INTERNATIONAL COTTON RESEARCHERS ASSOCIATION

Cotton

INNOVATIONS

Volume 1 , Issue 1 March, 2021

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Content

The Cotton Innovations Newsletter is published twelve times annually. Contributed articles, pictures, cartoons, and feedback are welcome at any time. Please send contributions to the Editorial broad (see below). The editors reserve the right to edit contributions. The deadline for contributions is one month before the publication date.

Editorial Board

News

About Cotton Innovations

This issue of cotton innovations newsletter, which are you reading now, is a monthly publication from the International Cotton Researchers Association, (ICRA) targeted towards providing current innovative information on cotton for breeders, growers, educators, manufacturers and other stakeholders in the cotton supply chain. We plan to provide information about current issues and challenges facing the cotton production and technology worldwide and the ongoing efforts of researchers at ICRA- the cotton task force and other contributors, in addressing these innovations. Our aim is to attract more interest in cotton activities in different cotton Countries by providing information on recent advances in cotton production and processing which includes breeding, biotechnology, agronomic, cultural practices, fiber technology and processing studied globally. We also want to promote value added products for the cotton industry.

Last but not least, I would like to draw your attention to register on website, www.icracotton.org

We hope that you will enjoy this first issue of Cotton Innovations We welcome regular contributions such as short notes and suggestions.

Dr. Mohamed Negm
Chairman of ICRA

A new Chair for ICRA

In the middle of January 2021, Dr. Michel Fok handed over the Chair of ICRA after four years in the position. Dr. Mohamed Negm, who had been the Executive Committee's Vice-Chair since 2016, has been appointed as his successor.
Dr. Michel Fok has steered our association successfully through these difficult challenges and new opportunities with skill and aplomb. The Executive Committee, as well as the wider cotton researchers, thank him for his support and guidance and wish him well for the future.

Dr. Keshav Kranthi Named 'Chief Scientist'

Dr. Keshav Kranthi, the globally renowned cotton scientist who has served as Head of Technical Services for the International Cotton Advisory Committee (ICAC) since 2017, has been appointed Chief Scientist, reflecting recent changes both in his work and in the direction of the organisation.
'For decades, the role of the Head of Technical Services was largely unchanged but the ICAC has evolved and this change in title reflects that', said Kai Hughes, Executive Director. 'The ICAC's emphasis has changed in recent years from just providing technical information to taking a more active role in implementing the most cutting-edge science and best practices in cotton production and sustainability', he said. 'Implementing projects on the ground and developing international project-teams of cotton scientists are indicative of the fact that Dr. Kranthi has taken on a more robust role as "Chief Scientist"'.

In addition to his current responsibilities, Dr. Kranthi will now be providing technical leadership for collaborative projects across the globe to shape the future research agenda for enhancement of soil health, sustainable yield improvement, efficient crop protection and development of digital tools for technology transfer.

Editorial

M.V. Venugopalan, Principal Scientist, ICAR-Central Institute for Cotton Research, Nagpur- India

Chief Editor, March Issue

Diversity of cotton cultivation in India –a boon or bane?

The geographical, physical and cultural diversity of the cotton cultivation in India is amazing. Indian cotton growing region spans from the placid southern tip of Kanyakumari, Tamilnadu (8^0N) to the sub-Himalayan region of Punjab (32^0N) and from the arid, desert like region of Kutch, Gujarat (70^0E) with less than 300 mm rainfall to the eastern Garo hills in Meghalaya (92^0E) with 11500 mm rainfall. All the four cultivable species of cotton *viz., G. hirsutum, G. barbadense, G. herbaceum* and *G. arboreum* are commercially cultivated providing cotton that is spinnable from 6s to 240s. Cotton is grown on a variety of soils – Entisols, Aridisols Vertisols and vertic Intergrades, Inceptisols, Alfisols and Ultisols. Diverse cropping systems ranging from perennial system in North-East to mono-cropping of annuals, intercropping with cereals (sorghum and millets), pulses (black gram, green gram, pigeon pea), oilseeds (groundnut, soybean), vegetables (chilli, onion) and fruit trees (orange), double cropping (cotton-wheat, cotton-chickpea, cotton-paddy) are common. There are close to 6 million farmers from diverse socio-economic strata cultivating cotton. Production systems cut across zero budget natural farming at one end, through homestead and backyard farms, non GM organic farms and low input rainfed systems to the state of art intensive digital drip-ferti-herbigation based modern production systems at the other end. Understandably, the seed cotton yields range from less than 800 kg/ha to more than 6000 kg/ha.

