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COLOURED COTTON : PRESENT STATUS, PROBLEMS AND FUTURE POTENTIALS

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ABSTRACT

Naturally coloured cotton is a very enthusiastic proposition for all of us who share concern about health, safety and threat to ecosystem. The rapid strides of industrial progress has in its wake witnessed a number of environmental problems in almost all spheres of human activities; and textile industry is not an exception to it. Indiscriminate use of chemicals in cotton production as well as for dyeing and finishing of fabrics in textile industries adds to the environmental pollution. In the wake of recent ban on the Azo dyes and more than 100 toxic chemicals used in textile industry and increasing awareness about the deteriorating environment, use of coloured cotton is unique in cotton fabric and apparel market. In this article an attempt has been made to review most pertinent literature on the present status of research, breeding strategies, problems associated with commercial adoption of coloured cotton and its potential.

Key words : Coloured cotton, genetic resources, inheritance, breeding strategies, future potential, problems.

Coloured cotton is being grown and used by mankind as long ago as 2500 B.C. Excavation from Huaca Frieta on the North Peruvian coast reveals that coloured cottons were primitive form of *G. barbadense*. With the concerted research efforts since the middle of this century, superior white lint varieties have been developed, that cover majority of the area under cotton cultivation. However, this is by no means the primitive situation in the genus *Gossypium*. Most of the wild species including putative donors of present day tetraploid cotton, i.e., *G. herbaceum* race *africanum* and *G. raimondii* have coloured lint. The old world Asiatic diploid cottons are presumed to be early in origin than that of New world allotetraploid cottons. Coloured cotton were known in diploids and were under cultivation in Asia; particularly Indian subcontinent, China and Central Asian Republics of former Soviet Union.

In India, coloured cotton varieties, Cocanadas and Red Northerns, were under commercial cultivation mainly on black soils under rainfed condition in parts of

Andhra Pradesh. Red lint types were predominant and in high demand for their better dyeing qualities because dyeing procedures were not standardized as they are followed in textile industry now. Later the situation has changed with the advancement and standardization of dyeing techniques. Subsequently, cultivation of coloured cotton was discouraged and almost abandoned in the last half of this century, mainly because of low productivity per unit area, poor fiber characteristics and non uniformity of colours. Secondly, with the advancement of spinning and processing technologies, ease in imparting varied treatments of colours and shades during processing specially with the advent of synthetic dyes, greater emphasis was given on production of high yielding superior fibre quality cotton, which resulted in replacement of coloured cottons by white linted types [1]. Coloured cottons were grown very scarcely in isolated pockets and are about to vanish. However, research institutions in India and abroad have preserved various coloured cotton genotypes as genetic stocks to be used in research by posterity.

COTTON COLOURS

The lint colour of cotton under commercial cultivation is often white. Among the coloured ones commonly observed are brown and green. The brown colour is most common than the green one, and its shades range from light brown to an intense mahogany red. Depending on the intensity, it is named as light brown, khaki, brown, dark brown, dirty grey and red. Some of the genotypes in the germplasm collection of USA and Russian Republics are reported to have coloured lint with shades of pink, red, blue, green and also black colour. Ms. Sally Fox of Vresers Ltd. claimed to have developed multicoloured lint, i.e. development of more than one colour on the same lint strand [2].

Colours in cotton get expressed in a peculiar way. Boll bursting and exposure of the lint to sunlight are prerequisites for development of colours in the lint. It takes about a week for the lint to develop a complete natural colour. The intensity and the time taken for complete development of colour, varies with the genetic background of genotype. It is interesting to note that while sunlight is essential, continuous exposure leads to colour fading. Green colour is more prone to fading, fades faster than the brown and when turns white or off white it's identity in the field becomes more difficult. Brown colour also fades but gradually at a very slow rate.

Information on pigment development in cotton lint has been generated by different researchers. Stephens [3] differentiated and categorised coloured fibres as chocolate, brown and light brown or white by mounting them in 20 per cent sodium hydroxide. Under low power magnification, he observed that pigments formed a solid and continuous core in the lumen of chocolate coloured fibres. In case of brown shade, the pigment was lighter in colour, more diffused and found in scattered patches, whereas, there were no apparent pigments in lumen of white fibres.

