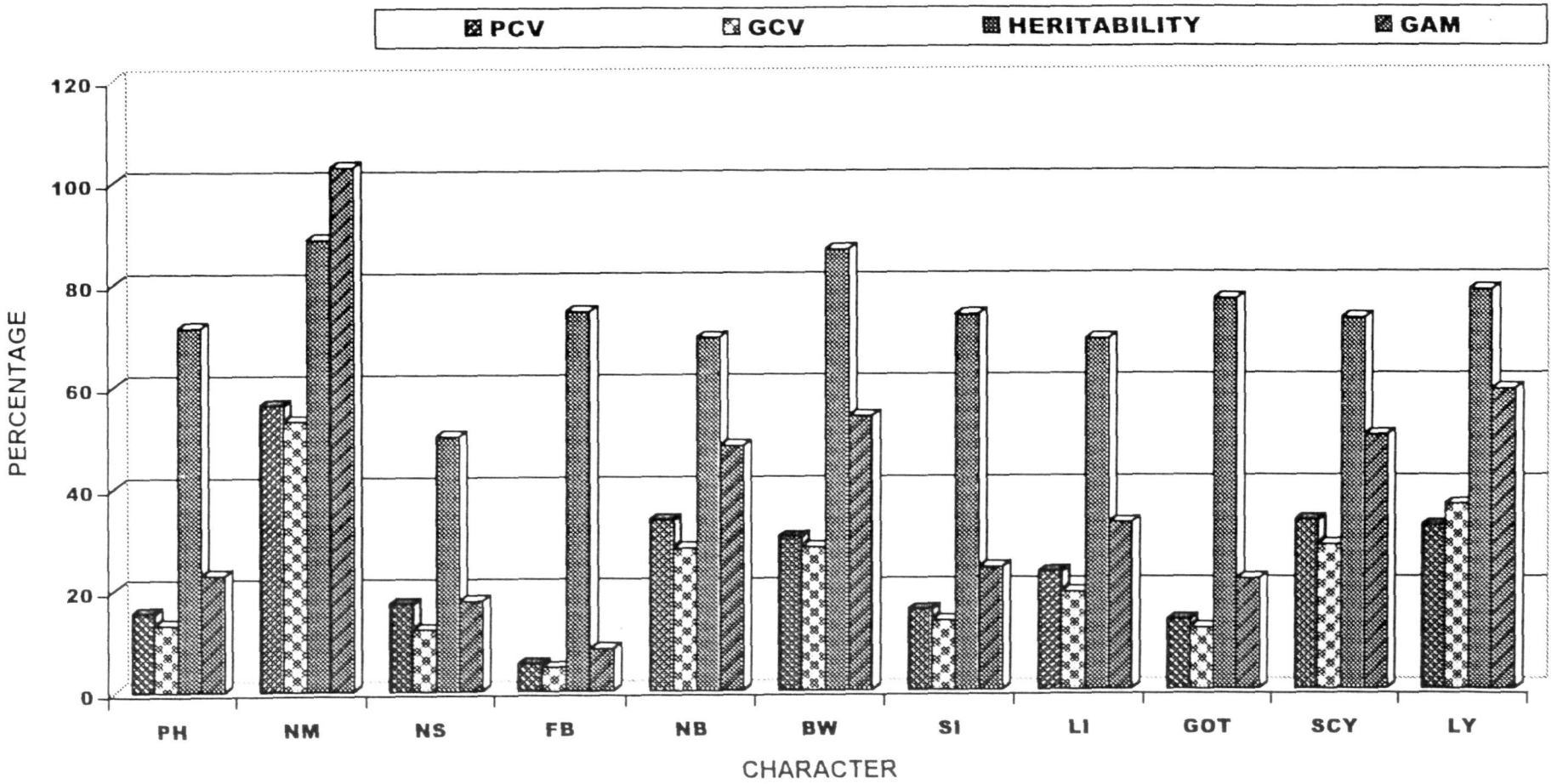


FIG. 2. Components of genetic variability in Dharwad colour cotton hybrids

number of monopodia only in hybrids. This indicated that these characters are possessing high additive fixable effects and for improvement of these characters simple selection method could be adopted (Panse, 1957). For most of the traits observation are in confirmity with other variability parameters studied.

The observation for plant height, number of monopodia in DCCV genotypes and number of sympodia in both hybrids and genotypes indicated presence of moderate additive effects, for days to first boll burst.

5.4 Genetics of fibre colour

5.4.1 Genetics of fibre colour in *G. hirsutum* cottons

The F_2 of white x colour cotton produced coloured and white linted classes. The ratio of colour to white was confirmed as 3:1 (3 colour:1 white). It was possible to classify colour class into another two broad classes viz., brown and cream which segregated into 1:2:1 which was brown:cream:white. It indicates here that colour expression is governed by single gene with incomplete dominance. Similar results were reported by Balls (1908) and Ware (1932).

Both colour classes could be further classified. Brown class could be categorised into dark brown, medium brown, and light brown, whereas cream could be divided into cream, light cream and off white (Fig. 3). In all theseclasses there was gradual increase in colour of the fibre from off white to dark brown. The gradual increase in the fibre colour resulted in continuous variation. Thereby indicating influence of some other genetic factors like modifying genes. However confirmation of the same is needed.

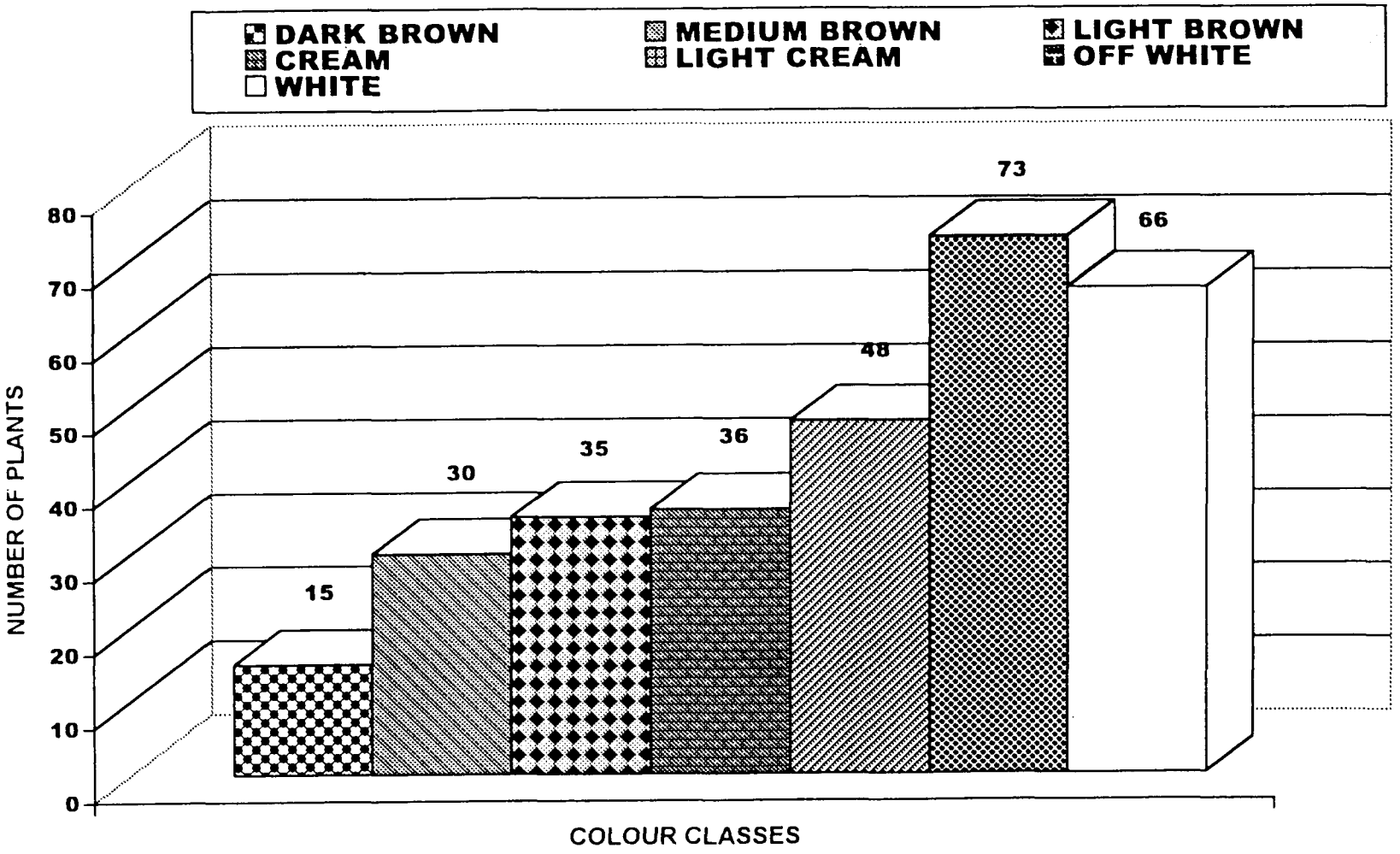


FIG. 3. Fibre colour classes of *G. hirsutum* F2 (white x brown)

5.4.2 Genetics of fibre colour in *G. arboreum* cottons

The F_2 segregation of diploid colour cotton of brown x white lint genotype indicates the presence of gene interaction. The F_2 segregation ratio 15:1 holds good if only colour linted and white linted classes are considered irrespective of variation in lint colour. It indicates that fibre colour development is controlled by a pair of genes with duplicate epistasis.

Detail study of only colour lint class revealed that it can be further categorised into six different classes which ranged from off white to medium brown. The colour classes showed gradual increase in fibre colour and many of the classes were merging with higher colour classes (Fig 4).

The variation observed for fibre colour was continuous and not discrete and the number of phenotypic classes observed were also high. Thus it indicates that brown colour of lint in diploid cottons is mainly controlled by two genes with some modifiers which contribute to produce continuous variation.

5.5 Character association

5.5.1 Growth and yield parameters

Character association or the correlation is the measure of the degree of association between two characters, which is very important in selection programmes. If the correlation between attributes are positive then simultaneous improvement of different characters is possible but if they are negative then it indicates a need to compromise between desirable traits.

Generally genotypic correlations would be higher than phenotypic. Falconer (1960) emphasized that environmental and phenotypic correlations would be lower than

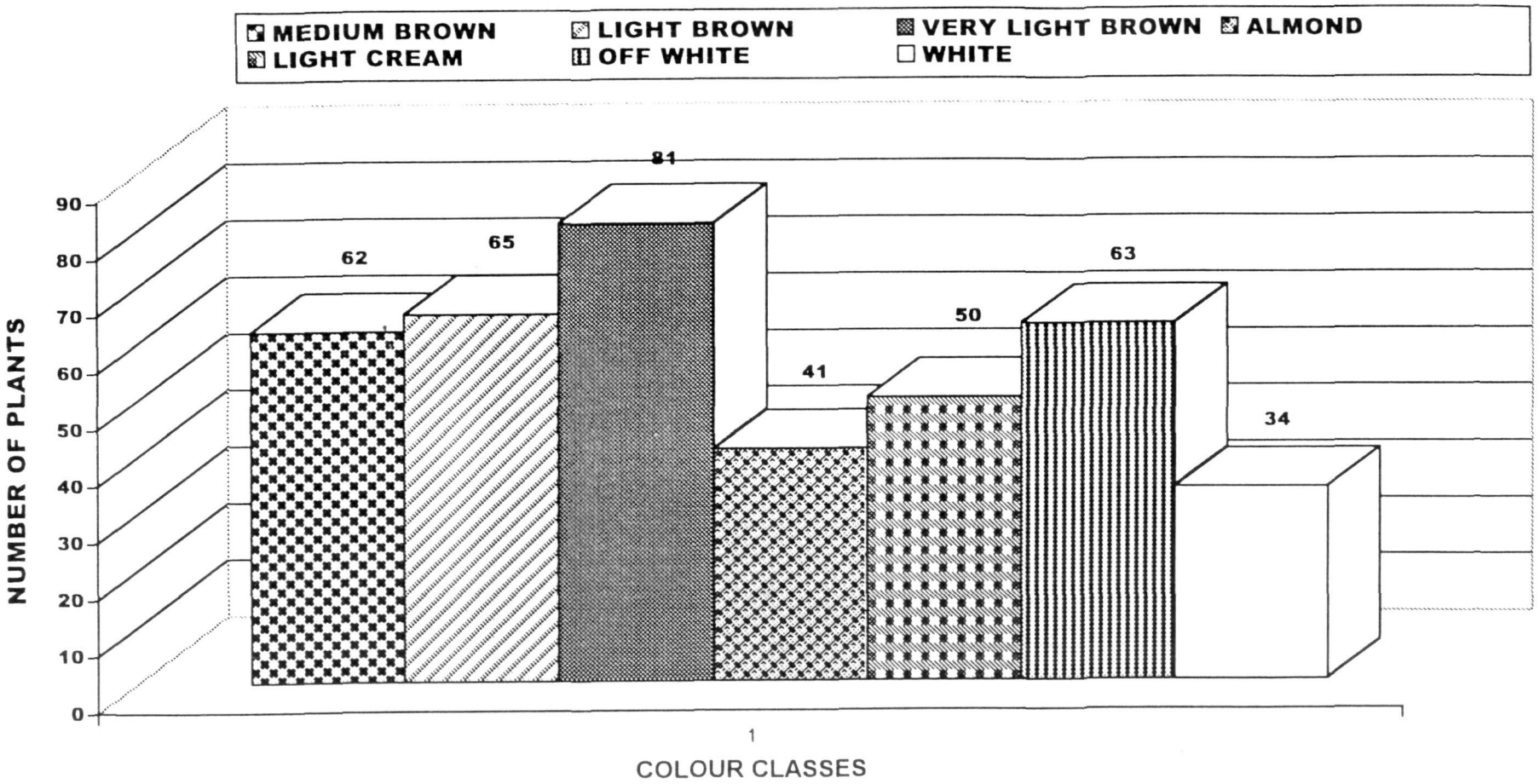


FIG. 4. Fibre colour classes of *G. arboreum* F2 (brown x white)

genotypic correlations in the characters with high heritabilities. Phenotypic correlations are expected to be higher only if the heritabilities of the characters involved are low and the environmental correlations are high. In the evaluation study of Dharwad colour cotton genotypes it was found that most of the genotypic correlations were higher than phenotypic and environmental correlations thereby indicating high heritable nature of characters. Some exceptions were observed (Table 57).

Seed cotton yield and lint yield were having highly significant positive correlation with each other and both were significantly and positively related to number of sympodia, number of bolls, days to first boll burst and ginning out-turn, whereas boll weight and seed index were negatively significantly related. In case of lint yield, positive significant correlation was seen with lint index. The relationship indicates that while selecting for seed cotton and lint yield characters to be considered are number of sympodia, number of boll, days to first boll burst, whereas boll weight and seed index should be given due consideration as they have negative impact. For lint yield improvement another two characters viz., lint index and ginning out-turn are also important. Thus while effecting selection for yields all these characters should be given due consideration.

The growth parameters like plant height, number of monopodia and days to first boll burst were significantly and positively related to number of sympodia thereby depicting their interdependency. So while selecting for one character, a caution is needed as any mistake in selection will affect all four characters which will inturn affect yeilds as three of these characters except monopodia number have direct positive relation with both seed cotton and lint yield.

Table 57. Classification of correlations in Dharwad coloured cotton genotypes

Characters	Positive correlation			Negative correlation		
	Highly significant	Significant	Non significant	Highly significant	Significant	Non significant
PH	NS	-	NM,NB,GP,SCY,LY	-	-	FB,BW,SI,LI
NM	-	NS,FB	NB	-	-	BW,SI,LI,GP,SCY,LY
NS	PH, GP,FB,SCY, LY	NM,NB	LI	BW,SI	-	-
FB	GP, NS, LY	NM,NB,LI,SCY	-	-	BW	SI,PH
NB	GP, SCY, LY	NS,FB	PH,NM,LI	BW,SI	-	-
BW	SI	-	LI	NS,NB,SCY,LY	FB	PH,NM,GP
SI	BW	-	LI	NS,NB,SCY,LY	-	PH,NM,FB,GP
LI	GP	FB,LY	NS,NB,BW,SI,SCY	-	-	PH,NM
GOT	NS,FB,NB,LI,SCY,LY	-	PH	-	-	NM,BW,SI
SCY	NS,NB, GP, LY	FB	PH,LI	BW,SI	-	NM
LY	NS,FB, NB, GP, SCY	LI	PH	BW,SI	-	NM

PH - Plant height; NM - No.of Monopodia; NS - No.of Sympodia; FB - Days to first boll burst; NB - No.of bolls;
BW - Boll weight; SI - Seed index; LI - Lint index; GOT - Ginning out-turn; SCY - Seed cotton yield;
LY - Lint yield

A precaution has to be excercised while selecting for boll weight and seed index as they are negatively related to lint yield, seed cotton yield, number of sympodia, number of bolls and days to first boll burst. Any improper selection either in these two characters or three yield related characters will drastically affect yield. Boll weight and seed index were positively related with each other thus indicating interdependence. It was also observed that lint index had significant positive relation with GOT, lint yield and days to first boll burst indicating that higher lint could be obtained from early bursted balls and lines with good GOT. These two characters can give higher lint index which inturn can result in higher lint yield. Interdependency of lint yield and seed cotton yield was evident from the fact that all three correlation coefficients were high and positively significant.