The enormous diversity helps to preserve native land races, enrich biodiversity, provide a natural risk abatement mechanism against several biotic and abiotic stress, caters to diverse end uses and enhance livelihood security. However, it complicates the development and standardization of production and protection protocols to suit such diverse growing conditions. Diverse systems also limit options for mechanization. Therefore the question 'Is diversity of cotton cultivation in India – a boon or bane' has no straight forward answers.

The era of long linted *G. arboreum* cotton has begun

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India has a unique distinction of cultivating all the four cultivable species of cotton. *G. hirsutum* is the dominant one grown in more than 93% area in the world as well as in India. *G. arboreum* that has its origin in the Indian sub-continent and once the dominant species cultivated here, is today cultivated in less than 2% of the cotton area. This is despite the fact that this species possesses traits that confer tolerance to sucking pests, immunity to Cotton Leaf Curl Virus disease and resistance to drought and salinity than their *hirsutum* counterparts. Long duration, tall and lanky growth pattern, small boll size with poor locule retention and poor fibre quality were some attributes responsible for their non-preference both by the farmers and the textile industry.

After decades of painstaking research, three outstanding varieties PA 810, PA 812 and PA 740 were recently released from Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India with good locule retention and with fibre quality comparable to the popular BG II hybrids. These are the world's best long-linted arboreums available today.

Fibre quality of long linted *G. arboreum* varieties

Variety	UHML (mm)	Bundle BS Strength (g/tex)	Mic
PA 812	30	29	4.6
PA 810	30	28	4.6
PA 740	29	27	4.7
Ajeet BG II hybrid	29	29	4.24

Field view of variety PA 812

In multi-location, multi season trials the mean yield of variety PA 812 under rainfed condition was 1250 kg/ha which was 11 per cent higher than the zonal check. In demonstrations on farmer's field, the yields ranged from 1020 to 1500 kg/ha. The variety was also extensively evaluated in experimental plots across varying soil types (vertic Inceptisols and Vertisols), rainfall pattern (normal, drought, excess rainfall), under timely and late sowing condition at varying spacing in the research farm at ICAR-CICR, Nagpur. The highest seed cotton yield realized was 3050 kg/ha on vertic Inceptisols at 60 cm X 15 cm spacing.The recommended practices for long linted *G. arboreum* was standardized.

Recommended practices

- Cultivation on shallow and medium deep soils (Inceptisols/ Vertic Inceptisols) not deep vertisols
- Spacing 90X30cm on heavy or 60/90x15 cm on light soils
- Sowing with the onset of Monsoon and crop termination by the end of December
- Sowing on ridges or preparing ridges after second interculture at 50-60 DAS.
- Application of 60:30:30 kg N:P_2O_5:K_2O and N (3 equal splits-sowing, squaring and flowering).
- Need based plant protection for Pink boll worm and Grey mildew
- Mechanical de-topping at 100 days after sowing or when there are 12-13 fruiting nodes (or application of Mepiquat chloride @ 25g ai/ha twice at 55 and 80 DAS)
- Foliar spary – 2% KNO_3, twice (2 week interval) during early boll setting
- Slashing the cotton stalks soon after harvest

Conscious efforts have begun in the state of Maharashtra which was over 4.0 million ha area under cotton to up-scale these long linted *G. arboreum* cottons with a dovetailed agronomy to provide a cost effective, sustainable alternate cotton production system in the wake of climate uncertainties.

