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Colour Cotton Research : Current and Future Perspectives

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Abstract: Naturally coloured cottons are gaining importance in the recent years due to the integration of ecology, fashion and public's rising interest in environmental issues and environment-friendly production processes. However, there are few drawbacks with these fibres which make the consumer non-enthusiastic to go for naturally coloured cotton fabric. The fibres are too short and weak to be spun into finer counts and also there is a basic limitation of non-availability of desired shades and colors. Studies have already been carried out to develop various colors and shades at the fibre stage of naturally coloured. Hence, in the present review of literature study we aimed to describe and delineate current and future perspectives on colour cotton research. In India, about 40 coloured genotypes of upland cotton (*G. hirsutum*), mostly of various shades of brown and green colour have been developed. Brown cotton lines are at the forefront and expects that one of its varieties, DDCC-1, was proposed for release in 2021. Furthermore, DMB-225, a medium brown variety was developed in 2013, along with three other varieties. However, DMB-225 was not released commercially on the grounds that it would contaminate white cotton, though its fibre quality was found highly suitable. By not using chemical dyes, as well as reducing the use of pesticides, the naturally colored cottons have become popular for being ecological and environmentally safe. However, The limitations which impede commercial cultivation of coloured cotton itself signalize future thrust area of research viz. (i) development of wide range of colours with different shades, uniformity and stability, (ii) improvement of fibre properties such as length, strength and maturity, (iii) development of high yielding, early maturing varieties and hybrids, (iv) development of coloured cotton varieties and hybrids amenable to mechanical picking, (v) development of male sterility based hybrids in desi and upland coloured cottons and (vi) development of coloured transgenic cottons.

Index Terms - Colour Cotton, Gossypium, Cotton genome E, Brown, Green.

I. INTRODUCTION

Cotton belongs to the genus Gossypium in the family Malvaceae and produces the single most important textile fiber, accounting for ~35% of the world's total annual fiber demands. It is also used as a model system to study plant polyploidization, cell elongation, and cell wall biogenesis [1,2]. The Gossypium genus comprises 45 diploid species (2n=2x=26) and seven tetraploid species (2n=4x=52) with extraordinary morphological variations, including different plant architectures ranging from wild perennial small trees and shrubs to cultivated herbaceous annuals, with variable leaf shapes and different fiber characteristics (Figure no. 1).

Cotton has long attracted attention from agricultural scientists, taxonomists and evolutionary biologists, as it exhibits extraordinary genomic diversity with global radiation, which has led to the evolution of eight diploid cotton groups (A-, B-, C-, D-, E-, F-, G-, and K-genomes) plus an AD-genome clade. The *Gossypium* genus can be divided into three major lineages primarily based on morphological and geographical evidence: the New World clade (D- and AD-genomes), the African-Asian clade (A-, B-, E-, and F-genomes), and the Australian clade (C-, G-, and K-genomes) (Figure no. 1k). Most wild cotton species have very short fibers that adhere tightly to the seed; only four cotton species, A1, A2, (AD)1, and (AD)2, have been domesticated to produce textile fiber (Figure no. 1l). Upland cotton, *Gossypium hirsutum* [(AD)1], presently dominates the world's cotton commerce by producing ~95% of the natural lint fiber used by the textile industry. There are four overlapping stages during fiber development: initiation, elongation, secondary cell wall (SCW) biosynthesis, and maturation, which are defined on the basis of the number of days postanthesis (DPA). Cotton fibers can be further classified into two types: adherent fuzz fibers, which initiate at 5 to 10 DPA and grow to a final length of less than ∼5 mm, and spinnable lint fibers, which initiate before flowering and grow to a final length of ∼3 cm.

