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Seed Times

The National Seed Association of India Magazine Volume 15, Issue 2, (May-August, 2023)

New Technologies and Approaches in Cotton Breeding, Seed Production and Seed Quality

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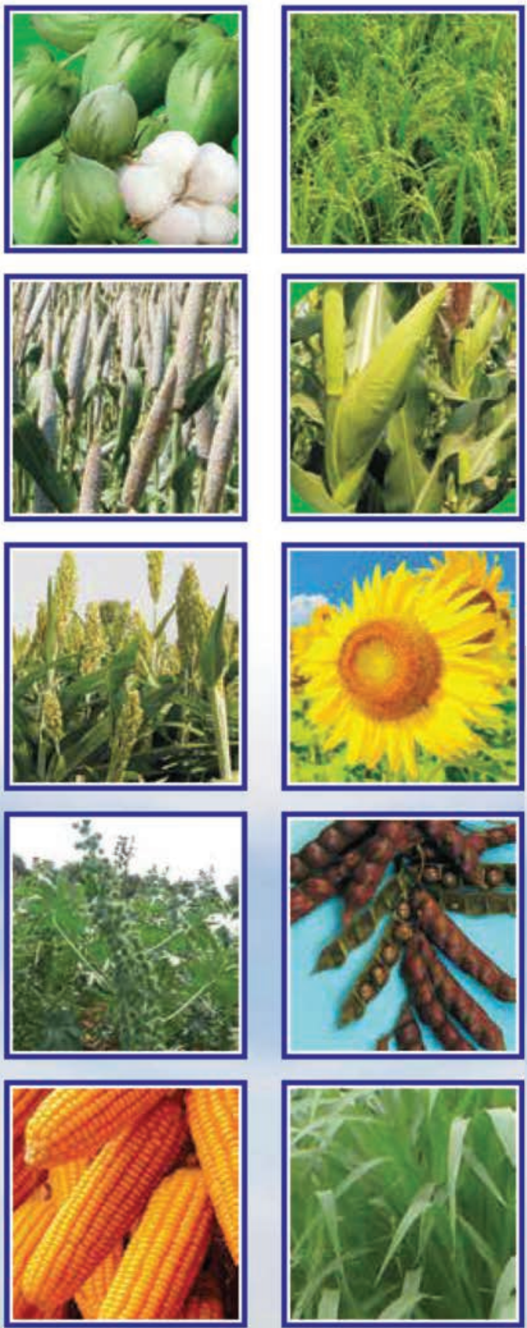

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About NSAI

National Seed Association of India (NSAI) is the apex organization representing the Indian seed industry. The vision of NSAI is to create a dynamic, innovative and internationally competitive, research based industry producing high performance, high quality seeds and planting materials which benefit farmers and significantly contribute to the sustainable growth of Indian Agriculture.

The mission of NSAI is to encourage investment in state of the art R&D to bring to the Indian farmer superior genetics and technologies, which are high performing and adapted to a wide range of agro-climatic zones. It actively contributes to the seed industry policy development, with the concerned governments, to ensure that policies and regulations create an enabling environment, including public acceptance, so that the industry is globally competitive.

NSAI promotes harmonization and adoption of best commercial practices in production, processing, quality control and distribution of seeds.

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Message from Desk of President

We all know that Seed is one of the most critical inputs responsible for boosting agricultural production and productivity. Good quality seeds not only provide food security for the rising population but also ensure nutritional security. In order to encourage farmers for using quality seeds, we would require to provide adequate quantity of seeds, meeting quality standards and suited to different agro-ecological situations, with a reasonable price.

Amongst different agricultural crops, Cotton have gained more attention as a result of rising demand in textile industry.

Cotton production faces many challenges in the 21st century. Between the rapid increase in human population and the loss of arable land due to soil erosion, soil salinization, harsher climate conditions, and urbanization, the demand for promoting cotton yield is increasing dramatically. Establishing research initiatives to tackle these challenges depends on identifying the major factors that limit increases in yield. They include biotic stresses and abiotic stresses (particularly the water shortage that many regions are experiencing), global climate change, genotype by environmental interactions, limited germplasm resources, and the negative association between yield and fiber quality.

The seed industry can help in overcoming these challenges by developing high yielding varieties of Cotton tolerant to abiotic stresses and having resistance to insect pests and diseases. Promoting good agricultural practices and HDPS in cotton would greatly help in fiber quality and higher productivity of cotton. The seed industry is, therefore, expected to play a greater role by introducing improved cultivars and producing high-quality seeds of cotton that possess the desired traits and have good germination capability and genetic purity.

I am happy to see that this edition of "Seed Times" has been brought out on the theme **"New Technologies and Approaches in Cotton Breeding, Seed Production and Seed Quality"**, which is need of the hour. I am sure, the readers will have opportunity to go through quality articles on Cotton, enabling them to contribute their best in achieving sustainable production of cotton and ultimately economic growth of the nation.