In the evaluation of Dharwad colour cotton hybrids, most of the genotypic correlations were higher than other two correlation coefficients which indicates high heritabilities for the characters involved. But it was observed that genotypic correlation of seed cotton and lint yield with plant height, number of bolls and seed index and also of lint index with seed index were less than phenotypic correlations which were less than environmental correlations. This cannot be attributed to low heritability values as all these characters have high heritability. It may be attributed to either pleiotrophy or to some unknown factor either environmental or genetic (Table 58).

The correlation results indicated that traits like plant height, number of monopodia, number of sympodia, days to first boll burst and number of bolls were significantly and positively related to each other. They also had significant negative association with boll weight and seed index. None of these six characters were directly related to yield. But the traits number of bolls and seed index were related to GOT and lint index respectively, which were having high significant positive relation with seed cotton

Table 58. Classification of correlations in Dharwad coloured cotton hybrids

Characters	Positive			Negative		
	Highly significant	Significant	Non significant	Highly significant	Significant	Non significant
PH	NS,NM,NB	FB	LY,GOT,SCY	BW,SI	-	SI,LI
NM	NS,FB,NB,PH	-	GOT,LY	BW,SI	-	LI,SCY
NS	PH,NM,FB,NB	-	GOT,	-	LI	SCY,LY
FB	PH,NM,NS,NB	-	GOT,SCY,LY	SI	BW	LI
NB	PH,NM,NS,FB,GOT	-	LI,SCY,LY	BW,SI	-	-
BW	SI,LI, All three	-	GOT,SCY,LY	PH,NM,NB	FB	-
SI	BW	-	LI,SCY	PH,NM,FB,NW	-	GOT,LY
LI	BW,GOT,SCY,LY	-	NM,NS,FB,NB	-	-	PH,NM
GOT	NB,LI,SCY,LY	-	NM,NS,FB,BW	-	-	PH,SI
SCY	LI,GOT,LY	-	PH,FB,NB,BW,SI	-	-	NM,NS
LY	LI,GOT,SCY	-	PH,NM,FB,NB,BW	-	-	NS,SI

PH - Plant height; NM - No.of Monopodia; NS - No.of Sympodia; FB - Days to first boll burst; NB - No.of bolls;
BW - Boll weight; SI - Seed index; LI - Lint index; GOT - Ginning out-turn; SCY - Seed cotton yield;
LY - Lint yield

yield and lint yield. This association seems to be very complex so while selecting for any character a farsighted approach is required. Any undesirable selection in these characters may finally affect economic yield. The relationship between seed index and boll weight, seed cotton yield and lint yield seems to be very strong as all three correlation coefficient were significant and positive. Seed cotton and lint yield were positively and significant related to lint index and GOT. Thereby confirming the strong relation.

5.5.2 Correlations among fibre quality parameters

In Dharwad colour cotton genotypes the association studies indicate that 2.5 per cent span length is most important character which is related positively to most of the characters like fibre strength, FQI, count and CSP, thereby influencing quality of fibre, yarn and fabric. Another important fibre quality parameter indicated by this study is fibre which is related to all other parameters negatively thereby pointing towards its influence over fibre quality. From this a conclusion can be drawn that these two parameters i.e., 2.5 per cent span length and fibre fineness are most important traits which influences overall fibre quality. But both characters are negatively related to each other indicating that a fine balance is needed while selecting for these characters. As range of desirable value for fineness is very narrow, special care has to be taken while selecting for this character so that it should not affect other characters adversely. Similarly while selecting for high fibre length precaution should be taken to see that micronaire value should not be affected so as to prevent deterioration of fibre quality.

In Dharwad colour cotton hybrids the results indicated positive and significant correlation between all fibre quality parameters except with fibre fineness. Micronaire value was negatively related to all other characters. Thus it follows a known trend. It also indicate that it is possible to improve one or more character as all of them are positively related.

These correlation study indicate that relationship between fibre quality parameters is following known trend. For quality cotton micronaire should be between 3-4 as the range is very narrow proper precaution should be taken. It will be desirable to select for about 3.5 mic. So that it will not affect other fibre quality parameters.

5.6 Path analysis

Path analysis is used to study the cause and effect relationship. It dissects the correlation coefficient into direct and indirect effects thereby giving exact picture of the relationship among different characters. Path analysis can help to pin point exact effect of characters on dependent variable and how the relation can be utilised. In present study different paths were studied in both sets of evaluation (Table 59).

5.6.1 Genotypic path analysis for seed cotton yield in Dharwad colour cotton genotypes

Path analysis for seed cotton yield was performed with number of monopodia, number of sympodia, number of bolls, boll weight, seed index, lint index and ginning out-turn.

The trait number of monopodia had positive direct effect on seed cotton yield but its correlation with seed cotton yield was negative, this was due to its higher negative indirect effect through boll weight. It also had high positive direct effects through seed index and lint index which helped to compensate the high negative indirect effect through boll weight. It was observed that eventhough direct effect of number of sympodia was negative its final correlation was positive and moderate. This was because of high positive indirect effect through seed index and ginning out-turn which was neutralised by high negative indirect effect through boll weight thereby reducing correlation value.

Table 59. Path analysis for different characters in Naturally coloured cottons

Path analysis of	Characters used	Characters having high direct effect		Indirect effects of different Characters	
		Positive	Negative	Char - Positive	Negative
Seed cotton Yield in DCCV	NM, NS, NB, BW, SI, LI, GOT	NB, BW, GOT	SI, LI	NM - SI, LI NS - SI, GOT NB - SI, GOT BW - SI - BW LI - BW, GOT GOT - SI	BW BW BW SI, LI, GOT LI, GOT. SI BW, LI
Seed cotton Yield in DCCH	NM, NS, FB, NB, BW, SI, LI, GOT	NB, SI	NM	NM - NB NS - NB FB - NB NB - FB BW - SI SI - NM GOT - NB	SI NM, SI NM, SI NM, SI NM, NB NB -
Lint yield in DCCV	NB, SI, LI, GOT, SCY, FB	SCY, LI	SI	NB - SCY SI - - LI - SCY GOT - SCY FB - SCY	- SCY - - -
Lint yield in DCCH	NM, NS, FB, NB, BW, SI, LI, GP, SCY	NM, GP, SCY	NB, LI	NM - NS - NM VB - NM NB - NM BW -NB, SCY SI - NB LI - GP, SCY GP - NB, SCY SCY - GP	NB NB NB - NM NM - LI LI
Fibre length in DCCV	UR, MIC, MC, FS	FS	MIC	UR - MIC, MC	
FL in DCCH	UR, MIC, MC, FS	MIC	UR	UR - MIC, FS	
FQI in DCCH	FL, UR, MIC, MC, FS	FL, FS	MIC	FL - MIC UR - MIC MC - MIC FS - MIC	
CSP	FL, UR, MIC, MC, FS, FQI	MC, FQI	-	FL - FQI MC - FQI FS - FQI MIC -	FQI

Direct effect of number of bolls was positive and moderate but its indirect effect through boll weight was negative and very high. This was neutralised by high direct effects through seed index and ginning out-turn. Thus making final correlation of number of bolls with seed cotton yield significant and positive. Boll weight had very high direct effect but this was neutralised by its high negative direct effects through all other characters except number of sympodia. As a result of this the final correlation of boll weight to seed cotton yield was negative and significant.

Seed index had high negative direct effect on seed cotton yield. The indirect effects through characters like lint index, ginning out-turn and number of bolls were also high and negative. But extent of negative effects was reduced by high indirect positive effect through boll weight.

Lint index had very high negative direct effect on seed cotton yield. But this was neutralised by its high indirect effects through boll weight and ginning out-turn, thereby making its final correlation with seed cotton yield positive. Ginning out-turn had very high direct effect on seed cotton yield but it was reduced by its negative indirect effect through boll weight and lint index.

Residual effect was very less thereby indicating that characters selected for path are contributing to the expression of seed cotton yield. The overall observation indicate that the traits, number of bolls, boll weight, seed index, lint index and ginning out-turn are most contributing characters to the manifestation of seed cotton yield. These characters had high direct effects and they also influenced indirectly through other characters.

5.6.2 Genotypic path analysis for seed cotton yield in Dharwad colour cotton hybrids

It could be noticed from the results, that number of monopodia had high negative direct effect but its correlation was very less, this was because of its high positive indirect effect through number of bolls.

Similarly, in case of number of sympodia the direct effect was less and positive but its final correlation was moderately negative, this was due to fact that high positive indirect effects through number of bolls was reduced by high negative indirect effects through number of monopodia, boll weight and seed index. Similarly, reduced correlation of number of bolls with seed cotton yield could be explained. Here also very high positive direct effects was reduced by its negative indirect effects through number of monopodia, boll weight, seed index and lint index (Fig. 5).

Seed index revealed a interesting relationship i.e., it had high positive direct effect on seed cotton yield but its final correlation was very low, this was due to its high negative indirect effect through number of bolls. Another interesting feature of the study was low indirect effects of seed index and ginning out-turn on seed cotton yield but their final correlation was very high which could be explained by their indirect effects through different characters like number of bolls, number of monopodia and seed index.

The study also brought forth another interesting relatinoship between number of bolls and number of monopodia, boll weight, seed index and lint index. It was noticed that wherever effect of number of bolls was positive, the effects of number of monopodia, boll weight, seed index and lint index were negative and vice versa. Thus it shows that for

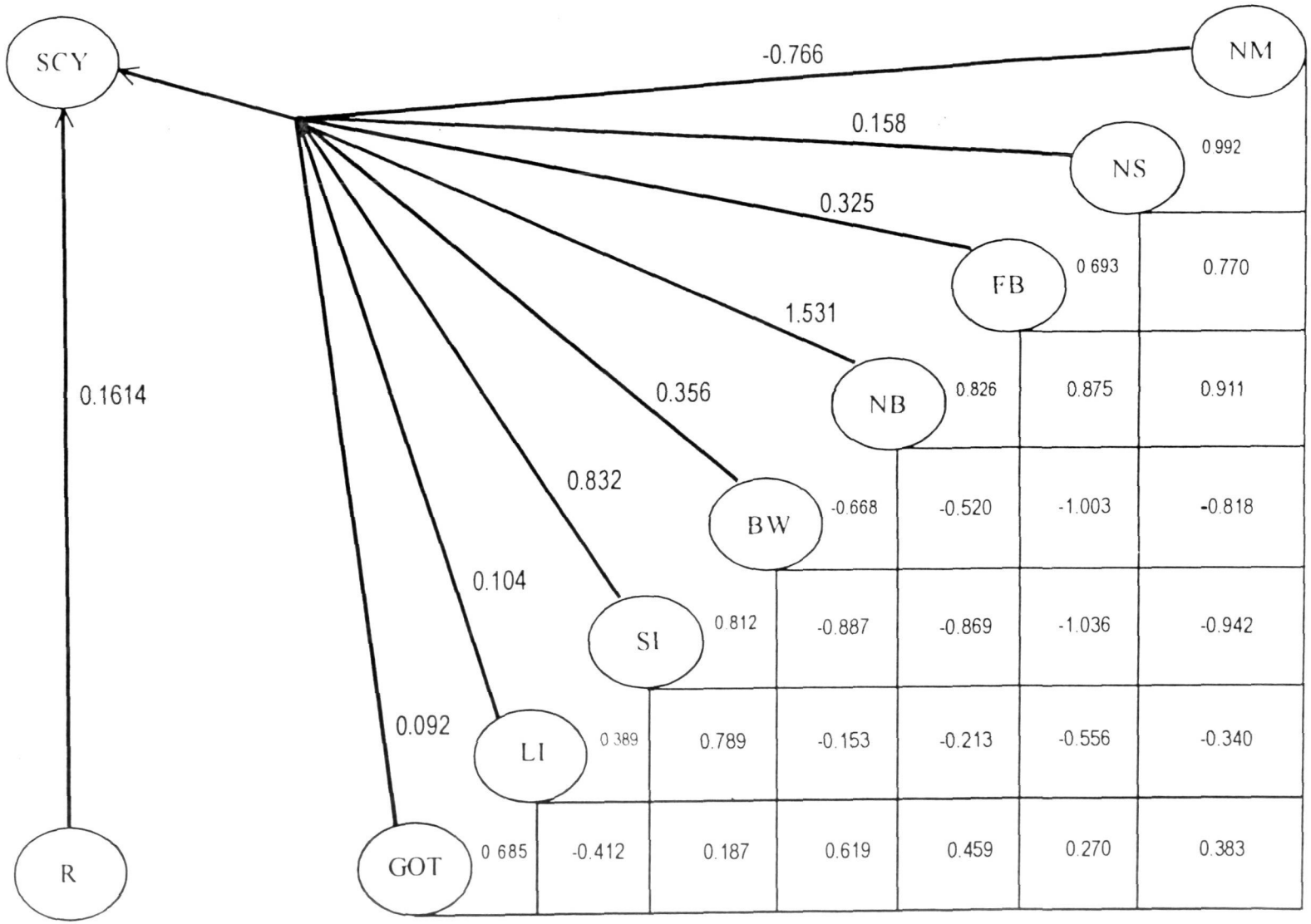


Fig. 5. Path diagram for seed cotton yield in Dharwad Colour Cotton Hybrids

SCY - Seed cotton yield; NM - No.of monopodia; NS - No.of sympodia; FB - Days to first boll burst; NB - Number of bolls
BW - Boll weight; SI - Seed index; LI - Lint index; GOT - Ginning out-turn; R - Residual effect;
Thick line - Direct effects; Thin line - Correlations

improving seed cotton yield. These are most important characters and while selecting care should be taken so as to balance all these characters as they are related against each other.

5.6.3 Genotypic path analysis for lint yield in Dharwad colour cotton genotypes

The path for lint yield was studied by considering number of bolls, days to first boll burst, seed index, lint index, GOT and seed cotton yield as independent variable. The direct effect of number of bolls on lint yield was negative and very low, but its correlation with lint yield was very high and positive, this was because of its high indirect effect through seed index, seed cotton yield and number of bolls. Seed index had moderate negative direct effect on lint yield but final correlation with lint yield was high and negative. This was due to the fact that except for number of bolls and lint index all other characters had negative indirect effect through it which resulted in shooting up of correlation coefficient significantly. Lint index had moderate direct effect which was added to moderate indirect effect through seed cotton yield to give higher correlation value. The direct effect of ginning out-turn was very low still then its correlation with lint yield was very high. This could be explained by the fact that its indirect effect through seed cotton yield and lint index was positive which resulted in high cumulative correlation. The highest direct effect on lint yield was that of seed cotton yield which was further enhanced by other positive indirect effects specially through seed index to give very high correlation. The days to first boll burst also had very low direct effect, but due to high indirect effect through seed cotton yield and seed index its correlation also soared up. The residual effect was also very low indicting that the independent variables selected contributed maximum to the expression of dependent variable i.e., lint yield. The most important trait which contributes to lint yield is seed cotton yield as it had higher direct effect and all other characters also had high indirect effect through it. Second important character seems to be seed index which had both negative direct and

indirect effects and also moderate positive indirect effects of seed cotton yield and days to first boll burst through it. Similarly another important character is lint index with moderate direct effect on lint yield and indirect effect through GOT (Fig. 6).

Similarly trend was seen for phenotypic path. The most important character which influenced lint yield was seed cotton yield as it had high direct effect and other characters also had high indirect effect through it on lint yield. The second important character influencing lint yield was ginning out-turn which had moderate direct effects and also moderate indirect effects of other characters through it. The residual effects observed for both the paths were very less indicating that the expression of dependent variable lint yield is due to the independent characters choosen for the study.

5.6.4 Genotypic path analysis for lint yield in Dharwad colour cotton hybrids

The character, number of monopodia had high positive direct effect on lint yield, but its correlation was low and negative. This was because of its negative indirect effects through days to first boll burst, number of bolls, boll weight and seed cotton yield. Eventhough its indirect effect through number of sympodia, lint index and ginning outturn was positive, it was less. The number of sympodia had moderate positive direct influence on lint yield. Its indirect influence through number of monopodia, lint index, and GOT was positive. This was counteracted by its negative indirect effect through days to first boll burst, number of bolls, boll weight and seed cotton yield.