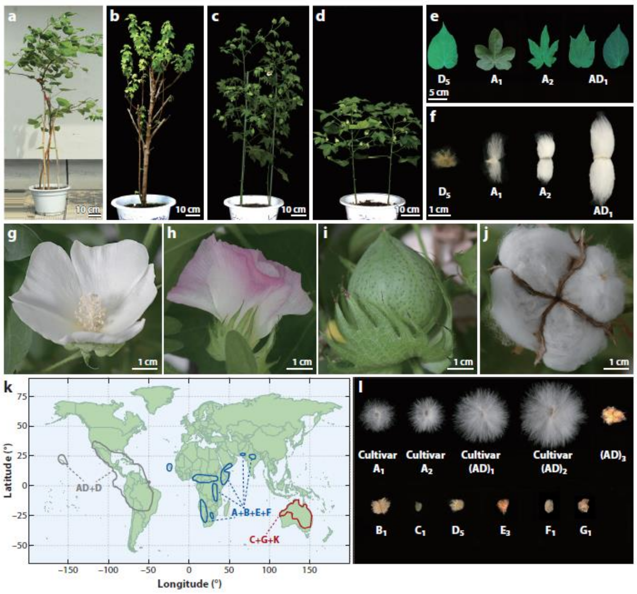


Figure no. 1: An overview of cotton phenotypes, geographical distributions, and seed trichome variation within the *Gossypium* genus. (*a*–*d*) Cotton plant architecture, showing (*a*) *Gossypium raimondii*, (*b*) *Gossypium herbaceum*, (*c*) *Gossypium arboreum*, and (*d*) *Gossypium hirsutum*. (*e*) Cotton leaf shape. (*f*) Cotton fiber. (*g*–*j*) Cotton flower and boll in *G. hirsutum*, including (*g*) white blooming flower, (*h*) reddened flower at 1 day postanthesis (DPA), (*i*) developing boll at 15 DPA, and (*j*) opened boll with mature fibers. (*k*) Geographical distributions of A- through G-, K-, and AD-genomes. Gray, blue, and red indicate the AD- and D-genome clade; the A-, B-, E-, and F-genome clade; andthe C-, G-, and K-genome clade, respectively. (*l*) Phenotypes of cottonseed trichomes among cotton species.

Naturally coloured cottons are gaining importance in the recent years due to the integration of ecology, fashion and public's rising interest in environmental issues and environment-friendly production processes. These naturally coloured cottons reduce or eliminate the costly dyeing and bleaching procedures [3]. Due to its ecofriendly aspect, coloured cottons have created a growing niche market in the developed countries. However, there are few drawbacks with these fibres which make the consumer non-enthusiastic to go for naturally coloured cotton fabric. The fibres are too short and weak to be spun into finer counts and also there is a basic limitation of non-availability of desired shades and colors. Studies have already been carried out to develop various colors and shades at the fibre stage of naturally coloured [4-7]. With this scenario, the present review of literature study was under taken to describe and delineate current and future perspectives on colour cotton research.

II. COTTON EVOLUTION: CURRENT UPDATES

Despite its different geographical origins and morphological and cytogenetic diversities, *Gossypium* constitutes a single monophyletic group that originated from a common ancestor ∼5–10 Mya [8]. Thus far, there are two views with regard to cotton evolution: One suggests that the B-genome is the primitive group that produced all other cotton species [9,10]; the second suggests that the D-genome is the common ancestor of all cotton taxa [11]. The incongruence of phylogenetic relationships in this genus has highlighted the necessity of using multiple and independent studies, especially genome analyses, to fully elucidate the origin of any given group of higher plants.

To date, seven allopolyploid cotton species, including $(AD)_1$, $(AD)_2$, *Gossypium tomentosum* $[(AD)_3]$, *Gossypium mustelinum* $[(AD)_4]$, *Gossypium darwinii* $[(AD)_5]$, *Gossypium ekmanianum* $[(AD)_6]$ and *Gossypium stephensii* $[(AD)_7]$ have been reported [12]. Phylogenetic studies indicated that, among the first five species, $(AD)_4$ may serve as the basal clade, with $(AD)_1$ and $(AD)_3$ forming the second clade, whereas $(AD)_2$ and $(AD)_5$ form the third clade (Figure no. 3a). This means the D_t-subgenome and A_t-subgenome in all of the five species originated from common diploid D- and A-genome species at 1.0 to 1.6 Mya and then gradually branched into five species within 0.20 to 0.63 Mya (Chen et al 2020). The two sub genomes in each of the five polyploid species are highly conserved at the chromosomal, gene content and nucleotide levels, with more substantial diversifications found in evolutionary rate, heterogeneities and the expression patterns of gene families and homologs. All tetraploid cottons are known to be directly descended from an allopolyploidization event involving hybridization between the A- and D-genome ancestors followed by genome doubling [13,14]. Asymmetric genome evolution seems to have occurred in both G. hirsutum and G. barbadense, as there is an overall acceleration in evolutionary rate in the Dt-subgenome relative to that of the At-subgenome [14].