M Prabhakar Rao

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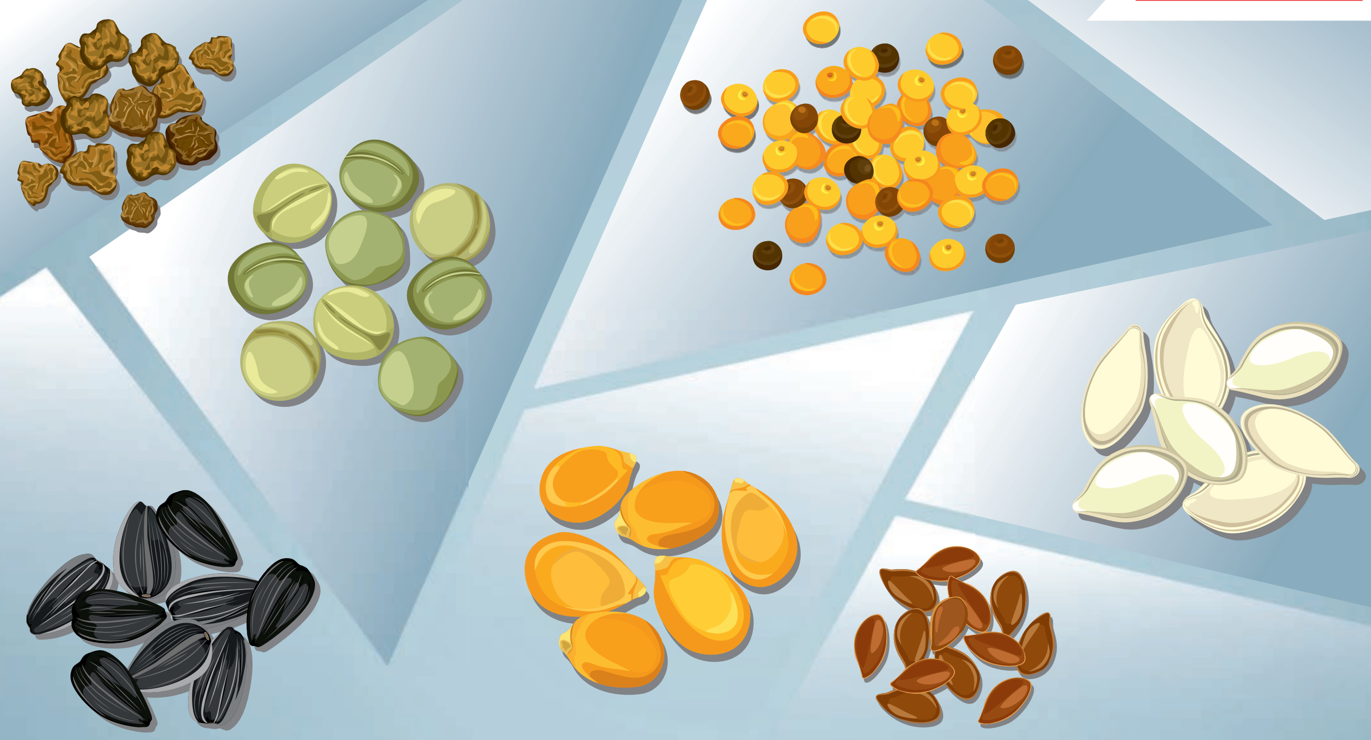

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Message from Desk of Executive Director

Dear Readers,

The most reputed NSAI quarterly magazine of the seed industry, the **Seed Times** covers scientific research papers/articles/review articles/information on various aspects related to seed industry. It is widely circulated to all the stakeholders of seed industries viz., ICAR, SAUs, Central Govt. Agriculture Departments, State Agriculture Departments, NSC, SSC, Private Seed Companies etc.

The theme of May-August 2023 issue of the Seed Times is **"New Technologies and Approaches in Cotton Breeding, Seed Production and Seed Quality"** with the aim to disseminate the knowledge about the quality seeds of cotton by eminent scientists and professionals involved in the cotton breeding.

Global climate change has a significant impact on cotton production through the complex impact of abiotic and biotic factors, reducing yields and fiber quality. This poses a task to breeders for developing new cotton varieties that are resistant to abiotic and biotic stresses. To challenge it, cotton varieties resistant to abiotic stresses are developed using molecular breeding methods, while genomic trans-genomic methods improve resistance to insect pests and pathogens (biotic stress). Introduction of genetically modified (GM) cotton and its adoption by major producing countries have altered the global trends in cotton production. GM cotton has ensured a reduction in the usage of insecticides. Sustainability of GM cotton could be challenged by the evolution of resistance in insects and weed biotypes.

Private seed companies have risen steadily and now playing a significant role by putting emphasis on Research and Development activities to increase production and improve seed quality of cotton.

I appreciate NSAI team for focusing on cotton in this edition of Seed Times which is need of the hour for agricultural and economic growth of the country. This creditable objective will raise the knowledge and skills of our seed industry persons in order to improve seed quality as well as seed production and deliver quality seeds of cotton to farmers.

I hope the readers would greatly be benefited from the magazine.

Happy Reading!

R K Trivedi

National Seed Association of India

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Cotton Cultivation: Assessment of Current Status and Trends

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Introduction

Cotton, one of the most important commercial and fibre crops of global significance. It is a multipurpose crop grown under various agro-climatic conditions (Reddy et al., 2020) and is also known as the "King of Fibre" or "White Gold". Cotton accounts for around 25 per cent of total global fibre production. It plays a notable role in the sustainable economy of India and livelihood of the

Indian cotton farming community (5.8 million cotton farmers). Cotton is the most favoured fibre among the Indian textile mills, as a major raw material for the textile industry. In the raw material consumption of the Indian textile industry the proportion of cotton is around 60 per cent (Anonymous, 2022). The country's cotton-growing region has been divided into three zones. Punjab, Haryana, and Rajasthan make up the northern zone; Maharashtra, Madhya Pradesh and Gujarat make up the central zone; and Telangana, Andhra Pradesh, Karnataka, and Tamil Nadu make up the southern zone. Gujarat, Maharashtra and Telangana are the three states that produce the most cotton among them (Cotton Corporation of India, 2022). As per the Cotton Corporation of India Limited Statistics (2022), world cotton production is estimated at 121.1 million bales of 217.72 Kg each, with the area of 32.9 million hectares (81.4 million acres). The major cotton growing countries in the world are China and India are projected at 27.5 lakh bales each followed by United States (16.5 million bales), Brazil (13.2 million bales) and Pakistan (6.2 million bales). During 2022-23, cotton area in China and India are projected to increase from 3.10 to 3.15 million hectares (7.8 million acres) and 11.96 to 12.7 million hectares (31.4 million acres) respectively. In India, the area, production and productivity of cotton are all expanding dramatically. The introduction of the Technology Mission on Cotton (TMC) in 2000, which was primarily focused on enhancing cotton production, productivity, and quality, followed by the introduction of Bt cotton in 2002, was a significant turning point in the growth of cotton production. Furthermore, the Government of India's programme to guarantee Minimum Support Price (MSP) through Cotton Corporation of India (CCI) significantly accelerated cotton growth.