Inability to extract the colour pigments from fibres using most of the proven solvents adds however, to different dynamics of fibre colours. Researchers working on structural aspects of fibre believe that fibre colour is not due to pigment accumulation but it is the structural dynamics and the orientation of cellulose crystallites to the fibre axis, in particular, responsible for imparting colour to the fibre. Particular orientation of cellulose fibrils absorbs and reflects light of definite wave length imparting specific colour to the lint but reaction of synthetically coloured and natural coloured fabrics to repeated washings does not seem to justify the argument. It is to be noted that dyed fabrics more or less fade with each washing, while on the contrary fabrics from natural coloured cotton improves fastness and intensity of colour with each washing. The structural hypothesists are of the opinion that when the fibres of natural coloured cotton do not possess any pigment, question of colour intensification after washing does not arise. It is the improved sharpness and reflectance, which shows resemblance to colour intensification after repeated washings. No published data is available to support the contention of the structural hypothesists and it appears that no efforts have been made in this direction. It is suggested that the above hypothesis of orientation of cellulose crystallite to the fibre axis may be evaluated in the light of data available on X-ray diffraction of mature and immature fibres and Hermans crystallite orientation factor which is the most reliable index of fibre strength [4]. Efforts should also be made to clearly establish the role of micronutrients, soil mineral content and location effect which are reported to have influence on intensity of colour.

GENETIC RESOURCES

Genetic resources are most vital for improvement of any crop. Most of the cotton growing countries over the world maintain these valuable resources in their national gene banks. In India, about 40 coloured cotton genotypes besides handful of wild species and races are maintained in the national gene bank for cotton, at Central Institute for Cotton Research, Nagpur. These genetic stocks are indigenous collection as well as exotic accessions from USA, earstwhile USSR, Israel, Peru, Mexico, Egypt etc. They represent different shades of brown, dark brown, red, khaki, green and light green lint colours.

The cultivable genotypes available in India includes Algeria brown, Arvin brown, Arkansas brown, Arkansas green, BGP 911, BGP 928, Brymer brown, Brown hirsutum, Cotonark dark brown, Cotonark light brown, Cotom 162, EC 1116, IC 7, IC 9, IC

677, Intense red green, Kampala colour, KCM, LS 63, Egyptian brown, Extreme okra brown, Fuzzy seed brown, Nankeen brown, Nankeen khaki, Parbhani American, Pima brown, SA 65, T 586, Tashkent khaki, Texas brown, Texas rust, Red 5-7, etc. Deshi coloured cotton genotypes include light brown, Khaki colour 8631, Khaki brown 7867, A 1418, Cocanadas-1, Cocanadas-2, Nandyal 14, Red Northerns, Rh 25, etc in *G. arboreum* and Kumpta red tinged in *G. herbaceum*. Most of the wild species of genus *Gossypium* have coloured lint, most common is the brown in different shades. Based on colour intensity of lint, *Gossypium* species are grouped into different colour groups as follows:

Brown colour	:	*G. aridum*	*G. hirsutum*
Brownish	:	*G. armourianum*	*G. australe*
		G. mustelinum	*G. darwinii*
		G. sturtianum	*G. somalense*
		G. stocksii	*G. capitis-viridis*
		G. anomalum	
Brownish grey	:	*G. areysianum*	
Greyish	:	*G. gossypiodes*	*G. harknessii*
		G. robinsonii	*G. longicalyx*
		G. herbaceum	*G. sturtianum* var. *nan*
Tan	:	*G. laxum*	*G. raimondii*
		G. trilobum	*G. incanum*
		G. lobatum	*G. arboreum*
		G. hirsutum	
Tan creamy	:	*G. triphyllum*	
Red brown	:	*G. tomentosum*	
Creamish	:	*G. barbadense*	

A large number of coloured cotton genotypes have been documented and preserved all over the world. The reports indicate that Uzbekistan possess genetic stock for pink, red, blue, green and black colours. Similarly, researchers in USA and Israel possess genetic stock specific for particular characters.

Investigations made on coloured cotton in the early half of this century indicate certain good attributes for number of yield components as well as fiber technological characters. Singh *et al.* [5] evaluated 17 coloured cotton genotypes of *G. hirsutum* and compared to superior white linted elite cultivar, LRA 5166 at CICR, Nagpur. The study indicates that not a single coloured cotton genotype was superior to LRA 5166 in yield and boll number though, some genotypes showed superiority with respect to certain other attributes. These are

Genotypes	Characters for which they are superior
Hirsutum Tashkent	Boll weight
Parbhani American, Hirsutum Tashkent, Nankin brown, Cotom 162	Lint index
Cotonark light and dark brown, Lc. 1-1, Cotom 162, Brown hirsutum	Fibre length
Lc. 1-1, Lc. 1-3, Lc. 55-682	Micronaire value

In addition, some genotypes possess resistance for insect pests and diseases, high potential for drought, salt tolerance and also intrinsic fineness and strength of fibre. The preliminary studies carried out at CICR and other centers indicated that, concerted efforts are required to improve coloured cotton for its economic attributes and quality parameters to make them suitable for commercial cultivation.