Polyploidization in cotton induced a wide spectrum of gene expression changes and novel interactions. A transcriptomic analysis of 35 vegetative and reproductive tissues has demonstrated that 20 to 40% of homoeologous gene pairs showed A_t- or D_t-subgenome biased expression in *G. hirsutum* [15]. Comparative fiber transcriptomes among wild strains, domesticated strains, and their F1 hybrids uncovered genome-wide and novel cis- and trans-regulatory patterns. A total of 1,655 fiber-expressed genes with cis- and trans-regulatory variations were found to form through divergence and domestication. Of these, 513 genes exhibited cis-only divergence, 301 genes exhibited trans-only divergence, and the remaining 841 genes exhibited both cis- and transdivergence. A_t-biased expression is more often associated with trans-only regulatory mechanisms, whereas, D_t-biased expression is more closely related to cis-only regulatory changes [16]. In addition, up to 80% of the long noncoding RNAs (lncRNAs) were reported to exhibit allelic expression in the allotetraploid cotton, leading to the hypothesis that hybridization and polyploidization enabled the neofunctionalization of lncRNA transcription [17].

III. COLOUR COTTON RESEARCH UPDATES

Worldwide

Recently, an important breakthrough was achieved in Australia, and its $2-billion cotton industry is anxiously awaiting new research by the Commonwealth Scientific and Industrial Research Organisation scientists. The plant breeders here have genetically modified cotton to create coloured cotton in black and other rich, dark colours which could become a “game-changer” in the years to come. Since the 1980s, California-based Sally Fox has made brown cotton famous the world over. China is already a leader in coloured cotton [18].

In India, about 40 coloured genotypes of upland cotton (*G. hirsutum*), mostly of various shades of brown and green colour are available in the National Gene Bank of Cotton maintained at the Central Institute for Cotton Research (Figure no. 2). These genetic stocks are indigenous collections as well as exotic accessions from the US, erstwhile USSR, Israel, Peru, Mexico, Egypt etc. In Asiatic diploid cottons (*G. arboreum* and *G. herbaceum*) about 10 germplasm lines possessing mostly light brown lint colour are also available [18].

India

India is no stranger to coloured cotton and naturally-coloured dark brown cotton grew in Bengal, yellow-green in the Garo hills, and light pink in peninsular India. The desi cotton grown in Gollaprolu region of Andhra has a characteristic light pink colour and is known as Yerra Pathi (red cotton). According to the Central Institute for Cotton Research, three coloured cotton varieties viz. Cocanda and two Red Northerns were released for commercial cultivation in parts of Andhra Pradesh in the mid-1900s but work on coloured cotton was discontinued due to low yield and poor fibre properties. Now, this is the focus since the 1990s and research in coloured cotton was in full swing in about 10 agricultural universities in south and central India. They were using material from ICAR-Central Institute for Cotton Research and the agricultural universities of Dharwad, Raichur, Surat, Nanded, Akola and Khandwa. The colours are a gradation from green to dark brown, and there are four to five distinctive colours [18].

Photo credit: University of Agricultural Sciences, Dharwad.

Figure no. 2: Naturally coloured cotton

Brown cotton lines from University of Agricultural Sciences, Dharwad are at the forefront in the All India Coordinated Research Project trials, and expects that one of its varieties, DDCC-1 (Figure no. 3), was proposed for release in 2021. University of Agricultural Sciences Dharwad has nine other colour genotypes which are also doing well [18].

Photo credit: University of Agricultural Sciences, Dharwad.

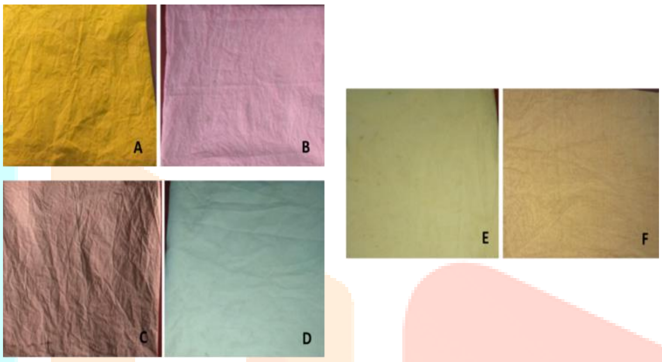
Figureno. 3:DDCC1 Coloured cotton

Furthermore, DMB-225, a medium brown variety was developed in 2013, along with three other varieties. However, DMB-225 was not released commercially on the grounds that it would contaminate white cotton, though its fibre quality was found highly suitable. Moreover, field trials on DMB -225 were conducted during 2020-21 and efforts were continued to improve upon the seeds. In 2002, the University of Agricultural Sciences Dharwad did have a limited commercial release of DDCC-1, an almond-coloured cotton variety and 25 farmers cultivated it in Uppinbatigeri village located in the Dharwad taluk of Dharwad district, Karnataka [18].