Bt cotton trends in India indicated significant developments in both production and productivity. Bt cotton, a genetically modified variety resistant to certain pests, gained widespread adoption among Indian farmers

since its introduction in the early 2000s. This led to a rapid expansion of Bt cotton cultivation across the country, contributing to India's position as one of the largest cotton producers globally. The technology's ability to resist bollworm pests translated into increased yields, boosting overall cotton production. However, challenges arose with the emergence of Bt-resistant pests, reducing the technology's efficacy in some regions. The Indian government has been actively monitoring the situation, approving improved Bt cotton varieties and implementing regulations to address concerns related to technology resistance and farmer welfare. For the latest information on Bt cotton trends in India, it is essential to consult more recent sources that provide up-to-date data beyond September 2021.

Area, Production and Productivity

The data on the area under cultivation (in lakh hectares) of cotton crops from 1950-51 to 2021-22 is presented in Table 1 (and Fig. 1) shows that the area under cotton crop has fluctuated over the years with some years experiencing a slight increase and others showing minor decreases. However, a Compound Annual Growth Rate (CAGR) of 1.01 per cent, indicates a slight increase overall. The variations in the area under cultivation may be influenced by factors such as changes in land use patterns, shifts in agricultural policies, and market demands. The Cuddy della valle index of 21.66 per cent shows relatively high extent of risks and variability in the area under cultivation. Over this period, there has been a significant increase in cotton production with a Compound Annual Growth Rate (CAGR) of 3.17 per cent, indicating a notable overall growth trend, whereas, the Cuddy della valle index of 43.46 per cent further reflects the extent of risks and variability in production, suggesting that the crop's performance fluctuated due to various factors such as climate conditions, pest infestations, and technological advancements. The increase in production suggests that farmers have been able to enhance their farming practices, leading to higher yields and improved crop management. There has been steady growth in yield, with a Compound Annual Growth Rate (CAGR) of 2.13 per cent and cuddy della valle (31.09 %) suggests fluctuating productivity. Moreover, the data reflects the changing dynamics of agricultural practices, influenced by various factors such as climate, market demands, and technological advancements. The rising yield can be attributed to adoption of high-yielding varieties, advancements in agricultural practices, efficient use of inputs like fertilizers and irrigation, and better pest management strategies. This enhanced yield is critical for sustaining agricultural productivity without expanding the area under cultivation excessively

Table 1: Area, Production and Productivity of cotton in India

Year	Area (lakh hectares)	Production (lakh bales of 170 kg each)	Yield (kg per hectare)
1950-51	58.82	34	99
1960-61	76.1	60	134
1970-71	76.05	57	127
1980-81	78.23	78	169
1990-91	74.39	117	267
2000-01	85.76	140	278
2001-02	87.3	158	308
2002-03	76.67	136	302
2003-04	76.3	179	399
2004-05	87.86	243	470
2005-06	86.77	241	472
2006-07	91.44	280	521
2007-08	94.14	307	554
2008-09	94.06	290	524
2009-10	103.1	305	503
2010-11	111.42	339	517
2011-12	121.78	367	512
2012-13	119.78	370	525
2013-14	119.6	398	566
2014-15	128.19	380	504
2015-16	116.85	364	528
2016-17	108.26	345	542
2017-18	125.86	370	500
2018-19	126.14	333	449
2019-20	134.77	365	460
2020-21	132.85	352	451
2021-22	120.55	315	445
CAGR (%)	**1.01**	**3.17**	**2.13**
SD	**21.93**	**117.61**	**145.15**
Mean	**100.48**	**256.41**	**412.07**
CV (%)	**21.82**	**45.87**	**35.22**
Cuddy della valle index (%)	**21.66**	**43.46**	**31.09**