Harnessing the potential of wild species of Gossypium

Vinita Gotmare

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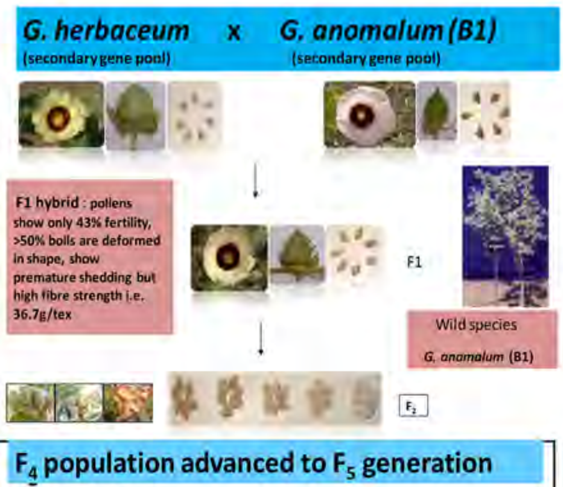
ICAR-Central Institute for Cotton Research (CICR), Nagpur is conserving 25 species of the 50+ known species of *Gossypium*, races of *G. arboreum* (6), *G. herbaceum* (1), *G. hirsutum* (7) and *G. barbadense* (1), perennials (20), sterile interspecific hybrids and synthetic polyploids (>40) in a unique Wild Species Garden cum Field Gene Bank (**Figure 1**). Inter-specific hybridization among the cultivated varieties and wild species followed by backcrossing is extensively done to introgress genes controlling the expression of desirable traits.

Figure 1- Wild species conserved in a unique garden

The Gossypium species have been grouped into three gene pools based on their ability to generate fertile hybrids between the donor and recipient species and the frequency of homologous recombination. The primary gene pool includes the cultivated *G. hirsutum* and *G. barbadense* and wild tetraploid species of Gossypium *viz., G. tomentosum*, *G. mustelinum*, *G. darwinii, G. ekmanianum* (Grover et al. 2015), *G. stephensii* (Gallagher et al. 2017). The secondary gene pool encompasses diploid species of Gossypium belonging to A, B, D and F genome groups while other species belonging to C, E, G, K genome have been categorized as tertiary gene pool (Stelly et al., 2007; Campbell et al., 2010).

Pre-breeding for utilization of wild species

- **Fibre quality:** *G. anomalum,* a 'B genome' species known for fibre strength was crossed with *G. herbaceum* to improve the fibre strength of the latter. A conventional hybrid between *G. herbaceum* and *G. anomalum* was a highly heterotic F1 plant which had broad, shiny, hairy leaves with big flowers larger than both the parents, bears >250 small fruits with exceptionally high fibre strength i.e., 36.7g/tex at 3.2mm gauge **(Figure 2)**. Evaluation of segregating selfed and backcrossed populations is underway.



anomalum **cross**

- *G. longicalyx* – an 'F genome' wild species belonging to the secondary gene pool is known to possess genes for fiber length, fineness and elongation. By obtaining a fertile cross with cultivated *G. arboreum* species through pre-breeding efforts, it has become possible to transfer these fibre quality traits to cultivated species. The advanced generations show improvement in fibre length and elongation **(Figure 3 a and b)**.

Figure 3 (a): ***G. longicalyx*** **(b) Advanced generation with improved fibre traits**

Drought tolerance:

Species belonging to the B-genome possess the characteristic features of drought tolerance as well as resistance to jassids and aphids while E-genome species (*G.stocksii*) of African origin are known to possess genes for drought tolerance. It was possible to obtain a rare interspecific hybrid between species of secondary and tertiary gene pool of Gossypium [*G.anomalum* (B1) and *G.stockii* (E1)] which is maintained as a perennial for further studies **(Figure 4)**.