INHERITANCE OF LINT COLOUR

Coloured types are relatively less common in both species of Asiatic cotton. Colours in *G. arboreum* ranges from very deep brown khaki to light brown but distinctly different from white one. *G. herbaceum* coloured cotton however, are lightly tinted with greyish, cream or dull white lint. Upland tetraploid cottons also lack range of colours. Under natural condition, germplasm lines with brown colour of different intensities and light green are commonly available. Green lint has not yet been reported in the Asiatic species. Inspite of availability and range of expression of the colour linted cotton, very little information on the inheritance of this character is available. This review, attempts to consolidate and bridge the gap with current knowledge on inheritance of lint colour of cotton.

Fletcher [6], while working on Mendelian inheritance in cotton stated that colour is dominant over white. Kottur [7] attempted an interspecific cross between *G. herbaceum*, a reddish tinted and *G. arboreum* white. F_1 hybrid was tinted and F_2 segregated into 120 browns : 200 dull whites : 180 whites, the proportion does not conforming to any standard scheme of segregation. This situation however, resembles to a single main gene segregation obscured by the action of modifiers, if brown and dull white are clubbed in one group.

Ramanathan and Balasubramanyan [8] proposed trifactorial interaction system and suggested one basic gene, X, is essential to produce colour pigmentation only if K_1 and or K_2 are present. K_1 and K_2 do not impart colour on their own. Hutchinson [9] while dealing with leaf shape inheritance showed that a gene for brown lint, termed K, is linked with locus for leaf shape by about 30 per cent cross over units. Later, on the basis of backcross ratio of 255 coloured : 32 white, (7 : 1) he postulated three factors governing lint colour. Of these, one gene K was shown to be linked with leaf shape and other two were symbolised as D_1 and D_2 [10]. Subsequent work with the same material also met with somewhat confusing situation with respect to segregation pattern. However, detailed analysis of 24 progenies by Silow [11] confirmed Hutchinson's observation about involvement of genes at three loci alongwith a variable complex of minor genes for lint colour. Later with the rationalised system of gene nomenclature in cotton [12] the K, D_1 and D_2 loci were resymbolised as Lc_1, Lc_2 and Lc_3, respectively. Silow [11] analysed each one of these loci individually and in combination with other morphological characters to find out linkages. At Lc_1, only one gene for khaki, Lc_1^K, was identified. It is completely dominant, least affected by modifiers in interspecific crosses and shows little fading. It is linked with leaf shape locus L and curly locus C. At Lc_2 a multiple allelomorph series occurs, whose members were identified as khaki Lc_2^K, medium brown Lc_2^M, light brown Lc_2^B and white Lc_2. Lc_2^K does not show much difference from that of Lc_1^K at heterozygous level, except for a very slightly lighter grade, and regarded as duplicate of Lc_1^K. Lc_2^B shows low dominance and highly susceptible to modifier effect and to fading. Lc_2^B is derived from the *G. herbaceum* strain H_3. In general, most *G. herbaceum* strains have been found to be least affected or at lower lint colour modifier level than *G. arboreum*. However, H_3 strain of *G. herbaceum* appears to be the typical one at *G. arboreum* level. Lc_2 is linked with glabrous lintless locus.

At Lc_3, only one light brown Lc_3^B gene was identified. Segregation pattern and colour shades due to this gene were not different from that of Lc_2^B and could be regarded as duplicate of Lc_2^B. A single light brown allele at each of Lc_2 and Lc_3 shows same phenotype of light brown in the homozygous phase. Lc_3 is linked with a locus for corolla colours Ya. Lc_2^B and Lc_3^B are probably cumulative in effect and their expression is more darker than that of Lc_2^K allele if they occur together in-homozygous state. Homozygous Lc_2^B shows nearly same colour intensity as that of homozygous Lc_1^K. Similar is the situation, when both are heterozygous. However, these can be distinguished as light browns which are more susceptible to fading, resulting in considerable variation in the colour classes. On the other hand, greater dominance of khakis show relatively more uniformity and stability in colour intensity in the progenies segregating for the gene. Silow [13] also reported the existence of another locus Lc_4 and identified only one khaki linted gene Lc_4^K. Balasubramanyan *et al.* [14] showed that different strains of Cocanadas carry Lc_2^B and Lc_2^V. Lc_2^V shows less dominance and on exposure to sunlight reveals considerable variability for colour indicating presence of high modifier levels.