Source: Statistical Database, Cotton Corporation of India

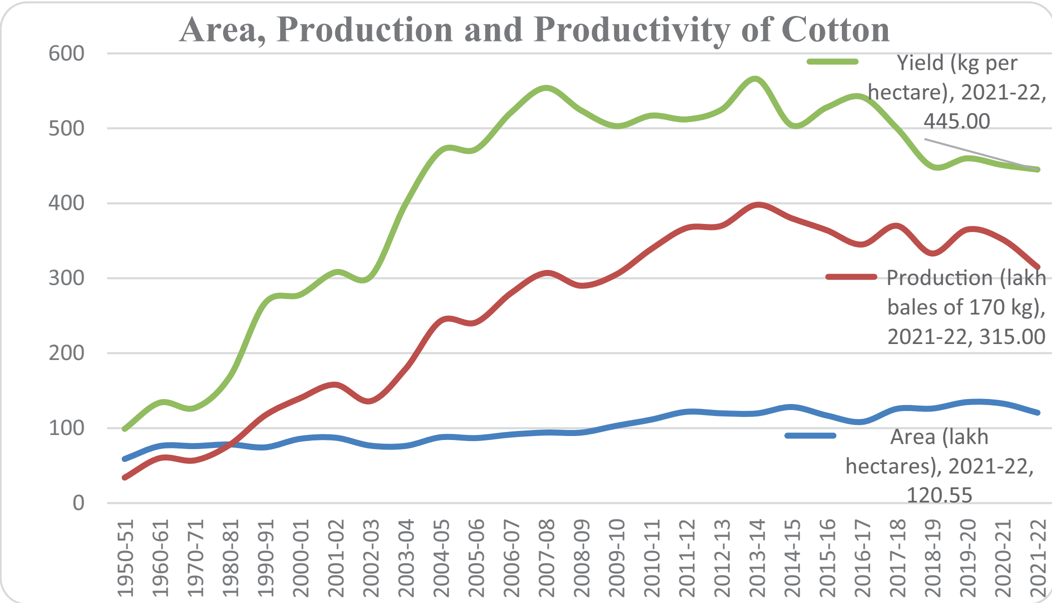

Fig 1. Trends in Area, Production and Productivity of cotton in India

Import and Export of Bt Cotton

The Table 2 presents data on the export and import of Bt Cotton measured in lakh bales of 170 kg each, over a specific period. Export volumes show a substantial Compound Annual Growth Rate (CAGR) of 14.87 per cent, indicating significant annual growth. In contrast, the CAGR for imports is much lower at 0.39 per cent, suggesting a slower rate of increase in imports. Both exports and imports exhibit variability, as demonstrated by their respective Standard Deviations (SD) of 3.34 and 0.86, indicating fluctuations in trade volumes over time. The coefficient of variation (CV) for exports is 54.9 per cent, and for imports, it is 62.92 per cent, highlighting a high relative variation in both trade flows compared to their respective means. For exports, the cuddy della valle index is 48.86 per cent, while for imports, it is 55.37 per cent. A higher index value suggests a greater degree of uncertainty and fluctuation in trade volumes over the observed period. These values indicate that both exports and imports have experienced significant variations in their trade volumes over time.

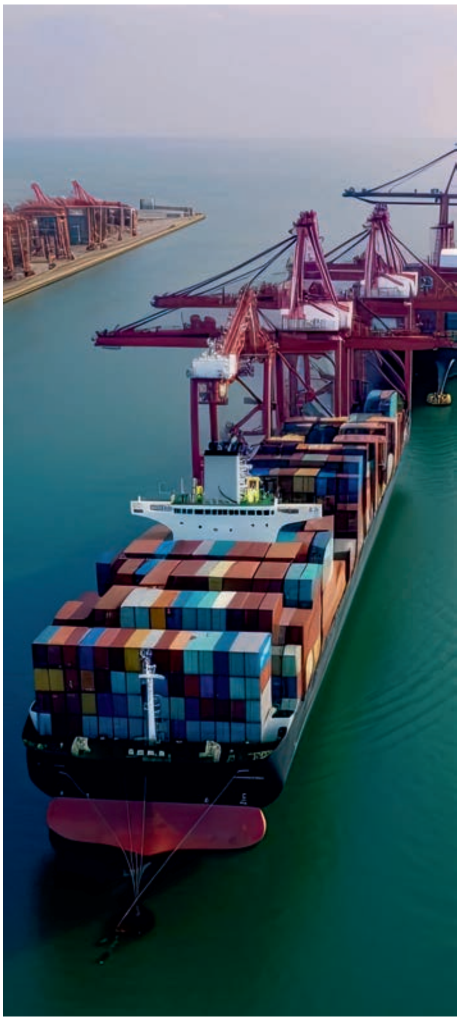

Table 2. Export and import of Bt cotton in India

Year	Export (lakh bales of 170 kg each)	Import (lakh bales of 170 kg each)
2002-03	0.25	1.85
2003-04	1.75	0.75
2004-05	1	1.25
2005-06	4.25	0.5
2006-07	5.85	0.55
2007-08	9	0.65
2008-09	3.75	1
2009-10	8.25	0.6
2010-11	7.85	0.25
2011-12	13	0.75
2012-13	10	1.45
2013-14	11.75	1.15
2014-15	5.75	1.44
2015-16	5.8	2.25
2016-17	5.85	3.1
2017-18	6.75	1.65
2018-19	4.35	3.55
2019-20	4.7	1.55
2020-21	7.75	1.1
2021-22	4	2
CAGR (%)	**14.87**	**0.39**
SD	**3.34**	**0.86**
Mean	**6.08**	**1.37**
Co-efficient of variation (%)	**54.9**	**62.92**
Cuddy della valle index (%)	**48.86**	**55.37**

Source: Statistical Database, Cotton Corporation of India

The export volumes have shown a varying trend over the years (Fig. 2), starting at 0.25 lakh bales in 2002-03 and reaching a peak of 13 lakh bales in 2011-12 before fluctuating around 4-8 lakh bales in recent years. Similarly, import volumes have also fluctuated, with values ranging from 0.25 lakh bales in 2010-11 to 3.55 lakh bales in 2018-19. These fluctuations in imports can be influenced by various factors, such as changing domestic consumption patterns, shifts in sourcing preferences, or variations in global market prices. The peak in imports in 2018-19 might indicate an increase in domestic demand for the cotton or limited domestic production capacity, leading to higher imports. Overall, the data suggests that the trade dynamics for cotton have been subject to various economic, geopolitical, and market-related factors.