Days to first boll burst had moderate negative direct effects, indirect effect through number of bolls and boll weight was negative. But its indirect effect through all other characters was positive thus making correlation with lint yield positive. Number of bolls had high negative direct effect which coupled with its indirect effect through days to

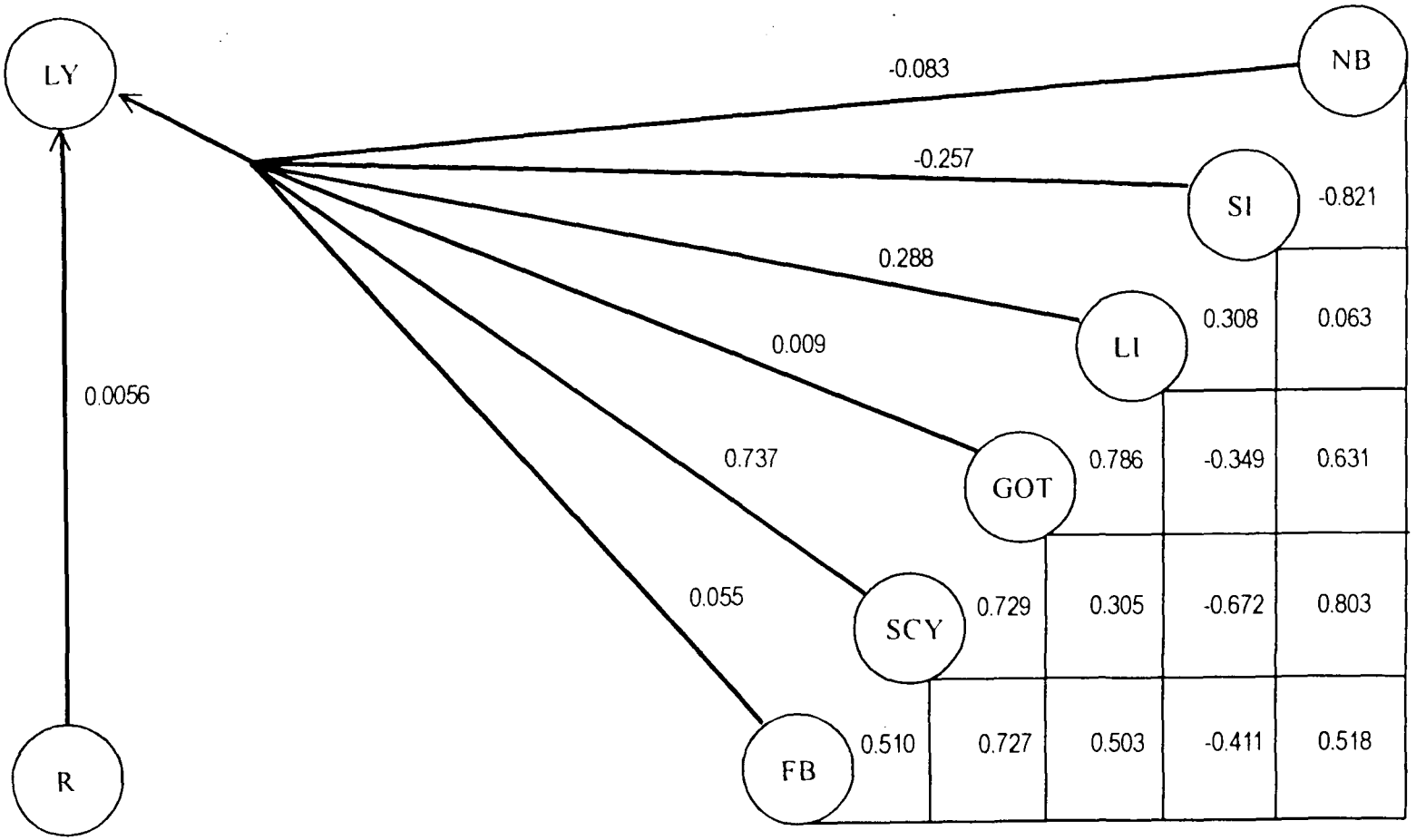


Fig. 6. Path diagram for lint yield in Dharwad colour cotton genotypes

LY - Lint yield; NB - No.of bolls; SI - Seed index; LI - Lint index; GOT - Ginning out-turn;
SCY - Seed cotton yield; FB - Days to first boll burst; R - Residual effect;
Thick line - Direct effects; Thin line - Correlations

first boll burst, and boll weight. But its indirect effects through all remaining characters were positive and their cumulative effects cancelled negative effects to give positive correlation with lint yield.

Moderate positive direct effect of boll weight was coupled with its indirect positive effects through seed cotton yield, GOT, number of bolls and days to first boll burst. Its indirect effects through number of monopodia, number of bolls, seed index and lint index were negative. These indirect effects nullified each other to give a correlation which was slightly higher than direct effect. Seed index had very low negative direct effect which was near to its correlation value. But it was observed that its indirect effects through different characters were nullified as both positive and negative indirect effects were nearly same in magnitude. Most important indirect effects were through number of monopodia and number of bolls.

Lint index had high negative direct influence on lint yield, but its indirect effect through other characters like seed cotton yield, GOT and boll weight were positive. Because of this its correlation with lint yield was positive. Ginning out-turn was also having high positive direct effect on lint yield. But its indirect effect through lint index was high and negative which was nullified by high positive indirect effects through number of bolls, thus resulting the final correlation to be positive and high. The seed cotton yield was having very high direct influence on lint yield and also had high positive correlation. Its indirect effect through lint index and number of bolls were negative, but this influence was nullified by its high positive indirect influence through GOT. The residual effect was found low which indicated that the characters selected are main contributor to lint yield.

5.6.5 Path analysis for fibre length in Dharwad colour cotton genotypes

Path analysis for fibre length was performed by considering uniformity ratio, fibre fineness, maturity coefficient and fibre strength as independent variable.

Uniformity ratio, micronaire value and maturity coefficient had negative direct effect on fibre length, but fibre strength had positive direct effect. Indirect effects of uniformity ratio through micronaire was positive but it was negative through maturity coefficient thereby increasing final negative correlation value with fibre length. Similarly, high negative direct effect of fibre fineness was reduced by its positive indirect effect through uniformity ratio and maturity coefficient. Negative direct effect of maturity coefficient was further increased by negative indirect effect through uniformity ratio, but it was reduced by positive indirect effect through micronaire value. In case of fibre strength, direct effect was high and positive whereas its indirect effects through other three characters were very less. The overall path analysis indicates that fibre strength is having maximum direct effect with little indirct effects thus selection of this character to influence fibre length is quite easy. But other three characters viz., UR, micronaire and maturity coefficient have negative direct effect on fibre length and they had indirect effects through each other thus making selection of these characters very difficult. Therefore a fine balance has to be achieved while selecting these characters for improving fibre length (Fig. 7).

5.6.6 Path analysis for fibre length in Dharwad colour cotton hybrids

Path analysis for fibre length indicated that fibre fineness (micronaire) was most important character on which fibre length depends as it had high negative direct effect and the other characters like uniformity ratio, maturity coefficient and fibre strength were also having their high indirect positive effect through micronaire. The uniformity ratio had negative direct effect on fibre length but its correlation was reduced because of its high

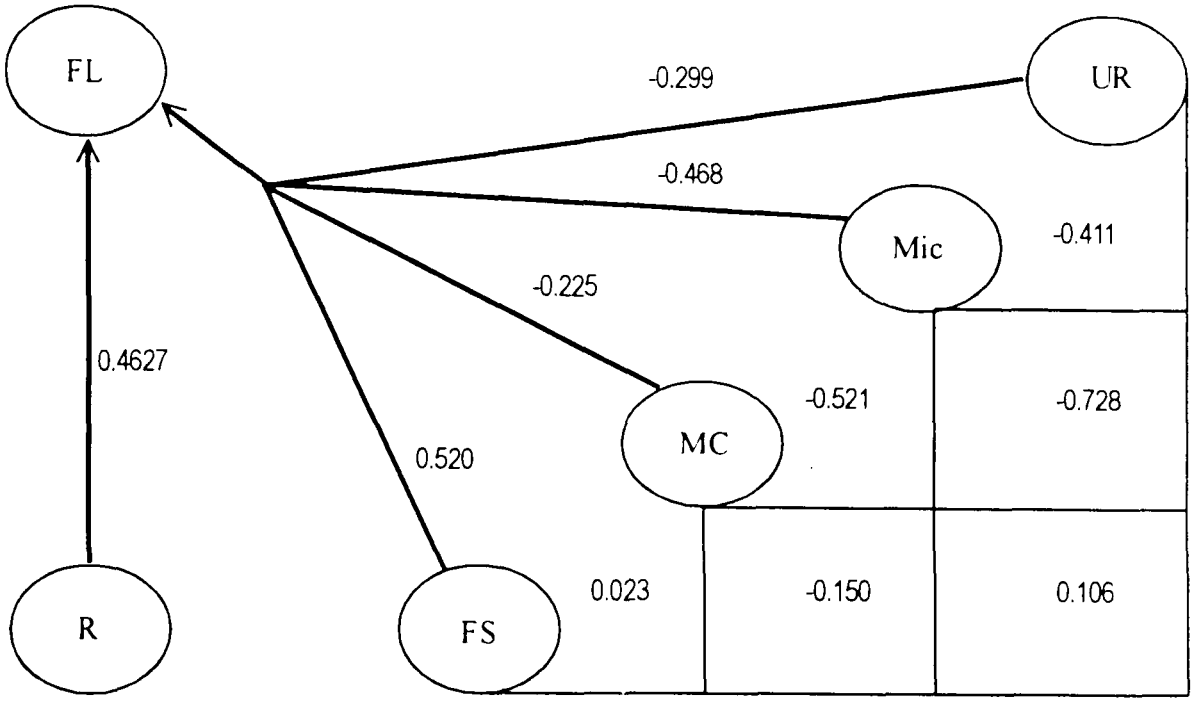


Fig. 7. Path diagram for fibre length in Dharwad Colour cotton genotypes

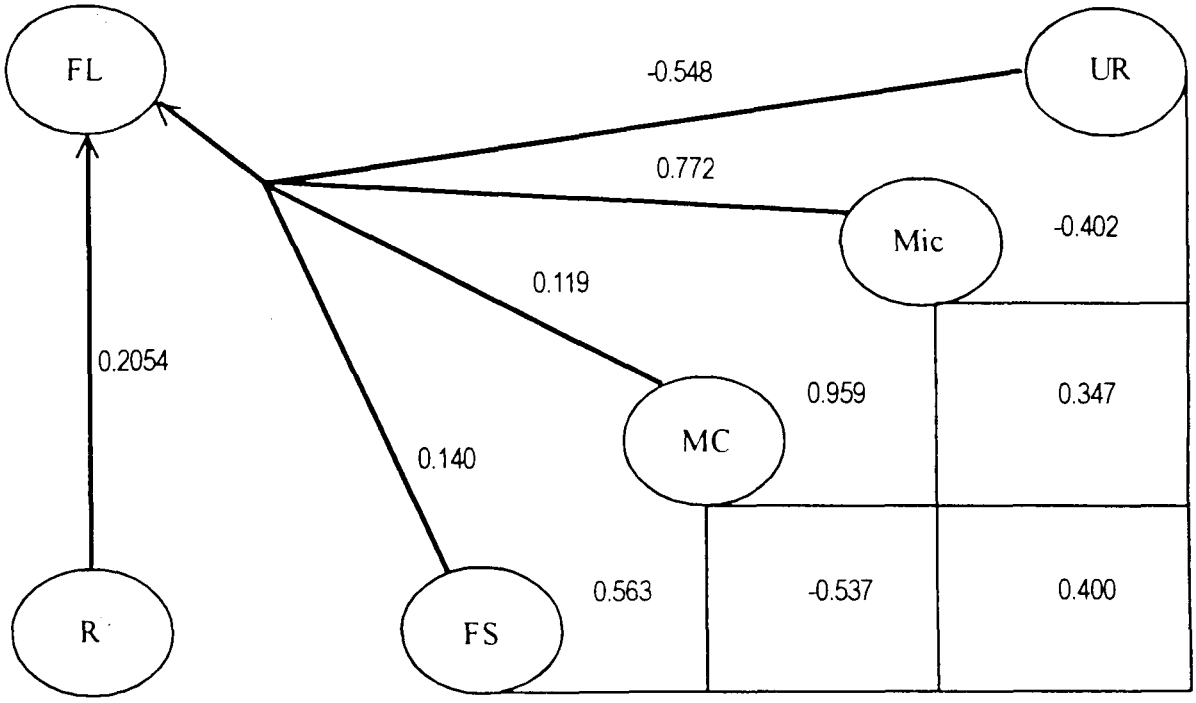


Fig. 8. Path diagram for fibre length in Dharwad Colour cotton hybrids

FL - Fibrel length: FS - Fibre strength: MC - Maturity coefficient: Mic - Micronaire value:
UR - Uniformity ratio: R - Residual effect: Thick lines - Direct effects: Thin lines - correlations

positive indirect effect through micronaire. Eventhough direct effects of maturity coefficient and fibre strength were positive and low, their correlation with fibre length was high as they had high indirect positive effect through micronaire. Thus micronaire, followed by uniformity ratio and maturity coefficient are important characters influencing fibre length in colour cotton hybrids (Fig. 8).

5.6.7 Path analysis for fibre quality index (FQI) in Dharwad colour cotton hybrids

The direct effect of fibre length on fibre quality index (FQI) was moderate but its correlation was very high, this was due to its high positive indirect effect through fibre fineness and fibre strength. Uniformity ratio was having very low negative direct effect but its correlation was positive. This was because of its indirect effect through micronaire and fibre strength. Fibre fineness had high negative direct effects and it had high negative indirect effects through fibre length and fibre strength. Maturity coefficient had low negative direct effect but its correlation with FQI was high as its indirect effect through fibre length, micronaire and fibre strength was high. Fibre strength had high positive direct effect and its indirect effects through fibre length, micronaire, were positive, thereby increasing its correlation with FQI.

5.6.8 Path analysis for count strength product (CSP) in Dharwad colour cotton hybrids

Eventhough direct effect of fibre length on count strength product (CSP) was low and negative, its correlation was very high. This is because of its high indirect effect through FQI. Similar case is that of uniformity ratio. In case of fibre fineness direct effect was very low and positive, but correlations with CSP was high and negative because of its high negative indirect effect through FQI. The fibre strength also had low positive direct

effect but high positive correlation which was also due to its very high positive indirect effect through FQI. Another important character is maturity coefficient which had moderate positive direct effect and other characters also had their low to moderate indirect effects through it.

5.7 Heterosis

5.7.1 Growth and yield components

Heterosis is the superiority of heterozygous genotypes with respect to one or more characters in comparison with corresponding homozygote. Heterosis manifestation shows increased size, greater vigour, higher productivity. Heterosis can be expressed when the parents of a hybrid have different alleles at a locus and there is some level of dominance among these alleles (Falconer, 1960). The two hypotheses that were proposed to explain are dominance hypothesis and overdominance hypothesis. Accordingly to dominance hypothesis, heterosis is caused by complete or partial dominance. In overdominance hypothesis, the value of the heterozygote is considered superior to the value of either homozygote (Shull, 1914). Dominance hypothesis is considered as it is based on levels of dominance that have been widely observed for qualitative characters and it is considered as genetic basis of heterosis.

In cotton existence of high magnitude heterosis was known since the dawn of century. But it was only in 1970 that first commercial hybrid H-4 was released. This was followed by an inter specific hybrid Varalaxmi, after which many hybrids both intra specific and inter specific were released. Hybrids have been also successfully tried for diploid cottons. Thus cotton hybrids have revolutionised Indian Cotton Scenario, to such an extent that as on today 40 per cent area is occupied by hybrids which contribute about 45 per cent of the production. Hybrids also have contributed to qualitative change with more than 50 per

cent of present production is in long and extra long staple category, which was imported at the time of independence.

Based on the experience of white cotton hybrids, an effort is being made to exploit heterosis in hybrids involving white x colour, and vice versa. Apart from improving yield potential, another main objective is to improve fibre quality. Earlier genotypes of colour cottons were poor in yield and fibre quality, so these were crossed with proven white linted genotypes like DS-28, Abhadhita and A-82-1-1 so that the hybrids obtained would have colour of colour linted parent and fibre and yield potential of white linted cotton. Development of colour cotton hybrids was also considered for quick development of colour linted cultivars. The results of the study indicate that the objectives of the work has been largely met (Table 60).