Inheritance of lint colour in New World cultivated tetraploid species *G. hirsutum* and *G. barbadense* have been extensively investigated than in the Asiatic species. Thadani [15] for the first time demonstrated allelomorphism of brown and white lint colour in upland cotton. Brown [16] reported 1:2:1 ratio in F_2 in a cross involving yellowish brown and white clearly indicating incomplete dominance. In a separate study, Ware [17] attempted four set of crosses i.e rust colour, dingy brown, yellowish brown and green lint crossed with white linted parent. The lint colour of the F_1 generation of each cross was intergrade between that of respective coloured and white parents. Based on the F_2 segregation ratio (1:2:1) and backcross ratio (1:1) he showed that the four lint colours- rust, dingy brown, yellowish brown and green, each governed by a single gene with incomplete dominance.

Harland [18] crossed an Egyptian Enan's brown with pale cream Sea Island and obtained blending inheritance in F_2. After three back crosses to dark brown, he obtained monohybrid segregation into dark, intermediate and light brown and inferred that an allelomorphic loci for dark brown and light brown, as a result of the presence of plus modifiers involved in Enan's brown. He demonstrated that the brown genes kH (from Guatemala khaki upland cotton) and k^B (from Egyptian Enan's brown) are duplicates and also independent. Later, these genes have been resymbolised as Lc_1^K and Lc_2^K, respectively by Hutchinson and Silow [12]. Balls [19] and Kearney [20] also attempted crosses between Egyptian brown and upland white and obtained intermediate F_1. They obtained varied F_2 segregation, not fitting well in one gene or two gene schemes and thus could not establish the relationship of various genes concerned.

Hutchinson [21] showed that the major brown gene in *punctatum* has lower lint colour intensity and is distinct from Lc_1^K. The data of Harland [18] supports that the major brown gene in *G. barbadense* var. *darwinii* is also independent of Lc_1^K. The mahogany gene is completely dominant and distinct in its effect on intensity of colour from that of the major brown gene in *punctatum* and *darwinii*. It also has large effect on fibre length, maturity and fineness. Two brown genes have also been identified in *G. tomentosum*. However, their relationship and homologies have not been worked out.

Hutchinson [21] made a distinction between genes which cause development of colour and those which only affect intensity, when the former is present. He found a gene in upland cotton which intensifies brown shade but has no effect on white. In var. *punctatum* and *marie-galante* of upland, *G. barbadense* and *G. tomentosum*, minor colour genes change white lint colour to off white or even to pale brown or intensifies the brown. Brain [22] studied brown lint character in five *G. hirsutum* and one *G. barbadense* type. He showed that *G. hirsutum* types possess two independent allelomorphic loci for the lint colour character.

Richmond [23] reported that Texas green lint, Nankeen brown and Texas rust each are conditioned by a single incompletely dominant gene. The gene for Texas green lint is independent of those for Nankeen and texas rust; and genes for Nankeen and Texas rust are alleles. Higginbotham brown gene found to be genetically distinct and independent of Nankeen brown and Texas rust, later on it was designated as Lc_2 allele by Kohel [24]. Richmond [23] observed that the genes for green and brown lint inhibit the development of fibre.

Kohel [24] analysed fibre colour variants in upland cotton. He demonstrated that all green fibre variants (lint and fuzz) were conditioned by alleles at a single locus, Lg, located on chromosome 15 in the D genome. The dark brown lint lines consisting of Algodon de Catamarca, TA 35, TA 36 and Lousiana brown tested for allelism were proved to carry alleles at Lc_1 locus. However, Lousiana brown carried a gene for light brown lint at an additional locus, its expression was so weak that, when isolated, it was difficult to identify readily in segregating population. Brymer brown, a light brown allele was identified at Lc_2 locus [25]. Allelism tests with light brown allele established that the light lint colour in Higginbotham and AD_3 was conditioned by Lc_2 allele. The Morrilli brown lint is governed by a dark brown lint allele at one new locus, closely linked to other new locus, carrying light brown alleles. These two new loci were not allelic to any of the designated brown lint loci, Lc_1, Lc_2 or Dw of *G. hirsutum*. Thus, the dark brown locus is assigned with the gene symbol Lc_3 and the second locus having light brown lint was assigned the gene symbol Lc_5 [24]. The light brown lint lines G 255 and TT were also found to carry potentially new loci those are independent of all other designated brown lint loci; and assigned gene symbol Lc_4 and Lc_6, respectively.