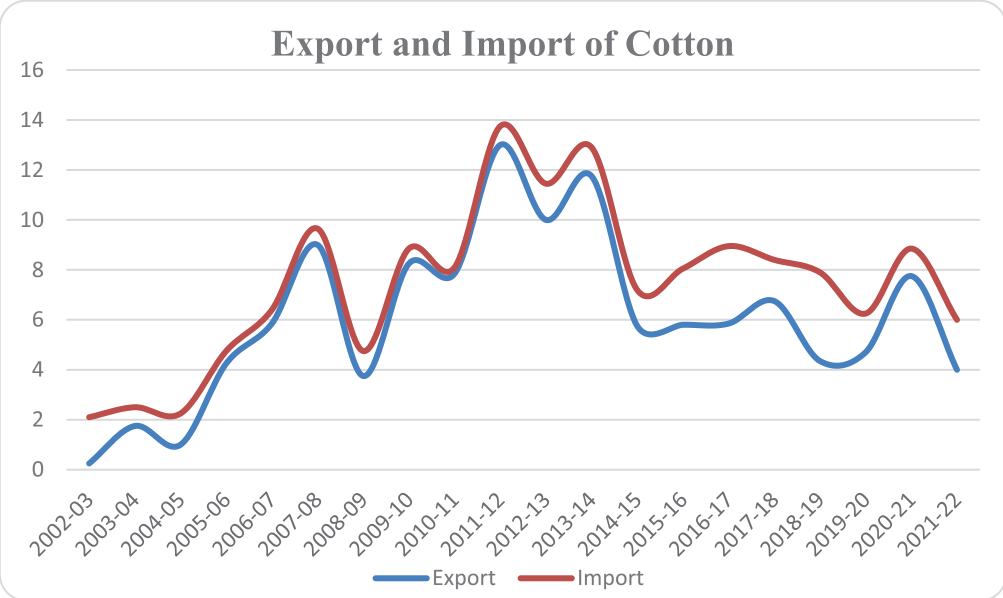

Fig 2. Export and import of Bt cotton in India

Bt Cotton and Sustainability

Bt cotton significantly contributes to sustainability in agriculture by reducing pesticide use through its built-in pest resistance. This genetically modified crop offers increased yields compared to conventional varieties, promoting efficient land use and conserving biodiversity by benefiting non-target insects and wildlife. Additionally, the reduced need for chemical inputs in Bt cotton cultivation contributes to water conservation, making it an eco-friendly choice, especially in water-scarce regions. Its economic benefits for farmers, through higher yields and income, enable investments in sustainable practices and technologies. Furthermore, Bt cotton's adaptability to climate change and lower greenhouse gas emissions associated with reduced pesticide usage enhance its sustainability. However, to ensure long-term sustainability, integrated pest management practices and responsible stewardship are crucial aspects of managing Bt cotton effectively.

Way Forward

Bt cotton in India involves addressing various aspects to ensure its sustainable and responsible use. Bt cotton has already been widely adopted and has had a significant impact on cotton production in the country. To maintain its effectiveness and optimize its benefits, continuous research and development are crucial. Developing newer varieties of Bt cotton that are effective against a broader range of pests and can adapt to changing environmental conditions will be essential. Additionally, providing farmers with proper training and education on the correct use of Bt cotton and sustainable farming practices is vital. This will help farmers make informed decisions and manage potential challenges effectively. Monitoring and regulation by agricultural authorities are necessary to prevent unauthorized or untested Bt cotton varieties from entering the market, ensuring the integrity and safety of its usage. Furthermore, addressing social and economic issues, such as farmer debt and distress, will contribute to the sustainable adoption of Bt cotton. Regular and thorough assessments of the environmental impact of Bt cotton cultivation are necessary to understand any long-term consequences on the ecosystem, biodiversity, and soil health. Engaging with various stakeholders, including farmers, scientists, policymakers, NGOs, and consumer groups, will foster dialogue and facilitate balanced solutions for the future of Bt cotton in India. By approaching these challenges with scientific rigor, environmental responsibility, and consideration for the well-being of farmers and consumers, India can continue to benefit from the advantages of Bt cotton sustainably.

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New Technologies and Approaches in Organic Cotton Breeding, Seed Production and Seed Quality Assurance

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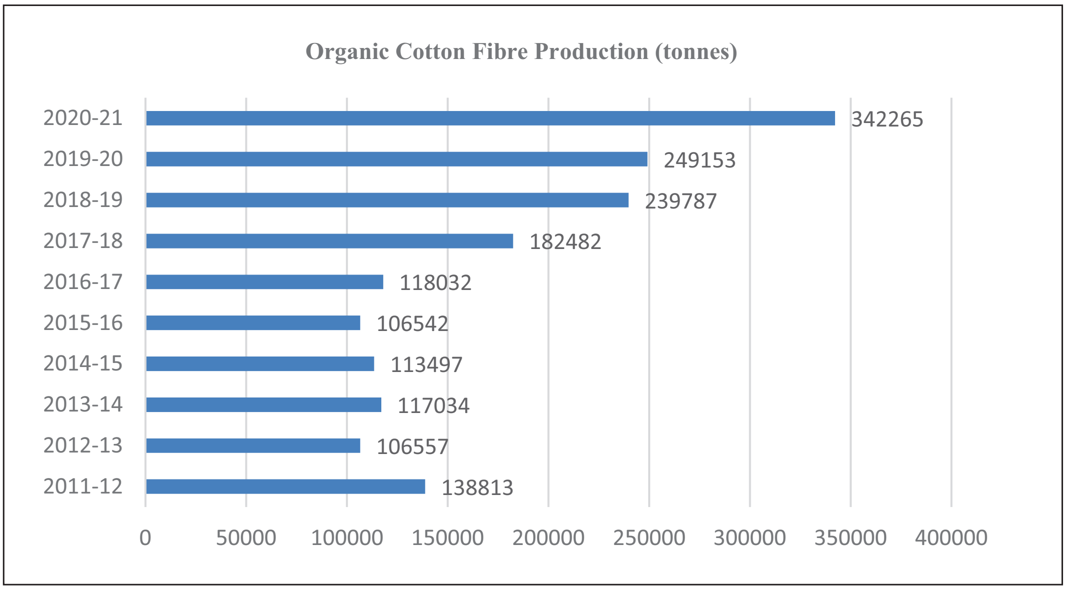
Organic cotton is a natural fibre that is grown without the use of synthetic fertilizers, pesticides and other harmful chemicals. An increase of 5.6% in production is recorded of organic cotton globally in the year 2020-21 from the year 2019-20. The total of 342,265 tonnes of organic cotton fibre produced on 621,691 hectares of certified organic land, compared to 249153 tonnes in the year 2019-20, with a contribution of 1.4% to the total cotton production of the world. Globally, 21 countries involved in organic cotton production. The 97% of global organic cotton was produced by just eight countries i.e., India (38%), Turkey (24%), China (10%), Kyrgyzstan (9%), Tanzania (6%), Kazakhstan (4%), Tajikistan (4%) and the US (2%). India is at top with the highest contribution of 38% in the world organic cotton production .