Figure 4: Hybrid between *G.anomalum* (B1) and *G.stockii* (E1)

Naturally Coloured cotton:

Vaidehi-95 (MSH-53), a naturally dark brown colour linted, multispecies introgressed, reverted tetraploid genotype was developed from hexaploid progenies of the cross between *G. hirsutum, G. raimondii, G. barbadense* and *G. thurberi* **(Figure 5)**. The genotype has open canopy, possesses leaves with long pedicel that allows better penetration of sunlight. By virtue of being a derivative of wild species *G. raimondii* and *G. thurberi* and it is also highly tolerant to jassids. It has a durable dark brown coloured lint, with a good yield potential (113g/plant) and acceptable fiber quality (fiber length of 24mm, fibre strength of 22.1 g/tex and micronaire 4.1). The genotype has been commercialized to provide valued added products (see the article by P. G. Patil in this issue).

Figure 5 : Naturally coloured cotton genotype Vaidehi-95 (MSH-53)

Reference:

Stelly, D.M.; Lacape, J.M.; Dessauw, D.E.G.A.; Kohel, R.; Mergeai, G.; Saha., S.; Sanamyan, M.; Abdurakhmonov, I.Y.; Zhang, T.; Wang, K.; Zhou, B. & Frelichowski, J. (2007). International Genetic, Cytogenetic and Germplasm Resources for Cotton Genomics and Genetic Improvement, *Proceedings World Cotton Research Conference-4*, P. 2154, ISBN, Lubbock, Texas, USA, September 10-14, 2007

Campbell, B.T.; Saha, S.; Percy, R.; Frelichowski, J.; Jenkins, J.N.; Park, W.; Mayee, C.D.; Gotmare, V.; Dessauw, D.; Gband, M.; Du, X.; Jia, Y.; Constable, G.; Dillon, S.; Abdurakhmonov, I.Y.; Abdukarimov, A.; Rizaeva, S.M.; Abdullaev, A.A.; Barrose, P.A.V.; Padua, J.G.; Hoffman, L.V. & Podolnaya, L. (2010). Status of Global Cotton Germplasm Resources. *Crop Science*, **50(**4):1161-1179, ISSN 1435-0653. https://doi.org/10.2135/cropsci2009.09.0551

Gallagher J, Grover C, Rex K, et al. (2017) A New Species of Cotton from Wake Atoll, *Gossypium stephensii* (Malvaceae). *Syst Bot* **42,** 115 - 123 https://doi.org/10.1600/036364417X694593

Grover CE, Zhu X, Grupp KK, et al. (2015) Molecular confirmation of species status for the allopolyploid cotton species, *Gossypium ekmanianum* Wittmack. *Genetic Resources and Crop Evolution* **62,** 103–114. https://doi.org/10.1007/s10722-014-0138-x

Enhancing trait value of upland cotton through introgressions from D- and A- genome cotton species

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Cotton leaf curl disease (CLCuD), a viral disease spread by whitefly, is a serious threat to upland cotton (*G. hirsutum*) cultivation in North Indian states of Punjab, Haryana, and Rajasthan. Previously recognized resistant upland cotton cultivars/stocks have become vulnerable to CLCuD due to the continuous evolution of newer viral races. Presently, there is no extant upland cotton cultivar resistant to CLCuD. Genetic resistance is the most viable alternative for the successful management of CLCuD and whitefly. Some related *Gossypium* species are being used in the pre-breeding programs at Punjab Agricultural University, Ludhiana, India to confer resistance to CLCuD along with other desirable traits.

G. armourianum: It is one of the non-progenitor D-genome cotton species. *G. armourianum* Accession PAU 1 **(Figure 1)** is resistant to both CLCuD and whitefly. The development of primary cross between this species and *G. hirsutum* was easy and did not face any pre- or post fertilization barrier (Kaur *et al.* 2016). The resulting F_1 hybrid (2n = 3x = 39) was highly sterile due to meiotic irregularities. The production of BC1F1 plants by crossing triploid F_1 with upland cotton was a herculean task. Nearly 15,900 flowers of the inter-specific hybrids (ADD) were pollinated using *G. hirsutum* as the male parent. Five BC_1F_1 seeds were produced, of which four germinated (Pathak *et al.* 2016). Two of the BC_1F_1 plants were found to be resistant to CLCuD. One more backcross was attempted to produce BC_2F_1 plants (Singh *et al.* 2019). Pre-breeding lines having introgressions from *G. armourianum* have been developed and are being evaluated for various traits including resistance to CLCuD and whitefly, lint yield, lint percentage, seed weight, seed cotton yield boll^{-1} and fiber quality.