BREEDING STRATEGIES

The studies pertaining to lint colour situation suggest a remarkable similarity between Asiatic and New World cotton Species. There are definite indications of modifier differences, both within and between the species. The main colour genes are uncommon in *G. hirsutum*, but the species as a whole is at a high modifier level, whereas creamy Egyptian and Sea Islands carries main brown gene and a strong suppressing modifier background. Moreover, involvement of number of allelomorphic loci conditioning the character and high influence of environmental factors or genotypic background on its expression due to presence of modifiers, limit the choice of breeding methods for coloured cotton improvement.

Richmond's observation that the genes for green and brown lint inhibit the development of fibre, deserves attention of the cotton breeders while developing breeding strategies. Results obtained by Singh *et al.* [5], Ravindra Nath *et al.* [26] and Amudha and Raveendran [27] partially support Richmond's observation. None of the coloured linted genotypes was superior to commercial white linted checks [5, 26]; as well not a single, out of 50 intra-hirsutum hybrids developed from coloured and white linted parents showed a high heterotic value or atleast comparable to white linted parents for yield and fibre characteristics [27].

Considering the complexity of character and its expression, it is very difficult to single out breeding method to be employed in the beginning. However, breeding methods aimed at disrupting gene pool, followed by strategic selection scheme coupled with rigorous testing for colour intensity and quality parameters, are expected to yield some good results. Interspecific crosses of wild with cultivated species and their synthetic polyploids with coloured lint, transfer of coloured genes into cultivars with good agronomic background by repeated backcrossing, induced mutagenesis of potential coloured linted germplasm lines would help to enlarge the variability for spectrum of colour and also to break certain undesirable linkages. Since some genes are cumulative in effect, certain colour types can be realised even by gene pyramiding. The crosses of various coloured types and white linted lines in diallel and line x tester fashion are expected to provide gene effects, combining ability of the genotypes and colour expression in different combinations. The crosses showing promise for acceptable lint colour types alongwith fibre characteristics and yield performance may be exploited further for their heterotic advantage. Recurring selection involving intermating of selected population in F_2 and F_3 among the coloured linted types may also be helpful to obtain transgressants holding promise. Pedigree breeding and pedigree selection may be considered as standard methods to be adopted to realise the desirable improvement.

Fibre quality characters such as, fibre length, bundle strength, micronaire value, maturity coefficient etc. are polygenically controlled. Joshi [28] suggested building up of new genepools through population improvement breeding, complex crosses and recurrent selections in intermated populations for polygenically controlled characters. Introduction of good agronomic differentials in early stages of selection and adoption of strict norms for yield components, have been suggested by Santhanam [29] so as to achieve the desired results. The suggestions meant for improvement of white linted cottons hold equally good for improvement of coloured cotton too and it is always possible to achieve desired results, following diverse approaches.

Recent advances in genetic manipulation techniques have come up in a big way which may help the breeders to resolve the entangle. Already, the genetically engineered cotton "Bollgard" have been developed by introducing a gene from soil bacteria *Bacillus thuringiensis* and has been made available for planting in U.S. Large scale trials over location and years have proved the worth of B.t. cotton [30]. A herbicide resistance gene, 2, 4-D monooxygenase, has been engineered into cotton; the analysis of the transgenic progeny showed, stable transmission of the chimeric tfDA and the plants were tolerant to three times the field level of 2, 4-D used for weed control [31]. These success stories can be repeated for a number of characters. In the above cases, the genes used for transformation were obtained from micro-organisms which are apparently AT rich and need to be modified to express in the plant system. However, a native gene isolated from a plant system, say gene for colour trait, hooked on a suitable promotor, and transformed to the good agronomic background may be expected to produce desired results. Gene used from the same species would be more compatible. Moreover, the problem of negative linkages could be overcome. This technique can also be useful for gene pyramiding or to increase number of gene copies, if the genes are cumulative in action.

It is suggested that some innate characteristics of the plant which contribute to host-plant resistance may be exploited to its advantage. One such key plant character is Okra leaf shape, which provides an open leaf canopy with an advantage of penetration of more light and in application of chemicals and saving of one or two insecticide sprays per season. The other morphological characters that promise better insect control are Nectariless, Glabrous leaf and Frego-bract. Usefulness of these characters in an Integrated Pest Management (IPM) has already been identified and these characters can be transferred to good agronomic background or promising colour cotton lines by conventional breeding.