India is the largest producer of organic cotton in the world, with 130849 tonnes organic cotton fibre, produced on 230125 ha of certified organic land in 2020-21with on year growth rate of 5.3%. The trend of increasing consumer demand for this eco-friendly white gold is expected to grow as the area under in-conversion to organic in India and other major cotton producing countries.

The cultivation of Cotton was started in about 16th Century in India, at that time the use of chemical fertilizers, insecticide and fungicide has not been in existence and cotton grown organically with credible quality and yield. The use of chemical fertilizers, insecticide and fungicide has been spread to almost all the countries in between 1965-1975. After that the volume of chemical fertilizers, insecticide and fungicide used in cotton crop can be seen in increasing pattern.

Though the concept of organic cultivation came into existence in about 1990 in India but the re markable growth can be observed in last 10 years. The cultivation of organic cotton at B.M. College of Agriculture, Khandwa is started in 1912-13 and now 25-acre land is converted under organic cultivation.

About the cotton

Cotton is a long duration crop and takes 150 to 180 days to mature. It covers three seasons starting from end of the summer to start of winter season. The cotton is C3 plant belongs to family-Malvaceae and genus Gossypium. The genus Gossypium is the oldest group of cultivated plants and have been used as a textile raw material from at least 7000 years. There are more than 50 plant species under genus Gossypium out of them only four species are used to produce fibre.

1. *Gossypium hirsutum: It covers more than 90% of the world cotton production.*
2. *Gossypium barbadense: It covers about 3-4% of the world cotton production.*
3. *Gossypium arboreum: It covers about 1-2% of the world cotton production.*
4. *Gossypium herbaceum: It covers about 1-2% of the world cotton production.*

These species can be grouped in two groups.

1. Old world cotton : The diploid cotton (2n=2X=26) *Gossypium arboreum X G. herbaceum*
2. New World cotton : Allo-tetraploids Cotton (2n=4x=52) *G. hirsutum X G. barbadense*

All New World tetraploid cotton (AADD) contain Cytoplasm from *G. herbaceum* (AA) and *G. raimondii* (DD).

Major Objectives in Cotton Breeding :

- High fibre yield
- High number of bolls
- Early maturity
- Synchronous maturity
- Improved fibre quality

- Resistance to bollworm complex
- Improved Seed quality

Organic Breeding Programme:

- The recent challenges of ever-increasing cost of chemical inputs, labour scarcity have been pushing cotton cultivation towards unsustainability and marginalized profits.
- The current American cotton hybrid systems that predominate more than 95.0% of the cotton area in India do not fall in the category of sustainable approaches.
- These hybrids are expensive to cultivate; input intensive and run the constant risks of collapsing under high sensitivity to biotic and abiotic stresses.
- What is imminently needed for India is a vision-based policy to plan towards sustainable profits.

Desi cotton provides the answers for sustainability and it is true "that India's cotton future lies in Desi Cotton". Some facts in the history of Desi cotton in India

- At the time of Independence, India had 97.5% of its cotton area under Desi cotton.
- The area under Desi was 25% before Bt-cotton made its entry into India.
- By the year 2011, the area shrunk to less than 2.0%.

Now it is important to understand why Indian farmers preferred Desi cotton over times immemorial until the invasion by Bt-hybrids. There are Desi varieties of *Gossypium herbaceum* and *Gossypium arboreum* which can grow in any kind of conditions such as saline soils, sodic soils, desert soils, light soils etc.,under dry conditions. There are hardly any varieties of the American cotton species i.e., Gossypium hirsutum that can survive such conditions. Desi varieties are highly tolerant to drought, salinity, diseases and a range of insect pests including the bollworms. It is this resilience to tough biotic and abiotic conditions that makes Desi cotton species the right choice for sustainable farming.

Two aspects that could strengthen Desi cotton production are: -

- Improvement of fibre traits.
- The exploitation of the existing traits for specialized purposes such as absorbent cotton and ancillary uses, for which Desi cotton is the best and other species cannot serve the purpose."

It is important to point out that India needs to move towards sustainable cotton cropping systems which are much easier with Desi cotton. Cultivating Desi cotton varieties is easy with low production costs. These are highly tolerant to drought, insects and diseases and give high yields with low inputs.

Deshi Cotton Variety : RVJK-SGF-1

This variety has been developed in Center of Excellence on Organic Cotton, B.M. College of Agriculture, Khandwa under SGF project in the year 2022-23. It has been developed in organic condition by hybridization and pedigree selection, the most important feature in the development of this variety is to transfer the fibre quality traits from wild source. This variety having fibre length and strength comparable to hirsutum varieties. It is suitable for all cotton growing area in Madhya Pradesh.