The Khadi and Village Industries Board of Karnataka had a nearby unit, which wove the cotton and made shirts out of it, in a unique collaboration that did not last due to lack of funding. That research was sponsored by the Cotton Corporation of India. DDCC-1 was not commercialised on a wider scale due to fears of contamination and it was not notified as a variety, which is necessary for its release. Research investigations were carried out to perfect a new genetic stock – Vaidehi 95 or MSH 53 and for the first time two wild species of cotton namely, G. raimondii and G. thurberi were introgressed with G. hirsutum and G. barbadense to improve its fibre properties [18].

IV. BLOOD SUPPLY OF LIVER NATURAL HERBAL DYES ON COTTON FABRIC

Economic use of natural dye is limited. They are good examples to neem, aloe vera, turmeric, onion and pomegranate. The chemical dyes create severe environmental problem like water pollution, soil pollution and toxic nature of dye causes death to the soil microorganism which in turn affect the agricultural productivity. Synthetic dye clothing come into prolonged contact with one's skin, the largest organ and so toxic chemicals are absorbed into the skin. The absorption has been shown to cause significant health effects, such as an increase in tumours. Textile dye can also cause allergies such as dermatitis and respiratory disease, allergies reaction in eyes, skin irritation and irritations to mucous membrane. These diseases are most prevalent in the workers who are dyeing the cloth as they are around the chemicals all day. But natural dyes are found from natural resource. No chemicals are used in its dyeing process. Natural dyes are not damage to the human body and protective against various skin infections [19]. Colour cloths using natural dyes from natural sources are represented in Figure no. 4.



Source: Kumar et al 2021

Figure no. 4 : Cloths coloured using dyes from Natural Sources; (A) Turmeric, (B) Beetroot dye, (C) Onion, (D) Aloe Vera,(E) Neem, (F) pomegranate

V. ADVANTAGES OF COLOUR COTTON

By not using chemical dyes, as well as reducing the use of pesticides, the naturally colored cottons have become popular for being ecological and environmentally safe. Commercial white cotton is by far the most pesticide dependent crop in the world. Although it only occupies 3% of the world's farmland, it consumes more than 25% of the insecticides and 12% of the pesticides used worldwide. Fifty-five countries rely upon cotton for a significant percent of GDP. After dyeing, the chemical residues are thrown in nearby river contaminating water and soil. When the fabric is manufactured from naturally coloured lint, there is no need of artificial dyes. The World Bank estimates that almost 20% of industrial water pollution comes from textile dyeing and treatment. They have also identified 72 toxic chemicals in our water solely related to textile dyeing. The use of naturally coloured cotton helps in reducing environmental pollution caused by artificial dyes and risks to the health of farmers and communities.
The dyeing process is omitted when naturally coloured lint is used for manufacturing of the fabric, reducing the cost of production. Compared to the white cottons, the naturally colored cottons are shorter and economically less profitable. If the coloured cotton is paid higher price than white cotton, then the reduction in the cost of production of fabric caused by omitting dyeing process is compensated by high price of coloured cotton fabric.
The mills producing cotton with artificial dyes have been reported to have adverse effects on the skin and human health (allergy, itching and cancer). Thus, fabric manufactured from coloured cotton has been found to be the best for labourers and also for consumers.
The reaction to washing of natural colours is quite different from that of synthetic colours. Dyed fabrics more or less fade with each washing. On the contrary, fabrics from naturally coloured cotton improves its fastness and colour intensity with each washing.

VI. CONCLUSION

Cotton is naturally grown today in varieties of colors: beige, red, earth brown, chocolate brown, gray and green. The use of naturally colored cotton has been historically suppressed, mainly due to the industrial revolution. Back then, it was much cheaper to have uniformly white cotton as a raw source for mass-producing cloth and fabric items. Currently, modern markets have revived a trend in using naturally colored cotton for its noted relevance in reducing harmful environmental impacts. Naturally colored cotton is already colored and thus do not require synthetic dyes during process. Furthermore, the color of fabrics made from naturally colored cotton does not become worn and fade away compared to synthetically dyed cotton fabrics.

VII. FUTURE PERSPECTIVES

The limitations in which the commercial cultivation of coloured cotton itself signalize future thrust area of research. These are as follows:

- Development of wide range of colours with different shades, uniformity and stability.
- Improvement of fibre properties such as length, strength and maturity.
- Development of high yielding, early maturing varieties and hybrids.
- Development of coloured cotton varieties and hybrids amenable to mechanical picking.
- Development of male sterility based hybrids in desi and upland coloured cottons.
- Development of coloured transgenic cottons.

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