Knowledge of the present status of performance and basic characteristics of coloured cotton genotypes, setting up of certain objectives becomes essential to make commercial cultivation of coloured cotton acceptable and viable to industry and trade. The broad objectives may be as follows:

i. development of wide range of colours and their different intensities, uniformity and stability. Possibility to develop multicolour strands may also be explored;
ii. development of genotypes with matching lint and fuzz colours, high lint hairs density and high ginning outturn;
iii. improvement of yield and fibre characteristics, such as length, strength, micronaire value, maturity coefficient, uniformity of fibres, absorbance and colour reflectance;
iv. selection of genotypes showing performance on par with commercial white linted cotton, suitable for rainfed and irrigated conditions showing resistance/tolerance to biotic and abiotic stresses; and
v. development of inter and intra specific hybrids in both Asiatic and New World species.

RESEARCH PROGRESS

Ms. Sally Fox is the first commercial cotton breeder to have developed colour linted genotypes/cultures, which are claimed to be comparable in all characters to pima cotton [2]. She developed varieties with brown, green and red coloured lints and also multicoloured lint, such as green and white, an off-white and tan, and a red and green. Reports indicate that, olive green and fawn brown coloured cotton have been developed and are under commercial cultivation in Israel. The brown coloured lint gene has been transferred from *richmondii* to Texas Marker 1 in China. The resulted brown lint cotton has a yield potential of 30 q/ha, however, it suffers from low ginning outturn of 30 per cent.

In India, brown linted varieties of Asiatic cotton Cocanadas-1, Cocanadas-2 and Red Northerns were under cultivation during the first half of the current century. However, coloured cottons being poor yielders, inferior in fibre properties and no apparent demand from textile industry has discouraged their cultivation. In recent years, research on coloured cotton has gained momentum specially after the much published work by Sally Fox [32]. In view of the growing awareness of environment hazards, 'Ecofriendly' character of the coloured cotton and apparent demand for it from the developed nations have acted as fillip to initiate research for its improvement. The varietal development work on American upland cotton was started at Jawaharlal Nehru Krishi Viswavidyalaya, Khandwa in 1990. It has resulted into development and identification of KC 94-2 [33], a shinning almond brown coloured culture, that yielded 15-20 q/ha and spun to 30's count [33]. Sundaramurthy *et al.*, [34] tested F_1 hybrids of coloured and white linted *G. hirsutum* strains and reported that the fibre quality of these hybrids were better than the coloured linted parents studied.

Singh *et al.* [35] evaluated 45 F1 combinations, involving five coloured strains as male and 13 white elite cultivars as females, for yield and fibre characteristics. The results showed that the four combinations (Vikram x LC 1-1, MCU 5 x LC 1-1, CNH 36 x LC 1-1 and Vikram x Parbhani American) out yielded LRA 5166, a check, in yield and had better ginning outturn than their parents.

At present, sufficient published data is not available to prove that coloured cottons have the same quality characteristics as that of commercially grown upland cotton. Realising the potential and demand for eco-friendly naturally coloured cotton, ICAR has sanctioned a separate scheme in 1996 with broad objectives - to study the inheritance of coloured lint, studies on mutation and polyploidization to develop new coloured types, to transfer brown and green colour genes to elite cultivars and development of high yielding coloured linted cotton varieties and hybrids with desirable textile traits. The scheme is being implemented involving all the three centres of CICR, Nagpur and PKV, Akola. Cotton Corporation of India has also shown keen interest in this potential area of research and currently funding a separate colour cotton scheme, which is under operation at two centres namely JNKV, Khandwa, M.P. and Univ. Agril. Sci., Dharwad, Karnataka.

FUTURE POTENTIAL

In processing, white lint cottons have to be bleached and dyed to impart various colours. In textile industry, about 300 different chemicals are used regularly, at various stages of processing. The disposal of the dyeing or finishing affluent is a major source of pollution. Some of these chemicals proved to have harmful effect on the human skin and health. In recent years, industrial waste has become a potential threat to the human health and environment, in general. Realising the potential danger, some of these chemicals have been red listed by European countries. Following the same suit, Indian Government have banned more than 100 toxic chemicals for use in textile industry.

The growing awareness about the toxicity and pollution caused by synthetic dyes have revived the interest in cultivation of organic cotton. The urge for eco-friendly cotton can only be fulfilled preferably by organically grown coloured cotton, dispensing harmful chemicals in dyeing and processing. Exploitation of coloured cotton on commercial scale will enhance aesthetic value, fashion textile, save dyeing and processing cost, offers special purpose novelty niche cotton, premium to the growers and above all satisfaction and safety to the consumers. Breeders have accepted the challenge and geared up their efforts to develop high yielding superior fiber quality coloured cottons. By virtue of its expertise in growing, handling and processing and also being pioneer in exploitation of heterosis to its advantage, India is in a strong position to meet the demand of coloured cotton for its local and export needs.