Features of the variety :

- The first Non-GM Desi Cotton variety of India bred under organic conditions and responsive to organic inputs.
- First variety developed in the country exclusively for organic cotton cultivation.
- Medium height (107-126cm).
- Medium maturity (144 – 160 days).
- High yield (Seed Cotton yield: 9-13 q/ha (Rainfed), 15-18q/ha (Irrigated).
- The variety is as per the industry requirement having long fibre length (28.77mm) and high fibre strength (27.12 g/tex).
- Suitable for 16s to 34s count spinning to make a good quality fabric.
- Resistance to sucking pest and pink bollworm.
- Wider adaptability in the region.

RVJK-SGF-1 : Crop

Single plant at maturity

Open Boll

Single plant at growth stage

American Cotton Variety: RVJK-SGF-2

This variety has been developed in Center of Excellence on Organic Cotton, B.M. College of Agriculture, Khandwa under SGF project in the year 2022-23. It is first Non GM variety of American cotton bred under organic conditions and responsive to organic inputs. It is adopted for wide range of climatic conditions in Madhya Pradesh, Gujrat, Rajasthan and Odisha.

Features of the variety:

- Medium Height (96-110 cm).
- Medium Maturity (145-155 days).
- High Yielding (Seed Cotton Yield: 9-15q/ha (Rainfed), 18-20 q/ha (Irrigated).
- High ginning out turns (34.8 %).
- The variety is as per the industry requirement having long fibre length (29.87mm) and high strength (29.92 g/tex).
- Suitable for 20s to 50s count spinning to make a very good quality fabric.
- Mild resistance to sucking pest and pink bollworm.
- Wider adaptability in the region.

RVJK-SGF-2 : Crop

Cotton plant at flower initiation stage

RVJK-SGF-2: Single plant at maturity

Open bolls

G. arboreum Germplasm utilize in development of varieties

S No	Desi cotton Varieties	Type of Variety
1	KGA-1	Compact
2	KGA-2	compact
3	KGA-3	Early maturing
4	KGA-4	Early maturing
5	KHA-5	Big bolls (3.5g)
6	KGA-6	Big bolls (3.5g)
7	KGA-7	High yield
8	KGA-8	High yield
9	KGA-9	High yield
10	KGA-10	Long linted (28-30mm)
11	KGA-11	Long linted (28-30mm)
12	KGA-12	Long linted (28-30mm)

Cotton plant at flowering stage

Procuction Technology:

The organic cotton production is increasing fast in Madhya Pradesh. Out of 10 major cotton growing district of Madhya Pradesh, major area under organic cotton is in Khandwa, Khargone, Badwani and Dhar districts. The climatic conditions of these districts favour the cotton growth and their production.

For more production following agro-technology should be followed.

Soil and climate

Cotton crop required light to medium black soil with very good drainage system. It is also growing well in very light, light lateritic soil in undulated topography of Jhabua, Dhar, Malwa and Nimar region of Madhya Pradesh under good crop management. Cotton crop flourished well in average annual rain fall between 600-800 mm.

Suitable Varieties/Hybrids

Desi Cotton *(G. arboreum)* : RVJK-SGF-1, JK-5, Jawahar Tapti, PA-255, PA-08

American Cotton : RVJK-SGF-2, RVK-67, RVK-11, JK-4, Suraj

Field preparation: An Integrated approach

i) Deep ploughing just after harvesting of Rabi crop (s) in April- May.

ii) One-time cultivator and rotavator with pata in 1st or 2nd week of June.

iii) In case of summer crop field should be prepared by one cultivator with pata after harvest of summer crop (s) in 2nd week of June.

iv) Green manuring by *Dhencha* crop – Sowing in April-May and mixing in soil by deep ploughing in May last week/June first week

v) FYM: 30-35 t/ha, Vermi compost: 5-8t/ha and Neem cake: 2-3q/ha

vi) Trichoderma-5l/ ha PSB -5L/ha, Azotobacter – lL/ha and mycorrhiza – 5l/ha before sowing.

Seed treatment

With *Trichoderma* : i) Liquid : 5-8ml/Kg seed

ii) Powder : 6-8 g/Kg seed

Inter Culture Operation

1. Point application of PROM @ 2t/ha at the time of sowing
2. Weed management
   - a) Kolpa (a bullock drawn small plough) : 4 times starting from 20 days crop age at the interval of 15 days
   - b) Hand weeding : Two
3. Nutrient management:
   - a) PROM: Ring application at 15 days crop age (3t/ha), Pit application at 35days crop age(3T/ha)
   - b) Vermiwash: drenching at 35- and 45-days crop age@ 1500l/ha
   - c) Biofertilizer Mix: drenching at 25-and 40-days crop age @ 600l/ha
   - d) Zeevamurit: Spray and Drenching at 10,20,30,50,70 days crop age @1500l/ha

4. Plant Protection

i) Insect Control

a) Sucking pest (Jassids, aphids) :

- 4 Spray of cow urine at interval of 7 days @ 5L/15L of water up to the crop age of 30 days and 3 spray at interval of 10 days
- 3 spray of Neem Oil at interval of 15 days @ 100ml/15L water
- 2 spray of *Verticillium lecanii/Metarhizium anisopliae* 100 ml/15 l water
- Use of sticky traps

b) Boll worm :

- 4 spray of cow urine at interval of 7 days and 3 spray at interval of 10 days @ 10 l/15l water
- 3 spray of Neem Oil at interval of 15 days @100ml/15 L water
- 2 spray of consortia: Beauveria *bassiana* 10ml/15l water
- Use of light traps
- Use of Pheromone traps

ii) Diseases control

a) 2 Spray of Microbial consortia with Trichoderma @ 100ml/15 L of water

5. Irrigation

In case of timely sown crop (15th - 30th June) irrigation is not required for germination, only 2-3 irrigations required at 90-130 days crop. In case of early sowing, 2-3 irrigations are required in May-June and from September onward at interval of 25 days.