Figure 1: *G. armourianum*

Synthetic amphiploid: The synthetic amphiploid has been developed through hybridization between *G. thurberi* (D_1) and *G. arboreum* (A_2) and doubling chromosome number of the inter-specific hybrid (Beasley, 1940). This synthetic **(Figure 2)** has been observed to be resistant to CLCuD and whitefly. Synthetic polyploid was used as the female parent as it was male- sterile. About 3200 flowers of the synthetic were pollinated using upland cotton as the pollen parent to produce 25 seeds, of which 16 seeds germinated. Both direct and reciprocal crosses were attempted to produce BC_1F_1 seeds. For this, a total of 7434 flowers were pollinated and 1868 BC_1F_1 seeds were obtained. A total of 296 (15.85%) BC_1F_1 seeds germinated, of which 194 plants were established (Vij *et al.* 2020). Substantial genetic variation for various economic traits has been recorded in the backcross derivatives. Transgressive strength and fibre fineness have been recovered.

Figure 2: Synthetic polyploid

***G. arboreum*:** This species is being used for the introgression of CLCuD, whitefly and leafhopper resistance in Upland cotton **(Figure 3).** The development of primary cross between *G. hirsutum* and *G. arboreum* was challenging. More than 10,000 flowers of upland cotton were pollinated with *G. arboreum* pollen. Two of the four interspecific hybrid plants were triploid (2n = 39). Interestingly, other two hybrid plants were found to have 52 chromosomes. The latter are likely to be the result of fusion between normal (haploid) gametes of upland cotton and unreduced (2n) gametes from *arboreum* cotton. The tetraploid F1s were partially male-fertile and were backcrossed to the upland cotton to generate BC_1F_1 seeds. The BC_1F_1 plants exhibited substantial variation for response to jassid and whitefly, lint percentage, halo length, seed weight, seed cotton yield etc.

Figure 3: *G. arboreum*

References

Beasley J O (1940) The origin of American tetraploid *Gossypium* species. *Am Naturalist* 74: 285-86.

Kaur H, Pathak D and Rathore P (2016) Development and characterization of an interspecific *Gossypium hirsutum* × *Gossypium armourianum* hybrid. *Appl Biol Res* 18: 146 - 54.

Pathak D, Kaur H, Rathore P, Singh B, Bala S, Sekhon P S and Singh K (2016) Introgression of cotton leaf curl disease resistance from *Gossypium armourianum* into *G. hirsutum. Proc. 1st Int Agrobiodiversity Cong.* pp. 198. New Delhi, India.

Singh B, Pathak D, Rathore P and Pooja (2019) Segregation distortion in cotton. *Agric Res J* 56 (1): 13-16. *doi. 10.5958/2395-146X.2019.00002.4*

Vij S, Pathak D, Rathore P and Nikhanj P (2020) Genetic analysis of some morphological traits in synthetic × naturally polyploid cotton derivatives. *J Genetics* **99**: 73 doi.org/10.1007/s12041-020-01230-w

Cotton stalk compost- an alternative to farmyard manure for cotton production

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Depending on the cotton genotype and growing conditions, about 3–5 tonnes of cotton stalks are produced per hectare. In India, around 30 million tonnes of cotton stalks are produced annually. Most of it is burnt on field bunds, polluting the environment. On the other hand, there is a scarcity of organic manures for farming. Several farmers have stopped the application of Farm Yard Manure (FYM) due to its non-availability. Tropical climate, intensive cultivation and reduced organic inputs lead to rapid decline in soil organic carbon that in turn, adversely affects physical, chemical and biological functions of the soil, indirectly reducing cotton productivity.