Heterosis for seed cotton yield per hectare was significant over colour linted parent in all ten hybrids evaluated, thus indicating that yield levels of colour cotton can be improved by exploiting heterosis. It was also observed that no hybrid had significant positive heterosis over white linted checks eventhough one hybrid DCCH-3 was on par with DHH-11 superior to NHH-44. This indicated that there exists scope for further improvement. The hybrids like DCCH-1, DCCH-2, DCCH-3, DCCH-6, DCCH-9, DCCH-10 had significant positive heterosis over white linted parents, DS-28, Abadhita and A-82-1-1, which indicated that colour cotton hybrids can yield better than some white cultivars. This dispells the fear that colour cotton hybrids may not be on par even with white cotton varieties. Except DCCH-4 and DCCH-7 all hybrids had significant positive heterosis over mid parents (Fig. 9). Heterosis in colour cotton was also reported by Amudha and Raveendran (1997), Ahuja *et al.* (1998), Khadi *et al.* (1998b) and Punitha and Raveendran (1998).

Table 60. Significant heterosis observed over different parents for various characters in Dharwad colour cotton hybrids

Characters		Hybrids									
		DCCH-1	DCCH-2	DCCH-3	DCCH-4	DCCH-5	DCCH-6	DCCH-7	DCCH-8	DCCH-9	DCCH-10
PH	+	CP	-	-	-	-	MP, CP	-	-	All	C1, C2
NM	+	-	CP	-	CP	-	-	-	-	CP, C1, C2	All
	-	-	-	BP, CP	-	-	-	BP, WP	BP, WP	-	-
NS	+	-	-	-	-	-	-	-	-	-	C1, C2
FB	+	-	WP	MP, WP	MP,BP,WP	MP,CP	MP,CP,WP	MP,BP,CP, WP	C1	-	CP, C1
NB	+	-	-	C2	-	-	CP	CP	CP	C1,C2	C1,C2
	-	-	-	-	-	C1	C1	-	-	-	-
BW	+	C2	C2	-	MP,CP,WP,C2	MP,CP,C2	CP,C2	MP,CP	MP,CP	-	-
	-	BP, WP	BP,WP	-	BP	-	BP,WP	-	-	C1,C2	C1,C2
SI	+	C1	C1	C1	WP,C1,C2	C1	-	C1	C1	C1	C1
	-	-	-	-	-	-	-	-	-	C2	C2
LI	+	CP	CP	CP	CP	CP	CP	MP,CP	CP,MP	-	-
	-	BP,WP	-	-	-	BP,WP	BP,WP	-	-	C1	-
GOT	+	-	-	-	-	CP	CP	MP,CP	CP	-	C2
	-	BP,WP	-	-	-	-	-	-	-	C1	-
SCY	+	-	MP,CP,WP	MP,CP,WP,C2	CP,C2	MP,CP	MP,CP,WP	CP	-	MP,BP,CP,WP	MP CP WP
	-	-	-	-	WP	WP,C1	C1	WP,C1,C2	WP	-	C1
LY	+	MP,BP,CP,WP,C2	MP,CP	MP,CP,C1	CP	CP	MP,CP	CP	CP	BP,MP,CP,WP	BP,CP
	-	-	C1	-	-	C1,C2	C1	BP,WP,C1	BP,WP,C1	-	C1

Table 60. Contd.....

Table 60. Contd.....

Characters		Hybrids									
		DCCH-1	DCCH-2	DCCH-3	DCCH-4	DCCH-5	DCCH-6	DCCH-7	DCCH-8	DCCH-9	DCCH-10
SL	+	CP,C2	CP,C2	CP,C1,C2	CP	CP,C2	CP,C2	-	CP	WP	WP
	-	WP	WP	-	WP,C1	-	-	C1	-	C1,C2	CP,C1,C2
UR	+	MP,WP,C1,C2	MP,WPC1	C1,C2	C1,C2	MP,WP,C1,C2	WP	WP,C1,C2	C1	MP,CP,WP,C1	MP,CP,WP,C1
	-	CP	CP,C2	CP	CP	-	MP,CP,C1,C2	-	MP,CP,C1	C2	C2
FF	+	-	-	-	-	-	-	-	-	C1,C2	CP,C1,C2
	-	CP	MP,CP,C1	-	MP,CP,C1	-	-	C1	-	-	-
MC	+	CP	C2	MP,CP	CP	MP,CP	MP,CP	MP,CP,C2	MP,CP	-	-
	-	WP,C1,C2	CP,WP,C1	WP,C1	WP,C1,C2	C1	C1	WP,C1	WP,C1	-	-
FS	+	All	CP,WP,C1,C2	All	All	All	All	All	All	MP,CP,C2	CP,WP,C1
FQI	+	All	All	MP,CP,C1,C2	MP,CP,C1,C2	All	All	CP,C2	MP,CP,C1,C2	-	-
	-	-	-	-	-	-	-	-	-	C1,C2	C1,C2
C	+	All	All	MP,CP,C1,C2	MP,CP,C1,C2	All	All	CP,C2	MP,CP,C1,C2	-	-
	-	-	-	-	-	-	-	-	-	C1,C2	C1,C2
CSP	+	All	All	MP,CP,C1,C2	All	All	All	All	MP,CP,WP	-	-
	-	-	-	-	-	-	-	-	C1,C2	C1,C2	C1,C2

MP - Mid parent; BP - Better parent; CP - Colour linted parent; WP - White linted parent; C1 - DHH-11; C2 - NHH-44;

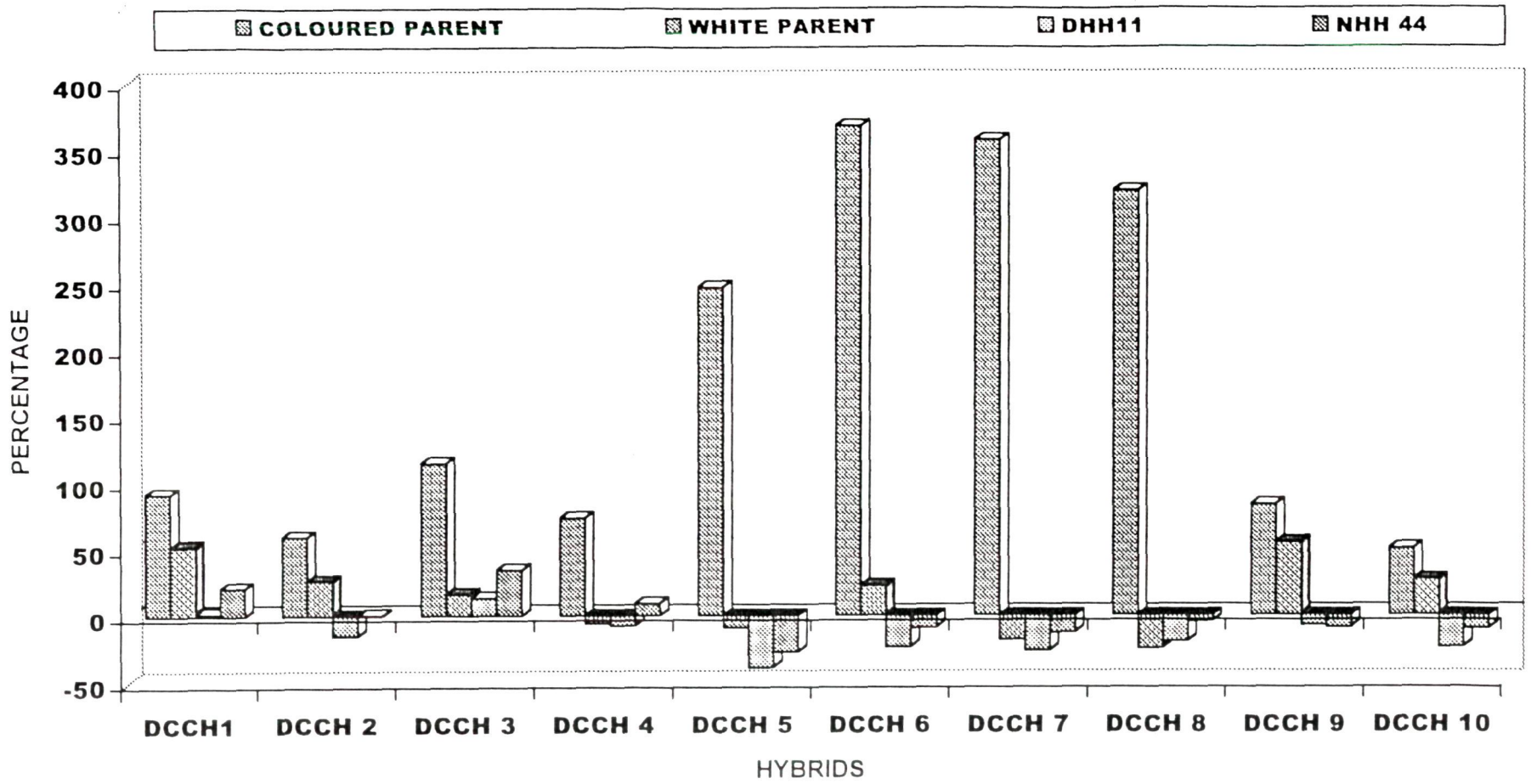


FIG. 9. Heterosis for seed cotton yield

The highest yielding colour linted hybrid DCCH-3 did not show any significant heterosis for any growth parameters, but had significant positive heterosis for seed cotton and lint yield. Another interesting observation was that diploid hybrids showed significant heterosis for all growth parameters like plant height, number of monopodia and sympodia, days to first boll burst and number of bolls, but negative heterosis over checks was observed for boll weight, seed index, lint index, seed cotton yield, and lint yield per ha. Thus indicating that in diploid cotton the manifestation of heterosis is more for vegetative/growth parameters. The hybrids with brown linted *hirsutum* except DCCH-4 did not show any significant heterosis for growth parameters. But for seed cotton yield and lint yield significant positive heterosis was observed, whereas other characters like boll weight, lint index, ginning out-turn showed negative significant heterosis over better parent and white linted parents. This observation points to the fact that the brown linted hybrids could not improve over their parents except for yield characters. They also show heterotic improvement over colour linted parent for lint index, seed cotton yield, lint yield.

Hybrids involving the green parent showed more significant negative heterosis over better parent and white linted parent for number of monopodia, boll weight, lint index, GOT, seed cotton and lint yield. Thereby indicating low degree of desirable heterosis. The character days to first boll burst showed significant positive heterosis in all hybrids except DCCH-1, whereas significant negative heterosis over BP, WP was seen for lint index and GOT (Fig. 10).

5.7.2 Heterosis for fibre quality parameters

Heterosis for fibre quality parameters like 2.5 per cent span length, uniformity ratio, fibre finess, maturity coefficient, fibre strength, FQI, counts and CSP was estimated and its results are discussed below (Table 60).

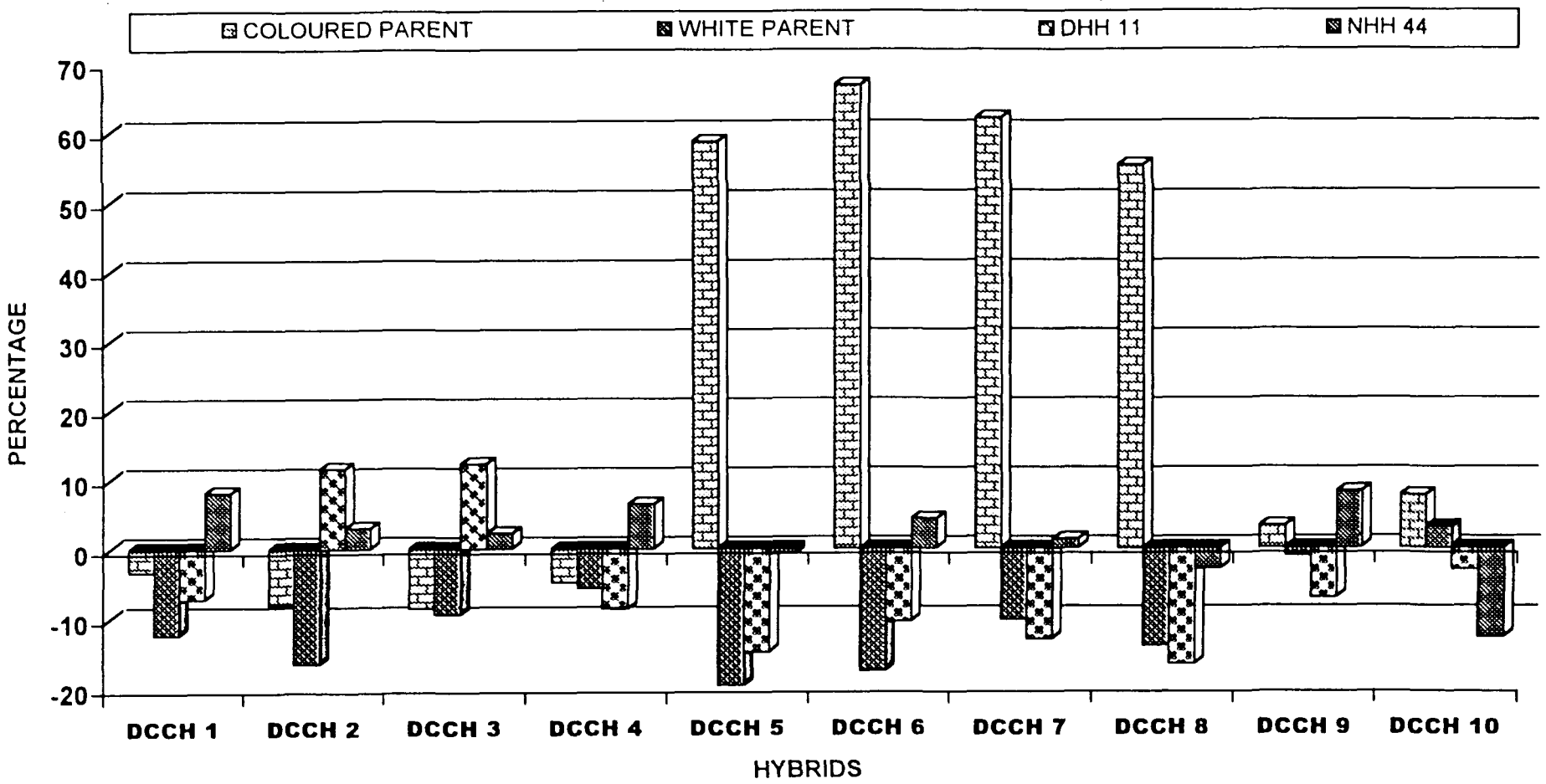


FIG. 10. Heterosis for ginning out-turn

All intra *hirsutum* hybrids except DCCH-7 had highly significant positive heterosis over their colour linted parents viz., DBH-95 and DGH-95 whereas the diploid hybrid showed significant negative heterosis over its colour linted parent. Thus indicating that it is possible to improve fibre length by hybridisation of colour cotton genotypes with white linted genotypes having good fibre length. The negative heterosis in diploid hybrid DCCH-10 was due to the fact that its white linted parent had very short fibre. DCCH-2 showed highly significant positive heterosis over white linted check DHH-11 so also DCCH-1, DCCH-2, DCCH-5 and DCCH-6 which showed significant positive heterosis over another white linted check NHH-44 thereby indicating possibility of developing colour cotton hybrids on par or better than white linted hybrids (Fig. 11). Similar results were also reported by Sundaramurthy *et al.* (1994), Amudha and Raveendran (1998) and Khadi *et al.* (1998b) in colour cottons. In white linted cotton heterosis for fibre length was reported by Borole (1992), Chaudhari *et al.* (1992), Hanuman Singh *et al.* (1995b), Patel and Pethani (1998).

The heterosis for uniformity ratio over colour linted parents in intra *hirsutum* hybrids was negatively and significant indicating that the colour linted parent used was better than the hybrids and also white linted parents. For this character also most of the colour cotton hybrids showed significant positive heterosis over both white linted checks DHH-11 and NHH-44, whereas it was opposite in case for diploid hybrids.