SOME CONCERNS

Coloured cotton, being environment friendly, has potential to become a part of cotton fabric and apparel market. With the change in thinking of consumers, research efforts have rightly been channelised to achieve the desired goals, though late it may be, a good beginning is made. However, growing colour cotton has its own limitations, besides it being a potential threat to cultivation and trade of white cotton.

1. *Contamination of white and coloured cotton.* Cotton is an often cross-pollinated crop. In natural conditions, cross pollination occurs to the extent of 5-20 per cent. Growing of coloured and white cotton in the vicinity will enhance the chance of contamination of white linted from coloured and vice-versa. Contamination due to cross pollination may upset the seed production and varietal maintenance programme. It is suggested that safer isolation distance, more than the presently adopted standard;

'one village one variety' concept or growing deshi coloured cotton in vicinity of white upland cotton and vice versa, would help to overcome the problem of contamination, due to outcrossing [36]. But contamination due to mechanical mixing during ginning, delinting of seeds, transport, handling of seed and its marketing may occur at any of the stages, unless separate processing units for coloured and white cotton are used.

2. *Market for coloured cotton*. Naturally grown coloured cotton is a very enthusiastic proposition for its commercial production and utilisation. Keeping an eye on export potential, major cotton producing countries have been promoting it as organically grown coloured cotton venture. Initially, it is likely to fetch a higher price because of its scarcity and novelty. Private firms and NGOs have already initiated assessing the requirement of seeds of hybrids and varieties of coloured cotton. But, where is the viable market for coloured cotton or organically grown coloured and white cotton for that matter? Even the developed Nations including USA do not have established viable market for organic coloured cotton so far. It is suggested that the demand for coloured cotton at home and abroad should be ascertained by an independent agency on continuous basis so as to restrict area under its cultivation and avert the danger of contamination and any loss to growers possibly due to its over production.

Cotton is being grown using synthetic pesticides such as Fenvalerate, Cypermethrin, Deltamethrin and Endosulfan in all the three cotton growing zones in India. Pesticide residue analysis in lint, seed and oil did not show any excess of residues beyond permissible levels as per International standard [37]. There is no evidence that, the chemical residues in lint has showed any harm to health. To some extent, it appears to be an artificial trade barrier on export of raw cotton, yarn and textile fabrics. Organic cotton or eco-friendly cotton cultivation can not be at the cost of intensive cultivation. Even otherwise, at international standards, Indian cotton cultivation consumes less chemicals. Further, in Central India at least 20 per cent of the area is already under natural farming - an euphemism for not using any chemical inputs as a risk aversion measure, than a concern for or awareness about organic cotton [38]. Perhaps, such pockets can be identified and targeted for promotion of organic coloured cotton cultivation. Proper genotypes and production technologies provided in a package, tied up with buy-back arrangement and assured market support would help to sustain the production and productivity to meet the demand of the society at large.