Since cotton stalks have high lignin (20%-22%) content, it is difficult to degrade it naturally. Further, direct application of cotton stalks as such or in chipped form without composting immobilizes soil nitrogen making them it unavailable for the subsequent crop. Composting cotton stalks offers a suitable and viable option to utilize cotton stalks without polluting the environment. It recycles the nutrients removed, leading to a sustainable cotton production. ICAR-CIRCOT, Mumbai and ICAR-CICR, Nagpur jointly developed and evaluated an accelerated process of cotton stalk composting using microbial consortium. Duration of composting is 80-90 days. The NPK content of this compost is 1.43:0.78:0.82 compared to 0.5:0.5:0.5 of FYM.

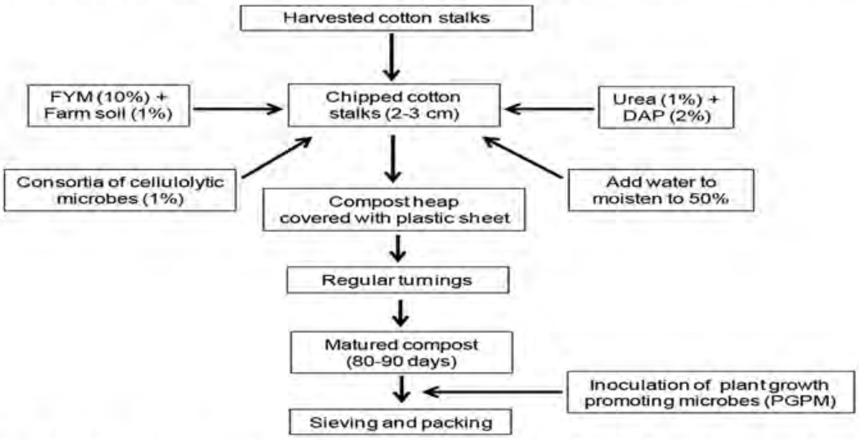

Fig. 1 Production technology of microbially enriched cotton stalk compost

We evaluated cotton stalk compost *vis –a-vis* farmyard manure (FYM) in long-term experiments under summer irrigated (North India), rainfed (Central India) and winter irrigated (South India) conditions. Results indicated that the substitution of cotton stalk compost in integrated nutrient management (INM) produced effects similar to that of FYM in enhancing cotton yield, fibre quality, nutrient availability, and soil health. The use of cotton stalk compost could reduce 50% costs on NPK fertilizers, and can save approximately US$ 34 ha^{-1} on nutrient management practice in cotton. Creating mass awareness of cotton waste management at on-farm level can enhance the use of cotton stalks as organic manure, reduce pollution and improve soil health.

Value Addition to Naturally Coloured Cotton

P. G. Patil
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Though most of the available cotton lint is white, some cotton genotypes bear colours. They are called as Naturally Coloured Cotton (NCC). NCC is naturally pigmented fibre that is available in shades of brown, green, tan, blue, black etc.

NCC genotypes developed in India

- JCC-1: Bright Almond lint- from Jawaharlal Nehru Krishi Vidyapeeth, Khandwa, Madhya Pradesh
- DDCC-1 Brown lint, from University of Agricultural Sciences, Dharwad, Karnataka
- DGC 78: Light green lint- from University of Agricultural Sciences, Dharwad, Karnataka
- Vaidehi-95 (MSH-53)- Dark Brown lint from ICAR-CICR, Nagpur, Maharashtra

Some more genotypes are being evaluated across different locations of India, prior to their commercial release.

Value Added Products from NCC

ICAR-CIRCOT took up the challenge for commercialization of Vaidehi-95 developed by ICAR-CICR, Nagpur and successfully developed technology to spin fibres in to good quality yarn though the cotton fibres were of short staple length. Various products from this fabric such as jackets, handkerchiefs, infant wears have been developed out of NCC spun yarn. These products are 100% chemical free, have very high wash durability (due to inherent colour), soft feel and are skin friendly.