For fibre fineness the hybrids like DCCH-1, DCCH-3 and DCCH-4 showed significant negative heterosis over colour linted parent which had higher micronaire. This indicates that hybrids developed had low micronaire (3.7-3.9) which is highly desirable. It was also observed that heterosis observed in DCCH-10 over colour linted parent was positive indicating that if both parents used are of higher micronaire the results will be of higher micronaire. Another observation made was that some hybrids were having negative

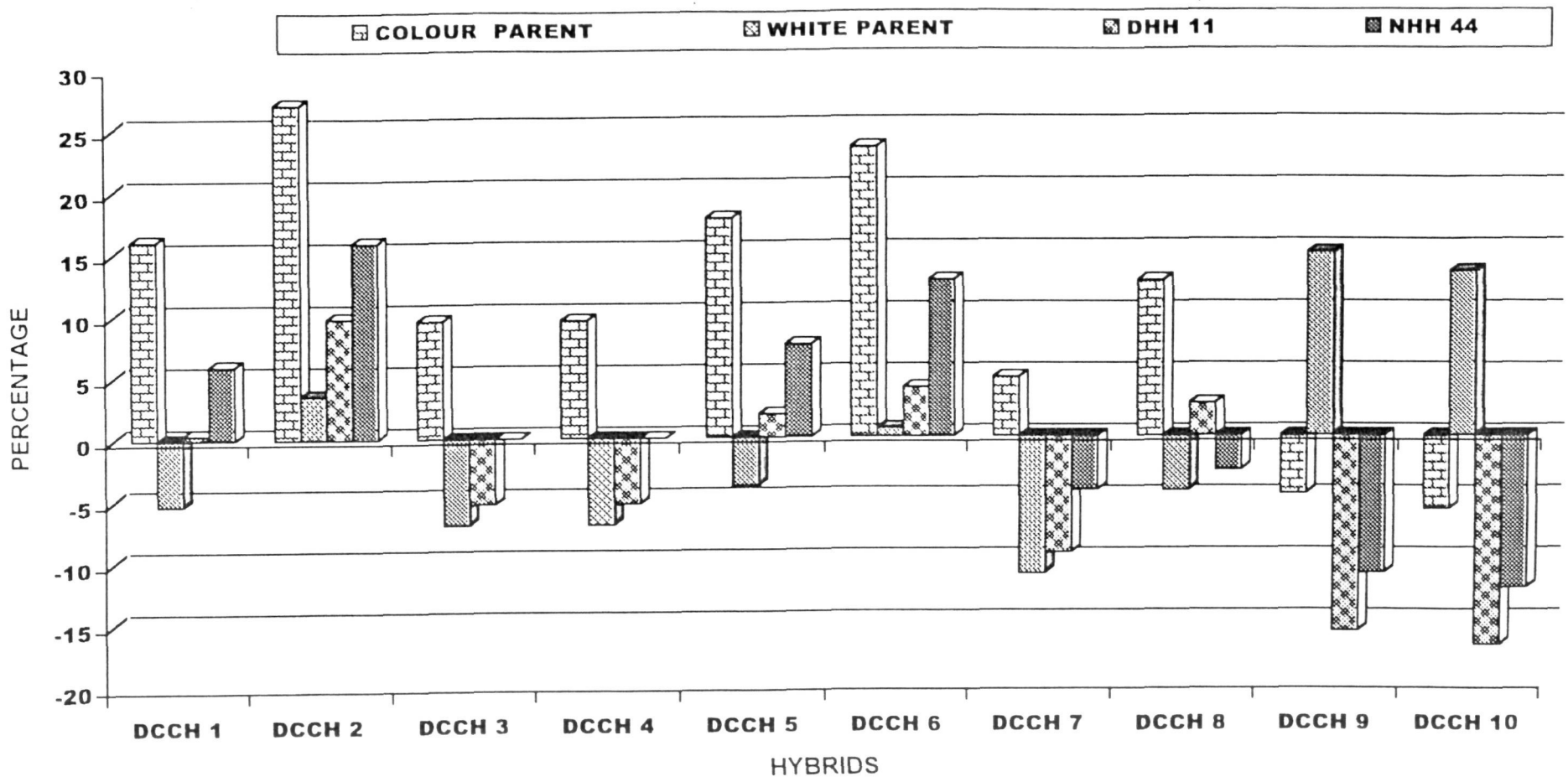


FIG. 11. Heterosis for 2.5% span length

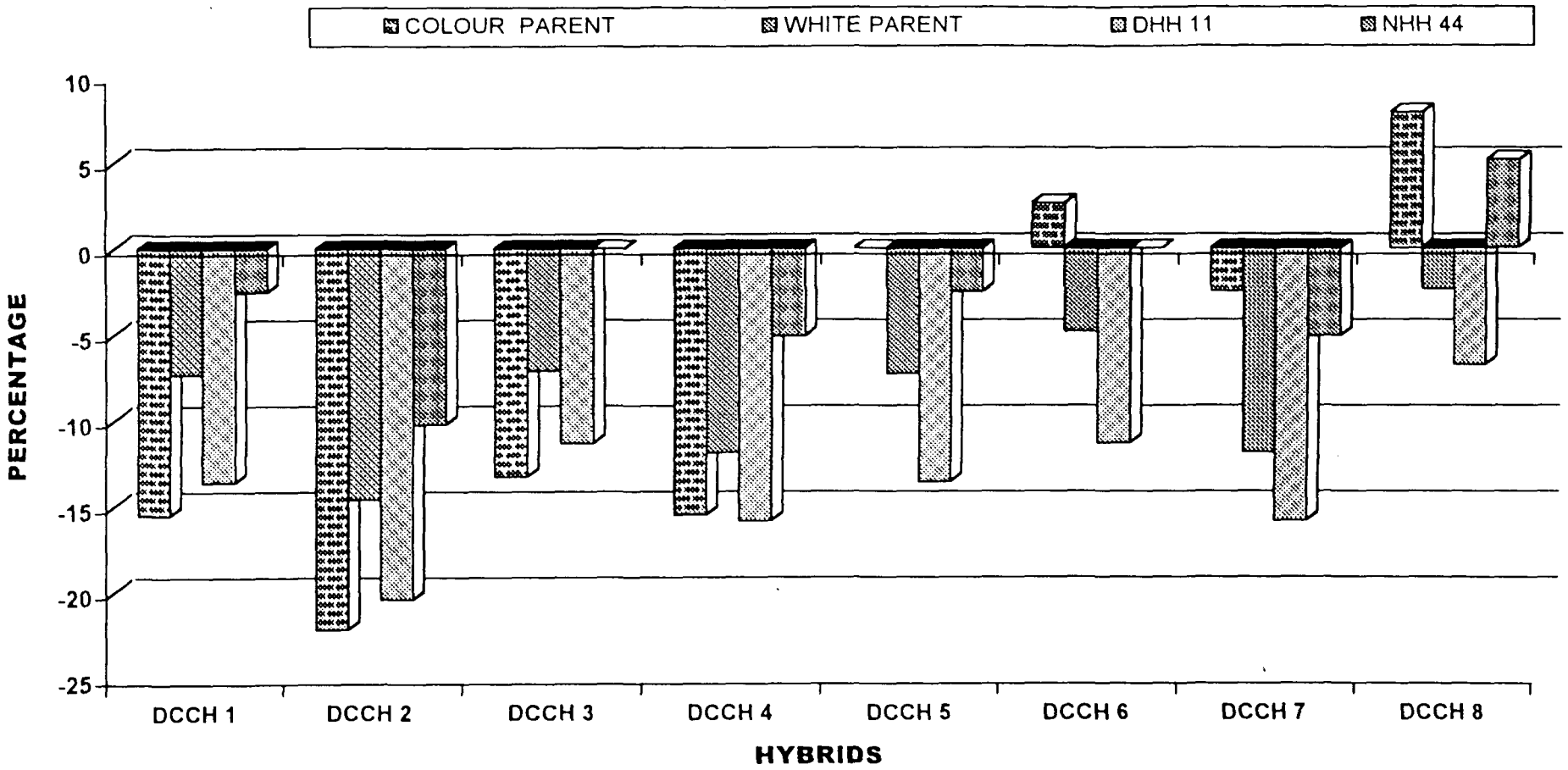


FIG. 12. Heterosis for fibre fineness

significant heterosis over DHH-11 indicating that these hybrids were having finer fibre than DHH-11 (Fig. 12).

The heterosis observed in all intra *hirsutum* hybrids over colour linted parent for maturity coefficient, FQI, counts and CSP was positive and significant thus indicating that these colour cotton hybrids are better than their colour linted parents. Most of these hybrids except DCCH-9 and DCCH-10 also showed positive significant heterosis over both checks indicating their superiority. Similarly for fibre strength all hybrids had significant positive heterosis over mid parent, colour linted parent, white linted parent, DHH-11 and NHH-44 only exception being the heterosis observed over colour linted parent in DCCH-2 (Fig. 13). These results supports other results that the colour cotton hybrids were better than their respective colour linted parents and also white linted checks. Thus it can be said that hybridisation improves fibre strength and it is possible to develop colour cotton hybrids on par with white cotton hybrids.

It was also noticed that for characters FQI (Fig. 14), Counts and CSP, most of the intra *hirsutum* hybrids had significant positive heterosis over mid parent, colour linted parent, white linted parent and checks DHH-11 and NHH-44.

Based on the overall discussion about heterosis for fibre quality some inferences can be drawn. The first and foremost is that the fibre quality of colour cottons can be improved by hybridization with white linted parents and hybrids produced were better than their colour linted parents for most of the fibre quality characters. Secondly it was observed that many hybrids developed were showing significant heterosis over commercial checks for most of the fibre quality parameters thereby, it can be said that some of these hybrids were on par with white or superior than white linted cotton. Third observation is the

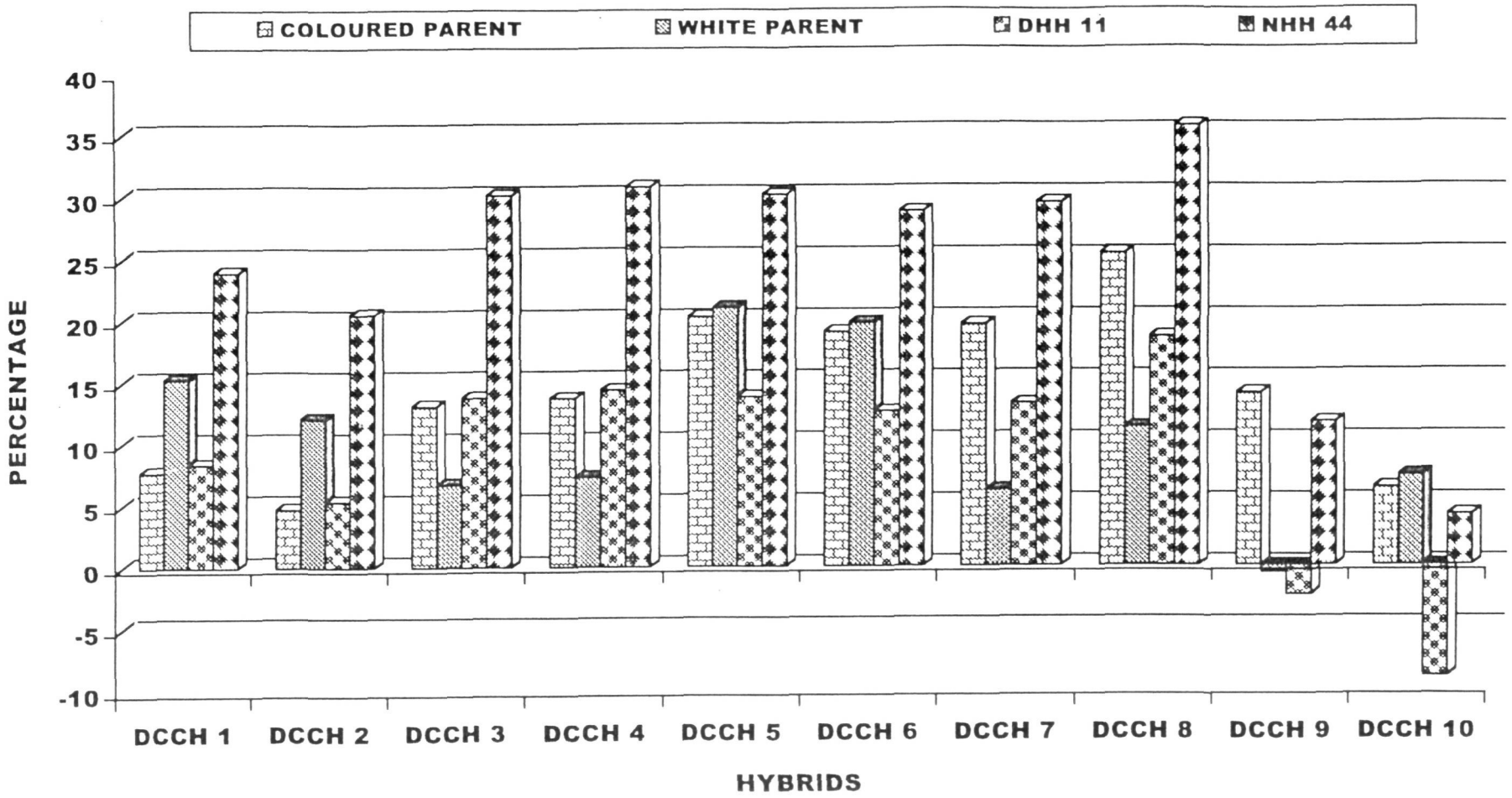


FIG. 13. Heterosis for fibre strength

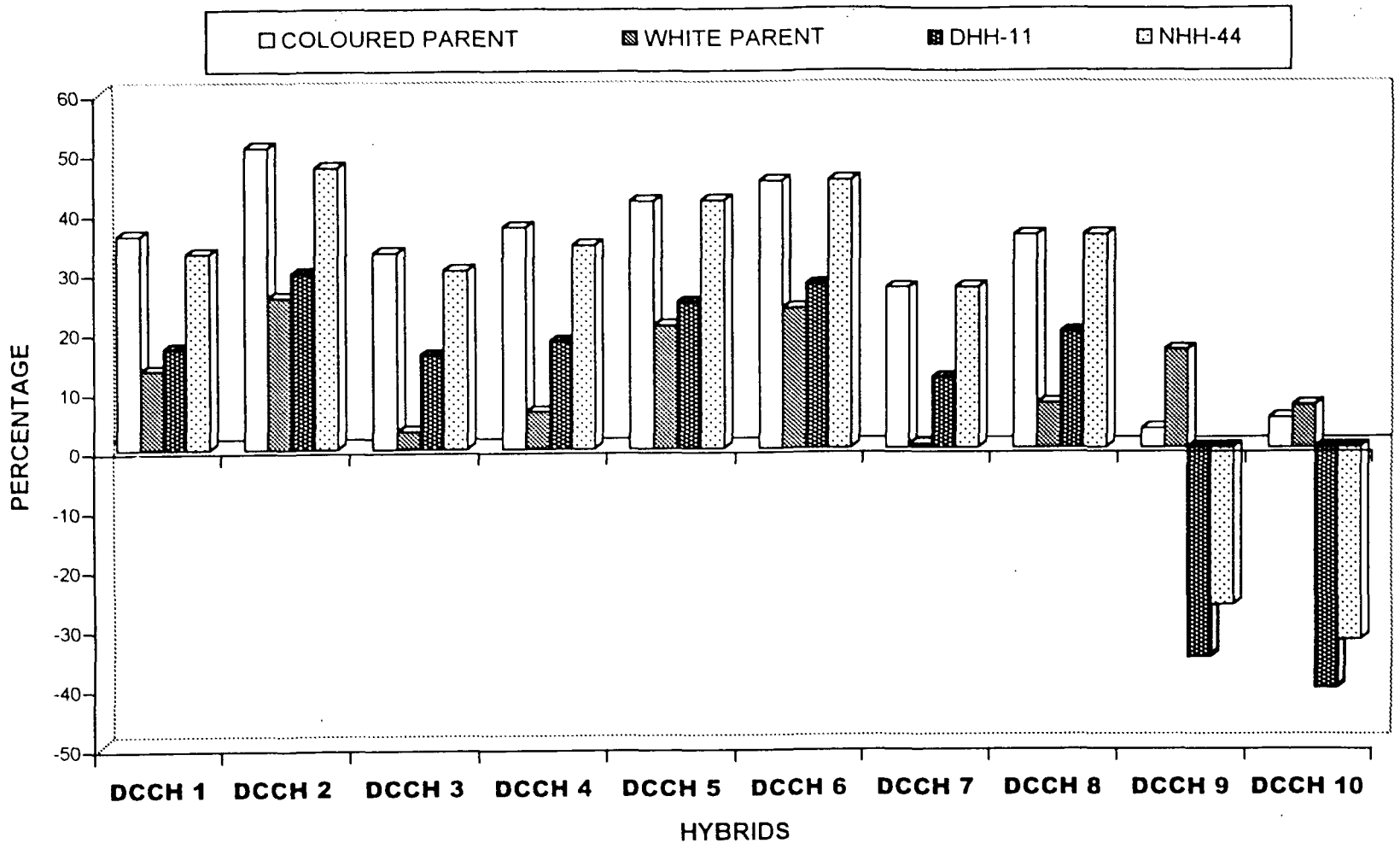


Fig. 14. Heterosis for Fibre quality index (FQI)

existence of heterosis for some quality parameters like FQI, counts and CSP indicated that, the quality of yarn and fabric of colour cotton hybrids would be better than their parents especially colour linted parent and also the white linted check DHH-11 and NHH-44.