REFERENCES

1. G. S. Ayyangar, M. V. Rao and I. V. Reddy. 1956. Preliminary note on the evolution of white cotton for Cocanadas Tract. Proc. Seventh Conference on Cotton Growing Problems, India (ICCC), 8-9 November, Chandigarh : 7-8.
2. Sally Fox. 1987. Naturally coloured cotton. SPIN OFF., December, p. 48-50.
3. G. S. Stephens. 1975. A re-examination of the cotton remains from Huaca Prieta, North Coastal Peru. American Antiquity., **40**(4): 406-418.
4. A. V. Moharir. 1987. Structure and strengh crystallite orientation relationship in native cotton fibres. Indian J. Textile Res., **12**: 166-169.
5. V. V. Singh, S. S. Narayanan, V. M. Kulmethe, G. R. Anap and S. N. Nagwekar. 1993. A brief review on coloured linted cottons documenting selected genotypes of *G. hirsutum* L. J. Indian Soc. Cotton Improv., **18**(2): 91-94.
6. E. Fletcher. 1907. Mendelian heredity in cotton. J. Agric. Sci. **2**: 281-282.
7. G. L. Kottur. 1923. Studies on inheritance in cotton. I. History of a cross between *Gossypium herbaceum* and *G. neglectum*. Mem. Dept. Agric. India Bot., **12**: 71-133.
8. V. Ramnathan and R. Balasubramanyan. 1933. Lint colour in Asiatic cottons. Curr. Sci., **2**: 128.
9. J. B. Hutchinson. 1934. The genetics of cotton. X. The inheritance of leaf shape in Asiatic *Gossypium*. J. Genet. **28**: 437-513.
10. J. B. Hutchinson. 1935. The genetics of cotton. XV. The inheritance of fuzz and lintlessness and associated characters in Asiatic cottons. J. Genet. **31**: 451-470.
11. R. A. Silow. 1944. The inheritance of lint colour in Asiatic cottons. J. Genet., **46**(1): 78-115.
12. J. B. Hutchinson and R. A. Silow. 1939. Gene symbols for use in cotton genetics. J. Hered. **30**: 461-464.
13. R. A. Silow. 1944. Further data on the inheritance of lint colour in the old world cultivated cotton. J. Hered., **36**: 62-64.
14. R. Balasubramanyan, V. R. Mudaliar and V. Santhanam. 1950. Inheritance of lint colour in Cocanadas Cotton. Indian J. Genet., **10**: 67-71.
15. K. I. Thadani. 1923. Linkage relations in the cotton plant. Agric. J. India. **18**: 572-579.
16. H. B. Brown. 1927. Cotton, New York.
17. J. O. Ware. 1932. Inheritance of lint colours in upland cotton : J. Am. Soc. Agron., **24**: 550-562.
18. S. C. Harland. 1935. The genetics of cotton. XIV. The inheritance of brown lint in New World Cottons. J. Genet., **31**: 27-37.
19. W. L. Balls. 1912. The Cotton plants in Egypt. Macmilan and Co., London.
20. T. H. Kearney. 1923. Segregation and correlation of characters in an upland Egyptian cotton hybrid. Bull. U.S. Dep. Agric., No. **1164**: 58.
21. J. B. Hutchinson. 1946. The inheritance of brown lint in New World Cottons. J. Genet., **47**: 295-309.
22. S. G. Brain. 1950. Heritable relationships of brown lints in cotton. Agron. J., **42**: 188-191.
23. T. R. Richmond. 1943. Inheritance of green and brown lint in upland cotton. J. Am. Soc. Agron., **35**: 967-975.
24. R. J. Kohel. 1985. Genetic analysis of fibre colour variants in cotton. Crop Sci., **25**: 793-397.
25. J. E. Endrizzi and R. J. Kohel. 1966. Use of telosomes in mapping three chromosomes in cotton. Genetics, **54**: 535-550.

26. K. Ravindranath, S. B. Mohiddin, P. R. Reddy, D. Balikondappa, D. T. Reddy and K. Sudhakar. 1996. Development of coloured cottons and priorities. J. Indian Soc. Cotton Improv., **21**(2): 177-179.

27. K. Amudha and T. S. Reveendran. 1977. Heterosis in coloured linted cotton *Gossypium hirsutum* L. J. Indian Soc. Cotton Imoprov, **22**(1): 20-22.

28. A. B. Joshi. 1995. Cotton research in India - the march into 21st century. J. Indian Soc. Cotton Improv., **20**(1): 3-13.

29. V. Santhanam. 1995. Cotton research and development general and breeding aspects. J. Indian Soc. Cotton Improv., **20**(1): 35- 46.

30. Anonymous. 1955. Commercial scale Bt cotton. ICAC Recorder., XIII 1: 3-5.

31. C. Bayley, N. Trolinder, C. Ray, M. Morgan, J. E. Quesenberry and D. W. Ow. 1992. Engineering 2, 4-D resistance into cotton. Theor. Appl. Genet., **83**(5): 645-649.

32. Anonymous. 1992. Natural colours of cotton-ICAC Recorder, X(4): 3-5.

33. K. C. Mandloi, K. R. K. Iyer, G. K. Koutu and R. Julka. 1996. Development of coloured American upland cottons, J. Indian Soc. Cotton Improv., **21**(2): 180-188.

34. V. T. Sundaramurthy A. R. Padmanabhan and K. P. Janakiraman. 1994. Colour fastness of naturally pigmented cotton. Indian Textile Journal., **105**(1): 126-128.

35. V. V. Singh, Punit Mohan and R. Kothandaraman. 1996. Naturally coloured linted genetic resources in National Cotton Gene Bank, their characterstics and utilisation. J. Indian Soc. Cotton Improv., **21**(2): 151-158.

36. S. S. Narayanan and V. Sundaram. 1996. Basic requirements and breeding procedures for developing naturally coloured cotton in India. J. Indian Soc. Cotton Improv., **21**(2): 159-169.

37. A. Regupathy. 1996. Pesticide residue in cotton ecosystem. Paper presented In: National Workshop on Pesticide Application Technology for Cotton. March 19-20, 1996 CICR, Nagpur.

38. P. Ramsundaram and H. L. Gajbhiye. 1995. Economics of rainfed cultivation. *In*: Annual Report, 1994-95, CICR, Nagpur., **83**.