Advantages of NCC products

- Antimicrobial, UV protective and better comfort
- Farm to fabric conversion without chemical processing

Though the demand for NCC based products is increasing due to sustainable issues in the processing of white lint, the availability of NCC is very limited due to restrictions in its commercial cultivation. Hence, ICAR-CIRCOT is collaborating with State Agricultural Universities for cultivating NCC in research farms to increase its production. The Agri-Business Incubation (ABI) Centre of ICAR-CIRCOT, Mumbai is promoting entrepreneurship and incubation of start-ups for "Product Diversification of Naturally Coloured Cotton" in line with 'Make in India' Program of Government of India.

Nanocellulose production and its applications

Dr. P. G. Patil

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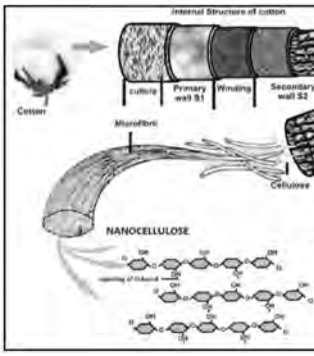
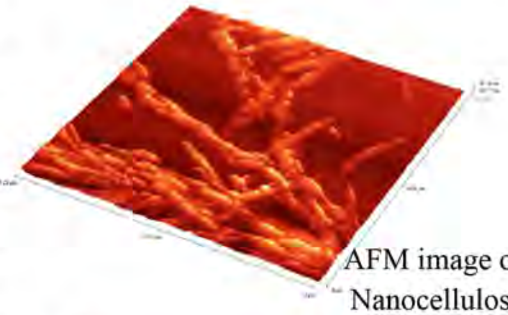
ICAR-CIRCOT, Mumbai caters to the needs of diverse stakeholders in post-harvest processing of cotton and value addition to cotton biomass. The Institute has taken the lead to explore the applications of nanotechnology in agriculture, cotton textiles and bio-composites. Nanotechnology, that has already revolutionized material science, pharma, electronics and industrial chemistry, is now spreading its wings in the fields of agriculture and allied sectors. ICAR-CIRCOT, Mumbai ventured into Nanotechnology in 2004 to impart novel functional finishes to cotton textiles to impart antibacterial and UV protection properties using silver and zinc oxide nanoparticles.



Nanocellulose from cotton fibres

Nanocellulose refers to cellulose polymer broken down to the nano-size range (1 nm = 10^{-9} m). The major attraction of nanocellulose is its high mechanical strength (Tensile strength = 1 to 10 GPa; Young's modulus = 100 – 130 GPa), more surface area to volume ratio (50 – 200 m^2/g), bio-degradability and novel rheological (shear-thinning) and optical properties. Cotton is one of the purest forms of raw material for production of nanocellulose. It has proven applications as (a) reinforcing agents in bio-composites, (b) additives in high-end papers & paints, (c) scratch resistant coating additives, (d) transparent display for electronics (e) carriers in drug delivery system and, (f) carriers of micronutrients delivery system in agriculture.



AFM image of Nanocellulose

The intrinsic architecture (crystalline structure with hydrogen bonding) of cellulose makes it highly energy demanding for conversion into nanocellulose. the Institute successfully attempted the preparation of nanocellulose from cotton linters and cotton wastes using a novel and energy-efficient chemo-mechanical process. The Institute has established a nanocellulose pilot plant at in Mumbai with a capacity of 10 kg per shift of 8 hours, which is a first of its kind in India and unique in the world that uses cotton biomass as the raw material. This nanocellulose pilot plant is used to demonstrate ICAR-CIRCOT's technology to various stakeholders, for product development, for technology incubation and licensing.

Nanocellulose

Nanocellulose Pilot Plant, ICAR-CIRCOT, Mumbai