5.8 Generation mean analysis

The role of gene action to understand the genetic variation in terms of fixable and non-fixable components of different characters is very important. Fisher (1918) first partitioned the heritable variation into an additive component which results from the average effect of genes, dominant component which arises from inter allelic interaction and an epistatic component which develops from intra allelic gene interaction.

The estimation of these genetic components requires precise biometrical methods and since long time efforts have been put to develop such biometrical method. The generation mean analysis is one among them, which estimates epistatic component in addition to estimation of additive and dominance components of total genetic variance.

The comparison of means of generations can also give an idea about probable gene action. The mean value of F_1 indicates the degree of dominance. If mean value of F_1 is between mid parental value and one of the parent mean value, it indicates partial dominance. If it exceeds the best parental value or falls below the lower parental mean value then it points to over dominance. If F_1 mean value is exactly equal to either of the parental mean value then it indicates complete dominance.

The expression of a particular character depends upon gene action and its interaction with the environment. The nature of the gene action such as additive, dominance and epistasis and their magnitude determines breeding methodology to be applied for improvement of the trait. If the character is governed by additive gene effects then the best

breeding method for improvement would be adaptation of different selection methods to develop a stable variety. But if the character is governed by non-additive or dominance effect then one can adopt hybridization and develop hybrids.

In white linted cottons many workers have studied gene effects for many quantitative characters, whereas in colour cottons such studies are not available. In order to know whether they behave similarly that of white cottons, present study was initiated. Another objective was to explore the possibility of exploitation of heterosis and to obtain desirable segregants. Five different crosses were studied and the results obtained are discussed below (Table 61).

5.8.1 Cross I - DS-28 x DGH 95

The results obtained indicated that the mean value of F_1 for growth parameters like plant height, number of monopodia, number of sympodia were less than both the parents. Thus showing over dominance of lower parent DGH-95, whereas for days to first boll burst the dominance of DGH-95 was complete as F_1 mean was equal to DGH-95. For yield and yield related characters like number of bolls and boll weight and so also for fibre length, the mean value of F_1 was higher than the better parent DS-28. This indicates presence of over dominance.

All gene effects viz., additive [d], dominance [h], additive x additive [i], additive x dominance [j], and dominance x dominance [l] were significant for plant height. The magnitude of dominance effects and its interaction were very high indicating that plant height is governed by dominance gene effects. Randhawa *et al.* (1987), Tyagi (1988) and Srivastava and Kalasy (1990) reported similar results in white linted cottons.

Table 61. Significant gene effects for various characters for five crosses of Naturally coloured cottons

Cross	Para-meter	Characters							
		PH	NM	NS	FB	NB	BW	YP	FL
DS-28 x DGH-95	GE	d,h,l,j,l	d,i	h,i,l	l,	-	-	j	h,i,j
	E	D	C	D	D	C	C	C	D
DS-28 x DBH-95	GE	h,i,l	h,l	i,j	i,l	-	i,j	l	i,j,l
	E	D	D	C	C	D	C	C	C
Abhadita x DGH-95	GE	h,i,l	j	j	-	d,i,j	l	h,i,j,l	-
	E	D	D	D	C	D	D	D	D
DBH-95 x DGH-95	GE	d,h,j	-	-	-	d,h,j	-	d,h,j	d,h,i,j
	E	D	C	C	C	C	D	C	D
DBA-95 x A-82-1-1	GE	h,i	-	i	-	d,h,l	-	d,h,l	d,i,j,l
	E	D	D	C	C	C	D	C	D

GE - Gene effects;
[d] - additive;
[h] - dominance;
[i] - additive x additive;
[j] - additive x dominance;
[l] - dominance x dominance

E - Epistasis; D - Duplicate; C - Complimentary
PH - Plant height; NM - Number of monopodia
NS - Number of sympodia; FB - Days to first boll burst;
NB - Number of bolls; BW - Boll weight;
YP - Yield per plant; FL - Fibre length

The trait, number of monopodia had additive [d] and additive x additive [i] gene effects significant with higher magnitude than other gene effects. Thus pointing to the fact that this trait is governed by additive gene action. The results are in confirmity with Kalsy and Vithal (1981) and Duhoon *et al.* (1983).

In case of number of sympodia the dominance effect [h] and its interactions additive x dominance [j] and dominance x dominance [l] were highly significant. This trait was controlled by dominance effects. Similar studies were reported by Duhoon *et al.* (1983), Patel (1980 & 1984) and Hiremath (1993). The trait days to first boll burst had only dominance x dominance effect [l] significant and the magnitude of dominance effect was higher indicating its control over the trait.

The additive x dominance [j] effect was significant for yield per plant. The yield per plant, number of bolls and boll weight were governed by dominance effects as the magnitude of these effects was very high than additive effects. The fibre length had dominance, additive x dominance and dominance x dominance effect which were highly significant. Like other character it was also governed by dominance effect. The results obtained are on par with the results of Randhawa *et al.* (1991), Bhatade *et al.* (1992) and Gupta and Singh (1984).

The traits like plant height, number of sympodia, days to first boll burst, and fibre length showed presence of duplicate type of epistasis as they had [h] and [l] with opposite signs. The remaining characters viz., number of monopodia, number of bolls, yield per plant and boll weight showed complementary type of epistasis as signs of [h] and [l] were same.

Based on results it could be concluded that in this cross all characters except number of monopodia were controlled by dominance effect. The non-additive effect is very predominant in this cross but most of the interaction effects are of additive types indicating its importance.

5.8.2 Cross II - DS-28 x DBH 95

The mean F_1 value was higher than the better parent thus indicating over dominance of white cotton parent, whereas for number of monopodia complete dominance of brown linted parent is seen as the F_1 value was equal to mean value of colour cotton parent. The traits number of sympodia and days to first boll burst showed partial dominance as the F_1 value lies between mid parent and one of the parental mean value. Among the yield parameters, number of bolls and yield per plant showed overdominance whereas boll weight and fibre length had partial dominance.

Highly significant dominance [h] and additive x additive [i] gene effects were observed for plant height. It also had significant dominance x dominance effect. This trait is strongly controlled by dominance effects with some contribution of additive x additive interaction. Similar results were reported by Singh *et al.* (1985).

The dominance gene effect and its interaction dominance x dominance gene effect were highly significant for the trait number of monopodia. It was controlled by dominance effects as the magnitude of [h] was greater than [d]. This finding is in confirmity with Hiremath (1993). The intreraction effect viz., additive x additive [i] and additive x dominance [j] were significant for number of sympodia and boll weight. Both these characters were governed by dominance effects but additive gene effects also have significant influence on the expression of these traits as indicated by significant interaction effects with

additive components. Duhoon *et al.* (1983), Patel (1980 & 1984), Hiremath (1993) and Malik *et al.* (1994) reported similar result.

The character days to first boll burst was governed by additive effect as the magnitude of [d] was higher than [h]. The additive x additive [i] and dominance x dominance [l] gene effects were significant, indicating that eventhough additive gene effects were important, the influence of dominance effects is also found important.

Eventhough non additive gene effects were also significant, the character number of bolls was governed by additive effects as magnitude of [d] was higher than [l]. Yield per plant was governed by dominance effects and it is confirmed by the fact that the interaction effect dominance x dominance [l] was significant. Similar results were reported by Kajjidoni *et al.* (1984), Sandhu and Singh (1988), Deshpande *et al.* (1991), Singh and Chhabra (1991), Vithal *et al.* (1991) and Patel and Pethani (1998).

The fibre length was also governed by dominance effects but additive gene effects also had some influence as indicated by significant additive x additive [i], additive x dominance [j] and dominance x dominance [l] gene effects. Randhawa *et al.* (1991) and Gupta (1983) observed similar results.

Duplicate type of epistasis was observed for characters viz., plant height, number of monopodia, and number of bolls as the signs of [h] and [l] were opposite. The traits number of sympodia, days to first boll burst, yield per plant, boll weight and fibre length were influenced by complementary type of epistasis. Most of the characters were governed by dominance effects but the additive effects were also important as evident by the significant interaction effects involving additive component. To improve different characters hybridization followed by selection in segregating generations can be adopted.

5.8.3 Cross III - Abadhita x DGH 95

The mean values of F_1 for all eight characters studied were between the mid parental value and mean value of either of the one parent thus indicating presence of partial dominance.

Highly significant dominance, additive x additive and dominance x dominance gene effects were observed for the character plant height. The magnitude of [d] is less than [h] indicating that the plant height is governed by dominance effects, but a degree of contribution of additive genes as indicated by presence of significant additive x additive interaction. The results were on par with Singh *et al.* (1985), Kajjidoni *et al.* (1984) and Tyagi (1988).

The trait number of monopodia was governed by additive effects as evident from the fact that magnitude of [d] is more than [h]. The additive gene effect was significant confirming above conclusion but as the interaction by dominance x additive [j] is significant, dominance effect also contributes to the expression of the trait. The results were on similar lines of Kalsy and Vithal (1981) and Duhoon (1983). Number of sympodia had significant dominance x additive effect and the magnitude of [d] was higher than [h] thus indicating that the number of sympodia is governed by additive effects with some contribution from dominance x additive interaction effects. Deshmukh *et al.* (1980), Patel (1980), Katarki *et al.* (1986) and Desai (1990) reported similar results. The days to first boll burst did not possess any significant gene effect but was governed by additive gene effects.

Highly significant additive, additive x additive, additive x dominance effects were observed for the trait number of bolls. The magnitude of [d] was less than that of [h]. Similarly the magnitude of [l] was higher than other two epistatic effect. Thus it can be

concluded that for the expression of this trait additive [d], additive x additive [i] and additive x dominance [j] were more important. Garg and Kalsy (1987), Desai (1990), Singh and Chhabra (1991), Sandhu and Singh (1988) and Malik *et al.* (1994) observed similar results. The expression of yield per plant was mainly due to dominance effect [h], and interaction effects viz., additive x additive [i], additive x dominance [j] and dominance x dominance [l] effects. Magnitude of [h] was more than that of [d] similarly magnitude of [l] was higher than both [i] and [j], thus indicating its importance. The results were on par with Deshpande *et al.* (1991), Singh and Chhabra (1991), Randhawa *et al.* (1991), Hiremath (1993), Malik *et al.* (1994).

The boll weight had significant dominance x dominance effect. The magnitude of [h] was higher than [d] indicating presence of non-additive gene actions. Similarly magnitude of [l] was higher than other two interaction effects. Thus for the expression of this trait non-additive gene action and dominance x dominance interaction have paramount importance.

The fibre length was influenced by additive gene action as the magnitude of [d] was higher than [h]. No other gene effects were having significant effects. Similar results were observed by Randhawa *et al.* (1991) and Gupta and Singh (1984).

Presence of duplicate type of epistasis was evident for all the characters except for days to first boll burst where complementary gene interaction was observed.

5.8.4 Cross IV - DBH 95 x DGH 95

The mean F_1 value for plant height was less than the lower parent thereby indicating presence of over dominance of green linted parent, whereas for number of monopodia the F_1 mean value was higher than better parent (brown parent) indicating its

overdominance. Partial dominance was evident for the character number of sympodia as F_1 value was between mid parental value and one of the parent. The trait, days to boll burst showed complete dominance of better parent as the mean values were nearly same. The F_1 mean value of number of bolls, yield per plant, boll weight and fibre length were higher than the better parental mean values, thus indicating the overdominance.

The character plant height was governed by non-additive gene action as the magnitude of [d] was less than [h]. It also showed presence of significant additive [d], dominance [h], additive x additive [i] and additive x dominance [j] gene effects, therefore it depends upon all above gene effects for expression. Dhanda (1987), Garg and Kalsy (1987), Randhawa *et al.* (1987) reported similar observations.

Only dominance gene effect was significant for number of monopodia indicating prepondence of non-additive type of gene action wherein it was confirmed by the fact that magnitude of [d] was far less than [h]. This observation was in agreement with Hiremath(1993). The traits number of sympodia and boll weight were also influenced by non-additive and additive gene action respectively. Similarly, days to first boll burst was also governed by additive gene action. In case of number of sympodia Duhoon *et al.* (1983), Patel (1980 & 1984), Hiremath (1993) observed similar results.

The gene effects like additive [d], dominance [h] and additive x dominance [j] were highly significant for number of bolls. Along with these significant effects it was observed that magnitude of [h] was higher than [d] which indicated importance of non-additive gene action. Additive [d], dominance [d] and additive x dominance [j] gene effect were significant for the expression of the trait yield per plant. The magnitude of [d] was less than [h] indicating importance of dominance gene action.

The character fibre length was governed by non-additive gene action. It was also governed by the additive [d], dominance [h] gene effects and their interacting effect viz., additive x dominance effect [j]. Complementary type of epistasis was observed in the characters number of bolls, yield per plant, number of monopodia and days to first boll burst. The duplicate epistasis was seen for the characters plant height, number of monopodia, boll weight and fibre length.

It could be concluded that in this cross both additive and dominance gene effect are equally important, so also their interaction [j]. No significant interaction effects of additive x additive, dominance x dominance were reported indicating that both additive and dominance effect work together. For improving different characters both methods viz., direct selection and selection from segregating generations after hybridization could be followed.

5.8.5 Cross V - DBA 95 x A-82-1-1

The mean F_1 value for number of monopodia and days to first boll burst was equal to the better parent thus indicating complete dominance. The mean F_1 value of boll weight was between mid parental value and one of the parental value which indicated partial dominance. The remaining characters like plant height, number of sympodia, number of bolls, yield per plant and fibre length had mean F_1 values higher than better parent indicating overdominance.

The magnitude of [h] was higher than [d] for the most of the characters viz., plant height, number of monopodia, number of sympodia, number of bolls, yield per plant, boll weight, and fibre length, indicating control of these characters by non-additive gene action. Only days to first boll burst was governed by additive gene action as magnitude of [d] was higher than [h].

The plant height reported significant dominance [h] and additive x additive [i] gene effect thus indicating along with dominance effect additive effect is also important for expression of the trait. Number of sympodia had only one significant effect i.e., additive x additive interaction. The traits number of bolls and yield per plant were significantly influenced by additive [d], dominance [h] and dominance x dominance gene effects. This indicated to the fact that for expression of these traits, it is not sufficient to have dominant effect, but additive effect and the interaction of dominance x dominance effect are also important.

The fibre length was influenced by significant additive [d], additive x additive [i], additive x dominance [j] and dominance x dominance [l] gene effects. In this case eventhough dominance effect is not significant, its interaction effects are significant indicating its importance. The characters plant height, number of monopodia, boll weight, and fibre length had duplicate type of epistasis, whereas number of sympodia, days to first boll burst, number of bolls and yield per plant reported complementary type of epistasis.

5.9 Mutation studies

In plant breeding available variability in nature has been used for crop improvement. But many a times these existing variability is very limited or it is exhaustively utilised. Since the discovery that ionizing radiation and certain chemicals can induce hereditary changes, the plant breeders have used this instrument to create and supplement the variability available in species. Eventhough frequency of valuable mutations are low and most of the mutations are deleterious in nature. It is possible to obtain useful mutations and use them in improvement. It has been demonstrated that induced mutation can increase yield as well as improve other characters like stiffness of straw, adaptability, maturity time, disease resistance, protein content, protein quality and many other aspects.

It was felt that induced mutations could be used for improvement of naturally coloured cottons. The characters concentrated were development of new shades of colour, improvement in yield, variability in fibre length, strength and micronnaire. To achieve these objectives both physical mutagens (20 kr gamma rays) and chemical mutagen (Ethyl Methyl Sulfonate) were used at various dosages.

The performance of M_2 generation of brown linted *hirsutum* indicated that highest range for yield was in treatment 0.4 per cent EMS and for fibre length it was 0.3 per cent EMS. The overall mean was highest in 0.3 per cent EMS for both yield (24.92 g/pl) and firbre length (20.2 mm). Along with these two characters visual observation for fibre colour intensity and strength was also done. It was observed that the treatment 0.3 per cent EMS was good. Seventyone plants were selected in 0.3 per cent EMS treatment, whereas 38 plants and 31 plant were selected in the treatments 0.4 and 0.2 per cent EMS, respectively. Thus indicating that 0.3 per cent EMS was best treatment for obtaining desirable mutants.

The performance of M_2 generation of brown linted *arboreum* obtained through mutagenesis with different dosages of EMS and Irradiation indicated creation of high degree of variability for yield (g/plant) and fibre length. The yield per plant ranged from 2 g to 284 g in the treatment 0.3 per cent EMS, whereas variance was highest in 0.2 per cent EMS indicating higher level of variation. In general variability created for yield per plant was quite high. Fibre length ranged from 15.3 mm to 26.3 mm in the treatment 0.3 per cent EMS, which also had highest variance. The variability obtained due to mutation was high and the plants could be classified in different fibre length categories. The number of plants advanced to M_3 were highest in 0.2 per cent EMS treatment (77 plants) followed by 69 plants (0.3% EMS), 66 plants (irridiated) and 29 plants (0.4% EMS). It was observed that best treatment that could give higher number of desirable plants was 0.2 per cent EMS. It was also

observed that higher dose of chemical mutagen EMS was not advisable as very less number of desirable plants were obtained. The irradiated mutants were on par with 0.2 and 0.3 per cent EMS for seed cotton yield and fibre length.

From the performance of M_2 generation of brown linted *hirsutum* and brown *arboreum* certain important conclusions can be drawn. In case of brown linted *hirsutum* best dose was 0.3 per cent EMS whereas for brown linted *arboreum* it was 0.2 per cent EMS. In general yield ranges were very high for all EMS treatments of brown linted *arboreum* as compared to brown linted *hirsutum*. But range for fibre length was higher in brown linted *hirsutum* as compared to brown linted *arboreum*.

Performance of M_3 generations of brown linted *hirsutum* for five characters was studied. It was observed that M_3 families of EMS treatment 0.4 per cent had higher ranges for seed cotton yield per hectare (2.7-18.69 q/ha), ginning out-turn (26.83-38.24%) and lint index (3.67-6.16 g), whereas M_3 families of 0.3 per cent EMS had highest range for seed index (8-12.0 g) and M_3 families from 0.2 per cent EMS treatment had highest range for fibre length (15-26.33 mm). These result indicate that for creation of variability in seed yield, ginning out-turn and lint index the treatment 0.4 per cent EMS is better than other treatments and for obtaining higher variation in seed index and fibre length the treatment 0.3 and 0.2 per cent EMS could be used, respectively.

Number of families above parental check were very less for yield per hectare in all three treatments. For yield, ginning out-turn, seed index and lint index the treatment 0.4 per cent EMS had higher percentage of families above check, and 0.2 per cent EMS had higher number of families above check for fibre length. These results indicate that characters lint index and ginning out-turn have very good positive response to mutation as compared to

other characters like, fibre length, seed index and yield as in former characters percentage of families above parental check was very high (Table 62) (Fig. 15). The probability of obtaining desirable mutation seems to be on par in all treatments for fibre length and ginning out-turn whereas for other characters it varies from treatment to treatment.

The performance of M_3 families of brown linted *arboreum* obtained from different chemical and physical mutagen treatments varied significantly. The range for yield (5.58-16.9 q/ha) and ginning out-turn (28.57-43.75%) was highest in the M_3 families obtained in the 0.2 per cent EMS treatment than other two EMS dosages and irradiation. The range for fibre length (17.33-28.33 mm) in the M_3 families derived from the 0.3 per cent EMS was higher than the M_3 families derived from other treatments. The range for lint index (3 to 5.8 g) was higher in M_3 families obtained from irridiation. These results indicate that the genotype responds varyingly to different mutagen treatments for different characters. The EMS treatment of 0.2 per cent EMS seems to be better than other doses of EMS and irridiation in brown *arboreum*.

This conclusion is supported by the fact that for three characters viz., yield, SI and fibre length, number of families above parental check was very high (Fig. 16). The results indicates that for ginning out-turn and lint index the number of families above parental check were higher in treatment 0.3 per cent EMS than other two doses. In case of irridiated M_3 families the number of families above parental check was very high for characters seed index (72.7%) and fibre length (83.3%). It also indicate that among all doses of EMS 0.2 per cent is the best and at 0.4 per EMS the genotype suffered very severely and its performance reduces drastically. It can also be stated from this results that irridiation will yield desirable mutants for seed index, lint index and fibre length.

Table 62. Number of better performing M_3 mutant families of brown *G. arboreum* and *G. hirsutum* in comparison with control

Characters	Brown arboreum								Brown hirsutum					
	0.2% Ems		0.3% Ems		0.4% Ems		Irradiated (20 kr)		0.2% Ems		0.3% Ems		0.4% Ems	
M_3 families studied	77		69		29		66		31		71		38	
Yield (q/ha)	52	(67.5)	21	(30.4)	2	(6.9)	8	(12.1)	1	(3.2)	2	(2.80)	3	(7.9)
Ginning	05	(6.50)	29	(42.0)	5	(17.2)	23	(34.8)	18	(58.1)	36	(50.7)	25	(65.8)
Out-turn														
Seed index (g)	62	(80.5)	60	(87.0)	22	(7.5)	48	(72.7)	9	(29.0)	17	(23.9)	18	(47.4)
Lint index (g)	13	(16.9)	45	(65.2)	10	(34.3)	34	(51.5)	14	(45.2)	28	(39.4)	23	(60.5)
Fibre length (mm)	54	(70.1)	47	(68.1)	18	(62.1)	55	(83.3)	12	(38.7)	19	(26.8)	13	(34.2)

Figures in parantheses indicate per cent of families above the check.

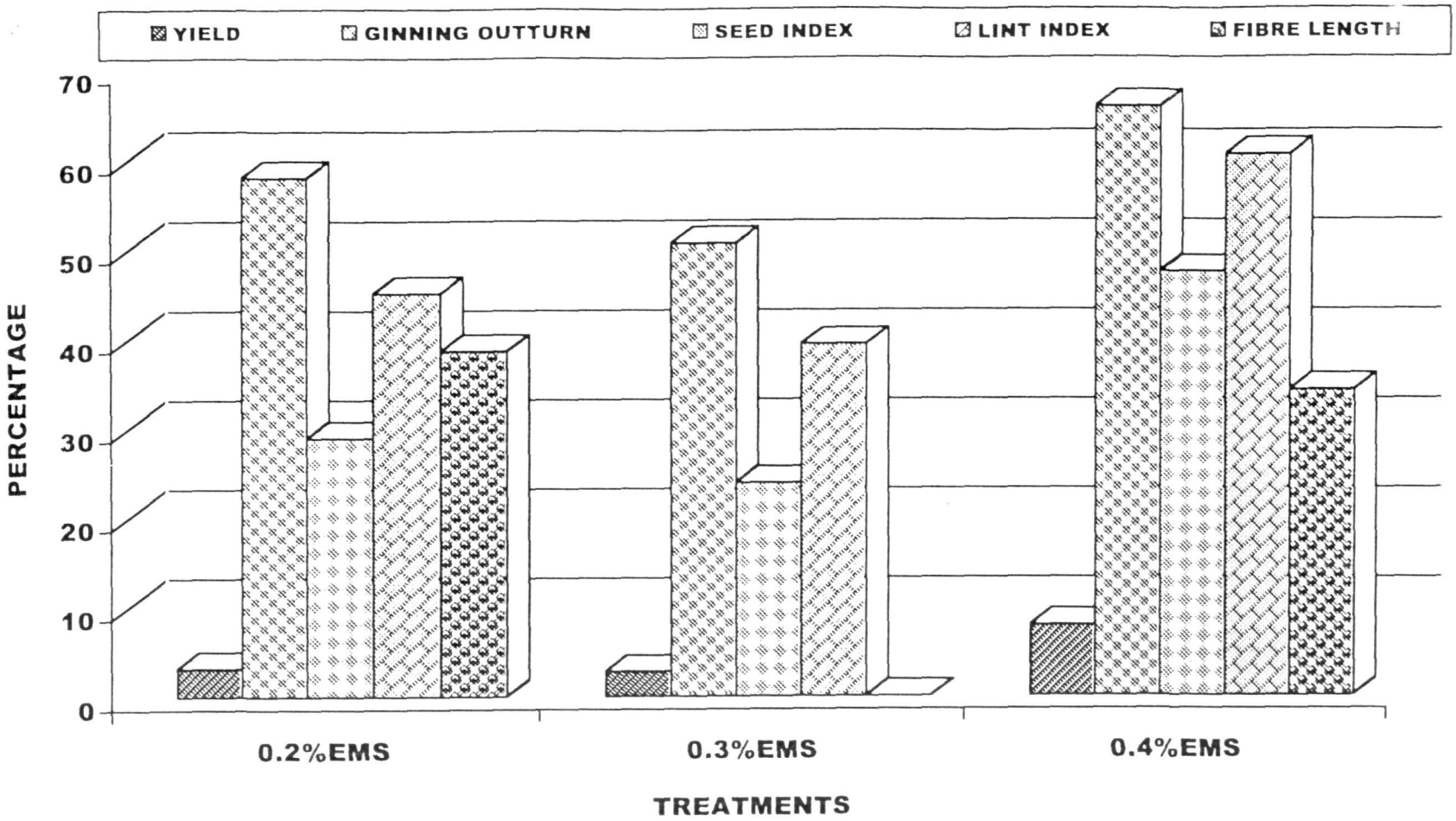


FIG. 15. Percentage of better performing M3 families in *G. hirsutum* colour cottons

If the performance of brown linted *arboreum* is compared with that of brown linted *hirsutum* some inferences can be drawn. First inference could be that many families surpassed the original check in case of 0.2 and 0.3 per cent EMS treatment in brown linted *arboreum* but in case of brown linted *hirsutum* it is not so. M_3 families performance have confirmed M_2 observation that 0.2 per cent EMS and 0.3 per cent EMS is better than other doses for brown *arboreum* and brown linted *hirsutum*, respectively. The performance of 0.4 per cent EMS was drastically reduced for most of the characters in M_3 families of brown linted *arboreum* than in brown linted *hirsutum*. Number of families above the parental check was higher for all characters studied in brown *arboreum* than in brown linted *hirsutum*. Thus it can be said that response of brown *arboreum* to mutation is better than that of brown linted *hirsutum*.

5.10 Fibre colour development in the fibres of naturally colour cottons

The study indicates that the colour development in the fibres of different colour genotypes is not same. The exact colour development after pollination differs from genotype to genotype and species to species. The colour development in fibre is early in *G. hirsutum* than in *G. arboreum*. Similarly in *G. hirsutum* it is early in green linted genotype than in brown linted genotype. Earlier study indicated that colour develops between 30 to 40 days after pollination in both green *hirsutum* and brown *hirsutum* (Khadi *et al.*, 1996a). Present study fine tunes to the actual number of days after pollination required for first appearnce of pigment in both gren *hirsutum* and brown *hirsutum*. The results concluded that pigment development is early in green *hirsutum* (34-35 DAP), which is followed by brown *hirsutum* (35-36 DAP).

In *G. arboreum* colour development takes 51-52 days after pollination until than the fibre will be white. Another observation made was that lint colour in *G. hirsutum* is

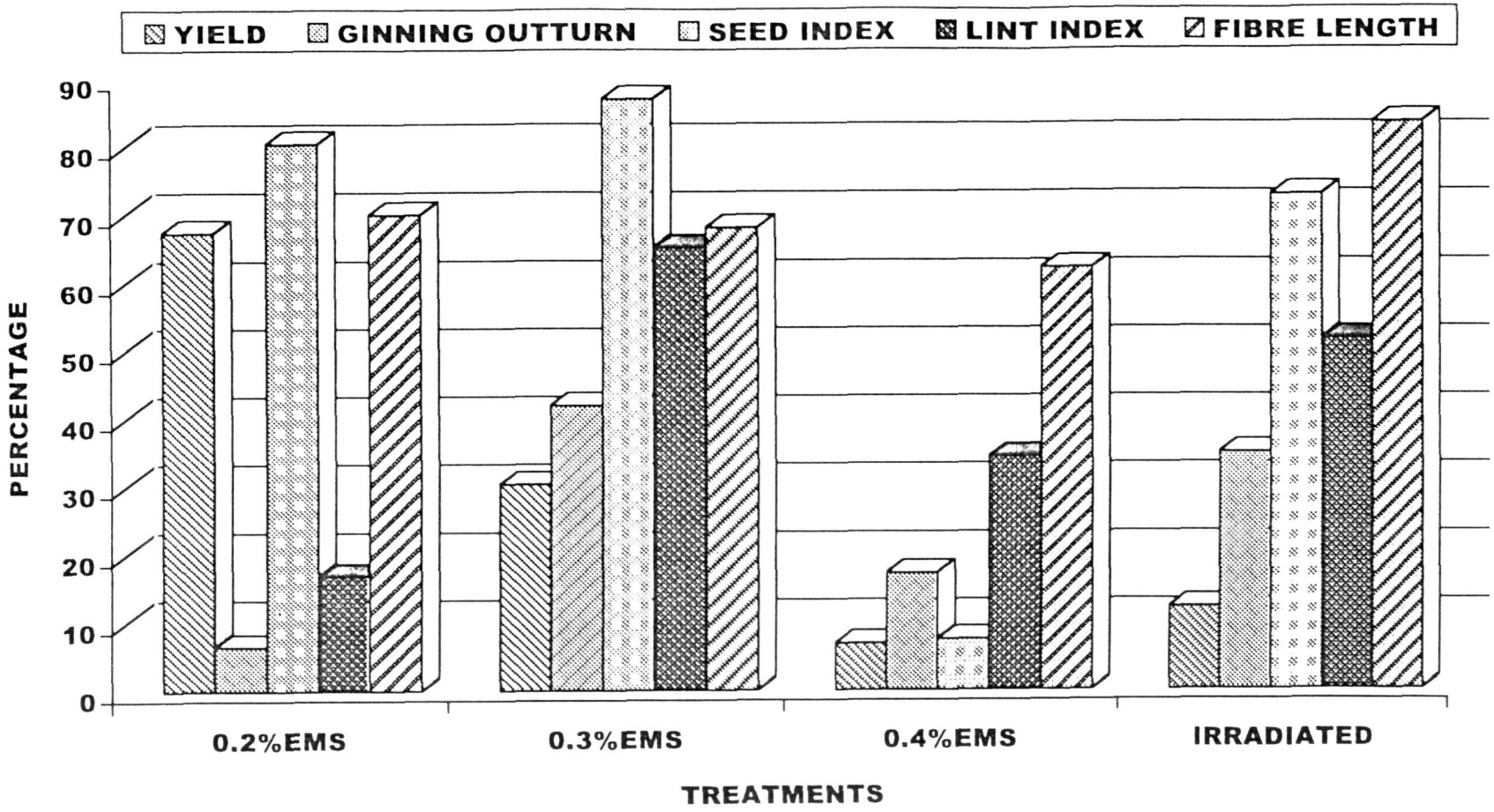


FIG. 16. Percentage of better performance M3 mutant families in *G. arboreum* colour cottons

comparatively more darker than *G. arboreum*. This could be because of the fact that more number of days are available before boll burst for pigment development in *hirsutum* after first appearance of colour in fibre. In case of *G. arboreum* the first appearance of colour is at the fag end of boll maturity and it opens within 8 days after first colour appearance thereby leaving very less number of days for pigment development and spread in the fibres.

5.11 Characterization of Naturally Colour cotton Through Electrophoresis

The results indicate very little possibility of using seed peroxidase polymorphism to characterise *G. hirsutum* colour genotype from *G. hirsutum* white genotype. This is because number of peroxidase band is same and the Rm values which indicate relative movement are also on par with white linted check Sahana. Four coloured genotypes viz., deep dark brown *hirsutum*, brown *hirsutum*, light brown *hirsutum*, and cream were having same Rm values as that of Sahana for both bands. Slight variation has been seen for medium brown *hirsutum*, and both green *hirsutum* as they show little lower and higher Rm values for band 1, respectively. These bands can be used for characterisation, but precision would be lacking (Fig. 17).

In case of *G. arboreum*, the peroxidase polymorphism can be used as colour linted genotype had only one peroxidase band, whereas the white genotype had three bands at different Rm values thereby making characterisation easy. Thus in *G. arboreum* colour linted genotypes could be distinguished from white on the basis of peroxidase polymorphism.

5.12 Studies on extraction and nature of fibre colour in naturally coloured cottons

The extraction and spectrophotometer studies of fibre colour indicate that the pigment responsible for fibre colour is in 490-550 nm spectrum in *G. hirsutum* colour cotton.

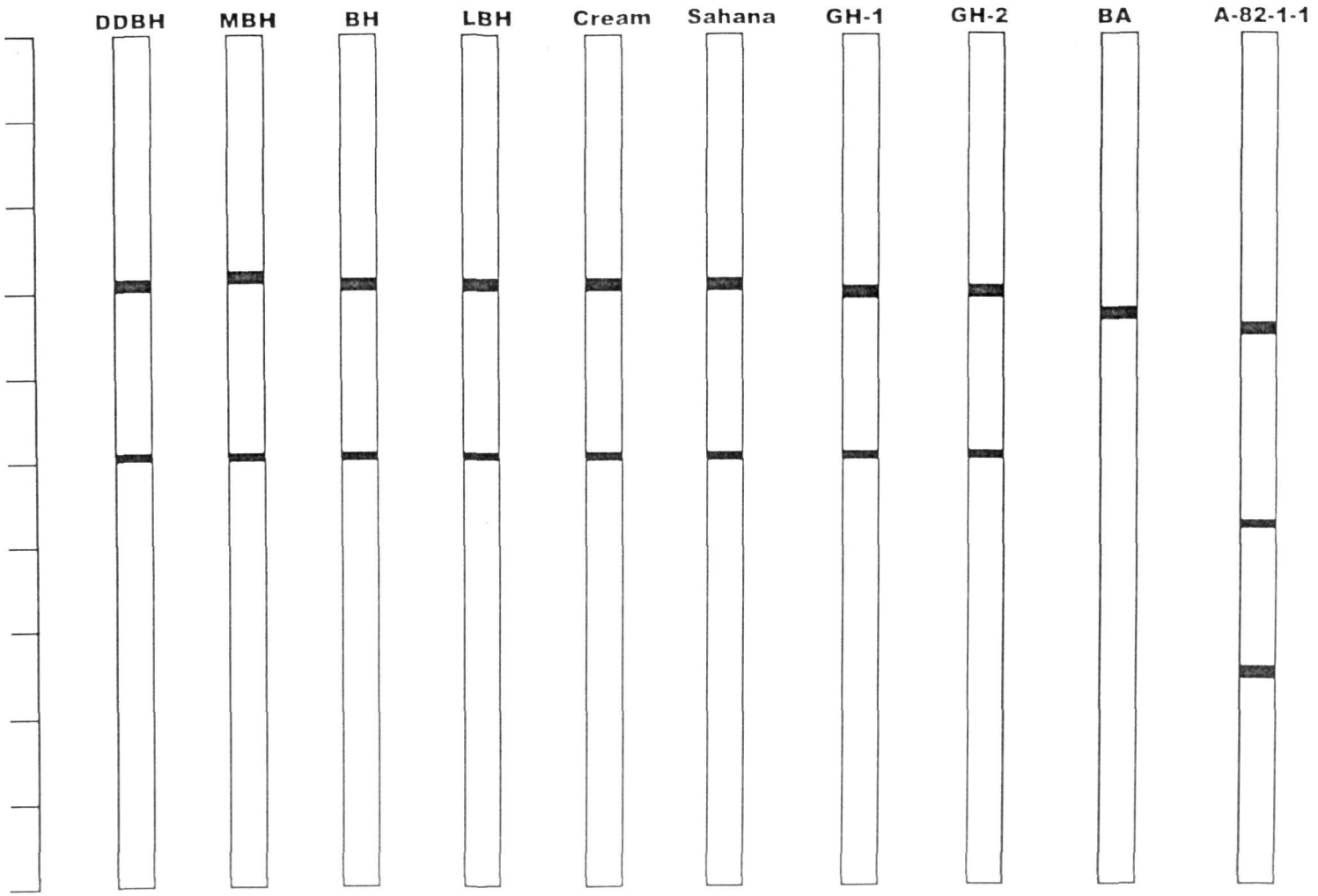


Fig. 17. Zymogram of peroxidase isozyme in Naturally Coloured Cotton

whereas it is from 430-480 nm spectrum in *G. arboreum*. Both species have different pigments responsible for fibre colour. In general it can be said that pigment responsible for fibre colour in cotton is from the 430-550 nm spectrum, which belongs to flavonoid group of pigment. As absorption peaks for *G. hirsutum* and *G. arboreum* are different it is clear that specific pigment or pigments responsible for colour of fibre are different.

5.13 Future line of work

The future work in naturally coloured cottons has to be carried out as follows;

1. The results obtained in this study indicate that large variability is available in Dharwad colour cotton genotypes for different characters. This variability has to be exploited either through selection and stabilising the selected genotype as variety or it has to be used in further breeding programme as a parent.

2. A general observation was made that brown *G. hirsutum* and *G. arboreum* genotypes were well performing. Some among them were high yielding and had average fibre quality. But green linted *G. hirsutum* genotypes were very poor in performance. Thus more efforts are needed to improve green linted genotypes. This should be done either by selection of good type, or by creating variability through mutation, hybridisation etc. In case of brown colour there are genotypes which can be stabilised and used as varieties.

3. The fibre quality studies indicated that no genotype belonged to long and extra long staple category. Therefore future strategy is to develop long and extra long staple genotypes. This could be achieved by crossing long or extra long white genotypes with colour genotypes. Thereafter, F_1 hybrid can be used directly or selection can be

practiced in segregating generation for long/extra long staple types and backcrossing it with colour linted so as to improve fibre colour. Another concern is that all these genotypes were having very low fibre strength. So more efforts are needed to improve fibre strength so that colour linted genotypes are suitable for modern day textile needs. For this also variability has to be created and fibre strength should be transferred from high fibre strength genotypes from either white or colour linted ones.

4. In case of hybrids, yield levels, and other characters of some hybrids were on par with or superior than white linted checks. So this opens a possibility of using colour linted hybrids for commercial cultivation. Here also no hybrid belonged to long or extra long staple category, and fibre strength was low. In this case also similar approaches have to be adopted.

5. Another problem in developing hybrids is reduction of fibre colour if one parent is white linted. So it will be better if both colour linted parents with good fibre quality are used.

6. The fabric/yarn parameters like FQI, count and CSP should also be improved. To achieve these improvement of fibre length, strength and fineness is a must.

7. The heterosis observed over colour linted parents for most of the yield and fibre parameters suggests that hybrids can perform better than parents. So further development of colour cotton hybrids should be encouraged.

8. Studies on genetics of fibre colour in both *G. hirsutum* and *G. arboreum* have indicated that there is continuous variation in fibre colour. But this can be confirmed only after individual F_3 and backcross are studied in detail.

9. Mutation breeding can be used in future as it has given desirable results. Varying doses of some more mutagens both physical and chemical can be tried so that new desirable mutant with good yield, fibre strength, colour and fibre length may be obtained.

10. In case of fibre colour development studies many questions remained unsolved. The nature of pigment, deposition of pigment in fibre and biochemical changes taking place are the future thrust areas.

Summary

VI. SUMMARY

The present study was undertaken at Agricultural Research Station, Dharwad Farm of University of Agricultural Sciences, Dharwad. The main objectives of the study was to know the genetics of fibre colour and genetic behaviour of colour linted cottons as compared to white cottons. For these purpose twenty two Dharwad colour cotton genotypes, Dharwad colour cotton hybrids, six generations of five crosses involving white and colour linted parents were studied. The genetic studies undertaken were variability, association and path coefficients for seed cotton yield, lint yield fibre length, FQI, CSP, heterosis for growth, yield and fibre quality parameters and gene effects. The *per se* performance of twenty two genotypes and 10 hybrids was evaluated for growth, yield and fibre parameters to arrive at conclusions about possible spinning potential, fabric quality and use. Mutations were attempted in both brown *arboreum* and *hirsutum* at various dosages, M_2 and M_3 generations were studied.

Apart from these genetic investigations, some basic work to know the exact period of colour development in fibre, and nature of pigment responsible was also undertaken. Some colour cotton genotypes were also characterised by electrophorosis. The results obtained and inferences drawn are summarised below;

1. Analysis of variance in both Dharwad colour cotton genotypes and hybrids indicated availability of significant variation among different genotypes for various characters. The varietal genotypes were less influenced by environment than hybrids.

2. Genotypic variance was higher than environmental variance for all characters except number of monopodia in genotypes and number of sympodia in hybrids, indicating that these characters had more genetic component of variation and are more stable.

3. Coefficients of variation (PCV & GCV) were moderate to high for all characters except for days to first boll burst indicating moderate to high diversity. Differences between PCV and GCV were low for all characters except for number of monopodia, days to first boll burst in genotypes and number of bolls in hybrids, thus indicating low sensitivity of these characters to environment.

4. Moderate to high heritability was coupled with moderate to high genetic advance of mean for most of the characters indicated the presence of moderate to high additive fixable effects.

5. *Per se* performance of Dharwad colour cotton genotypes indicated that large variability is available. It also points to the fact that some brown linted *G. hirsutum* and *G. arboreum* genotypes were better performing and could be utilised directly commercial cultivation whereas green linted genotypes were found poor in performance and more efforts are needed to improve them.

6. Fibre quality studies showed that no colour linted genotype had long and extra long staple length. Most of these genotypes were having good to excellent uniformity ratio, average to very high maturity, very fine to coarse fibre fineness. But it was observed that fibre strength of all these genotypes was very low. Thus special efforts are needed to improve fibre strength in addition to staple length.

7. *Per se* performance of F_1 colour cotton hybrids was better than their colour linted parents for most of the characters. It was also observed that for most of the characters the hybrids were on par with while linted check hybrids viz., DHH-11 and NHH-44.

8. The second objectives of developing hybrids was to improve fibre quality of colour cottons which has been met partially. It was observed that hybridisation has helped in the improvement of fibre length, micronaire and fibre strength of colour cottons, whereas in case of uniformity ratio and maturity coefficient there was no change.

9. Studies on genetics of fibre colour in *G. hirsutum* indicated that the fibre colour is incompletely dominant and is governed by a single gene if only colour and colourless are considered. But there exists many classes in the colour class which shows gradual increase in colour of fibre.

10. Studies on genetics of fibre colour in *G. arboreum* indicated that it is governed by two gene interaction viz., dominant epistasis if only colour and white classes are considered irrespective of the various classes in broad colour class. It was also noticed that colour class could be divided into six classes which showed a gradual increase in the fibre colour, thus indicating presence of continuous variation.

11. Genotypic correlations were higher than phenotypic and environmental correlations in both genotypes and hybrids. The growth parameters were related to each other significantly. The seed cotton yield and lint yield were related to each other and were significantly and positively related to number of sympodia, number of bolls, days to first boll burst and GOT. They had negative significant relation with boll weight, seed index. Lint yield was also related to lint index positively.

In case of DCCH, association was complex as indirect relations were observed between different characters. Lint yield and seed cotton yield were related to lint index. GOT which inturn were correlated with seed index and boll weight, which were negatively related to all growth parameters. Thus unwanted selection for any single character can result in affecting all other characters.

12. Correlation among different fibre quality parameters indicated importance of fibre fineness as it was negatively and significantly related to all other characters.

13. Path analysis for seed cotton yield indicated that boll weight, seed index, GOT and lint index were most important in DCCV genotypes, whereas in DCCH boll weight, number of boll and GOT were important. Path analysis of lint yield indicated importance of seed cotton yield, lint index and seed index in DCCV and seed cotton yield, GOT, LI and boll weight in DCCH.

14. Path analysis for fibre length also indicated that fibre fineness was most influencing character followed by uniformity ratio and maturity coefficient. Path for fibre quality index indicated that most contributing characters were fibre length, fibre fineness and fibre strength, whereas for CSP most influencing character was FQI.

15. For most of the characters colour cotton hybrids showed significant heterosis over colour linted parents. Six hybrids had significant heterosis over white linted parents for yield, two hybrids were superior over NHH-44 and one hybrid was on par with DHH-11. Thus establishing the positive performance of colour cotton hybrids.

16. The colour cotton hybrids were superior to colour linted parents for all fibre quality parameters, indicating possibility of developing hybrids for improvement of fibre qality

parameters. Thereby pointing to the possibility of using hybrids for improvement of fibre quality parameters.

17. Dominance gene effects and interactions with additive gene effects were predominant for most characters in the cross DS-28 x DGH-95 and DS-28 x DBH-95. In DBH-95 x DGH-95, both additive and dominance effects and interaction of additive x dominance effect was important. Additive gene effects and all types of interactions were predominant in Abadhita x DGH-95 cross. The case of DBA-95 x A-82-1-1 additive effects and dominance x dominance interaction was predominant.

18. In M_2 generation the yield ranges were very high in all EMS treatment of brown *arboreum*, whereas range for fibre length was high in brown linted *hirsutum*. It was found that 0.3 per cent EMS treatment was best for *G. hirsutum* colour cotton, whereas for *G. arboreum* 0.2 per cent EMS treatment was found to be best.

19. In M_3 mutant generation it was observed that EMS treatments of 0.2 per cent and 0.3 per cent were best for *G. arboreum* and *G. hirsutum* respectively. Thus confirming M_2 observation. A drastic reduction in performance was observed in the M_3 families derived from 0.4 per cent EMS treatment. High variability was created for most of the characters studied and even fibre colour variation was observed.

20. Fibre colour development studies showed that colour develops in fibres of *G. hirsutum* brown cotton between 35-38 days after pollination, whereas in *G. hirsutum* green it develops between 33-37 days after pollination. In case of *G. arboreum* fibre colour development was seen from 48-51 days after pollination.

21. Characterisation of naturally colour cottons through electrophorosis of seed peroxidase indicated that the *G. hirsutum* colour genotypes were behaving similar to that of white *G. hirsutum* genotypes and were having two bands one dense and another light at nearly same Rm value thereby making characterisation difficult. Whereas in diploid colour cotton characterisation was easy as colour *G. arboreum* had only one band whereas white *arboreum* had three distinct bands.

22. The fibre colour extraction indicate that both *G. hirsutum* and *G. arboreum* have different pigments responsible for fibre colour but they belong to general class of flavonoid pigments.

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GENETIC INVESTIGATIONS, CHARACTERIZATION AND FIBRE COLOUR DEVELOPMENT STUDIES IN NATURALLY COLOURED COTTONS

(*Gossypium* spp.)

1999

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ABSTRACT

Significant genetic variation, moderate to high heritability and genetic advance were observed in 22 genotypes and 10 hybrids. Some of the brown linted *G. hirsutum* and *G. arboreum* genotypes were high performing and could be used directly for commercial cultivation whereas green linted genotypes were poor in performance. No colour cotton genotype was having long, extra long staple length and all genotypes were very poor in fibre strength. The *per se* performance of colour cotton hybrids was better than their colour linted parents. Some of the colour cotton hybrids were on par with DHH-11 and NHH-44. Similar trend was observed for heterosis.

When only colour and white classes were considered it was observed that fibre colour was incompletely dominant and governed by single gene in *G. hirsutum* and by two-gene interaction (dominant epistasis) in *G. arboreum* and colour class could be divided into six overlapping classes indicating presence of continuous variation.

In colour cotton genotypes significant positive association of seed cotton yield (SCY) and lint yield (LY) was observed with all growth parameters, except for seed index (SI) and boll weight (BW). In hybrids, indirect relation between SCY, LY, LI, GOT and BW and SI made correlations very complex. The fibre fineness was most important fibre quality parameter as it had significant negative relation with all other characters. Its importance was confirmed by path analysis of fibre length.

In colour cotton genotypes BW, SI, GOT, LI and in hybrids BW, number of bolls (NB) and GOT were important contributors to seed cotton yield. Lint yield path analysis indicated the importance of SCY, LI, SI in colour cotton genotypes and SCY, LI and BW in hybrids. Path analysis for fibre quality index (FQI) indicated that fibre length, fibre fineness and fibre strength were most important and for counts strength product (CSP) FQI was found most important. Six generation analysis revealed that gene effects like dominance and interaction (DS-28 X DGH-95, DS-28 X DBH95), additive, dominance and additive X dominance (DBH95 X DGH95), additive and interaction (Abadhita X DGH95), additive and dominance X dominance (DBA95 X A-82-1-1) were predominant. The EMS treatments of 0.2 and 0.3 per cent were best for *G. arboreum* and *G. hirsutum* respectively as they could yield high number of desirable mutants and high variation for yield fibre quality and fibre colour shades.

The number of days required for development of colour in fibre varies with genotypes and species. It was 33-37 days after pollination (DAP) in *G. hirsutum* green, 35-38 DAP in *G. hirsutum* brown cotton, and 48-51 DAP in *G. arboreum* brown cotton. It was possible to characterize electrophoretically *G. arboreum* colour cotton from white ones as it had only one band as compared to three bands in white linted genotypes. In case of *G. hirsutum* colour and white linted genotypes characterization was difficult as both had two bands nearly at same Rm distance. The actual pigments responsible for fibre colour in *G. hirsutum* and *G. arboreum* were different but pigments belonged to general class of flavonoids.