6. Picking : 2-3 picking

First picking is expected to come up to 130-140 DAS, pick cotton from fully opened bolls only, do not try to open semi opened bolls forcibly, if there are moisture in fibre then delay picking. The quality of cotton fibre maybe affected by picking at that time to a great extent, if it is too delay then it cause blackening of fibre and increase trace content. Second picking may be after 15-25 days of first picking.

7. Seed Cotton Yield :

1. Desi Cotton : 12-16 q/ha (Irrigated), 8-10 q/ha (Rainfed)
2. American Cotton: 18-22q/ha (Irrigated), 10-15 q/ha (Rainfed)

Organic Cotton Based Cropping System

The area of organic cotton is slowly growing up in Nimar and Malwa region of Madhya Pradesh. The following cropping system are followed in this area :-

1. Cotton: Wheat/Chickpea: Soybean/Pigeon pea
2. Cotton: Onion/Maize: Green gram/Black gram

Except these cropping systems, following two cropping systems are also followed by some progressive farmers in some district of Malwa -Nimar region

1. Cotton: Water melon/ Muskmelon: Maize/soybean
2. Cotton: Bitter guard: Maize/Onion

After harvesting of cotton in Nimar and Malwa region, farmers generally grow wheat and chickpea. At present, organic wheat and Chickpea are preferred by the consumer society due to unhealthy (conventional) food grown by the farmers. Wheat and chickpea crops are the main component of Indian meal.

Diversification / Inter Cropping Systems

Inter cropping is not common in Nimar valley, but it is being practiced in Malwa region. However following combination is recommended by research station.

1. Cotton : Maize (4 : 2) : Onion (5 Row)
2. Cotton : Pigeonpea (6:1)

3. Cotton : Soybean (1: 4) : Onion (5 Row)
4. Cotton : Minor millet (2:8) : Onion (5 row)
5. Cotton : Cowpea :: 1 : 1
6. Cotton : Bitter guard :: 2:1

Future prospect of organic cotton in India

The current production of organic cotton in India is 1.40 million tonnes. Madhya Pradesh and Odisha are the leading states showing high growth rate followed by Maharashtra, Gujarat and Rajasthan. In the last five years, these states have produced 99% of the total cotton production in India. Another indication of bright prospects is that the Indian Council of Agricultural Research with associated bodies have released 64 non-GM cotton varieties and hybrids from 2017 to 2021. Organic cotton growers can adopt these varieties. More than 6.5 million cotton farmers are directly cultivating the crop. There are approximately 10.5 million workers in allied sectors.

Rising production and increasing growth, mark the outlook for organic cotton in India. Stricter norms for organic cotton cultivation and processing have instilled renewed confidence in quality. Many organizations and industry experts are helping to streamline the supply chain. These activities will create favourable conditions for buyers and suppliers to promote the industry. A body called the Organic Cotton Accelerator is boosting farmer prosperity and creating a transparent and responsible supply chain. Environmentally-friendly production systems drive best practices across the entire textile industry. Organic cotton has the potential to transform farming communities, improve livelihoods and reduce climate change. It minimizes pollution and poverty and will be, better for people and the planet.

Cotton Leaf Curl Disease and Whitefly: Unravelling the Virus-Vector Relationship

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Introduction

Cotton (*Gossypium* sp.) is the world's most valuable cash crop, fibre producer and oil seed crop. Cotton leaf curl virus disease (CLCuD) is one of the primary limiting factors accountable for its low production and productivity over the last one and a half decade. The sickness is caused by the Gemini virus, which is spread by whiteflies. Whiteflies (*Bemisia tabaci*) are well-known agricultural pests that serve as vectors for a variety of viral infections, including those that harm cotton plants. A little whitefly (Hemiptera: Aleyrodidae) is a major cotton sucking pest. It is a very polyphagous pest that has been observed to feed on over 900 distinct hosts (Byrne and Bellows, 1991) and causes both direct and indirect damage. In the 1990s, the most serious danger to cotton was the Lepidoptera insect, specifically the American bollworm and mealy bug. Whitefly replaced bollworms as a major threat to cotton output at the beginning of the twenty-first century. If not regulated, it can lead to crop failure.

As vectors, whiteflies transmit viruses from infected plants to healthy ones as they feed on plant sap. This can lead to the rapid spread of viral diseases, causing significant damage to cotton crops and impacting yields. The main viral diseases of cotton that are transmitted by whiteflies include:

1. Cotton leaf curl virus (CLCuV)
2. Cotton leaf crumple virus (CLCrV)
3. Cotton leaf mottle virus (CLMoV)
4. Cotton yellow vein virus (CYVV)

Cotton leaf curl virus (CLCuV)

Farquharson (1912) made initial observation of the disease, caused by a whitefly-transmitted Gemini virus, in *Gossypium peruvianum* and *Gossypium vitifolia* in Nigeria. This disease, known as Cotton Leaf Curl Virus Disease (CLCuD), later emerged in India on American cotton (*Gossypium hirsutum*) in the Sriganganagar area of Rajasthan state in 1993, as reported by Ajmera (1994). By 1994, it had further spread to Haryana and Punjab states, posing a significant threat to cotton cultivation in northern India (Rishi & Chauhan, 1994 and Nawaz *et al.*, 2019).

The causative agents of CLCuD are classified as *Begomoviruses*. Notably, prominent strains responsible for inflicting massive production losses include Cotton Leaf Curl Burewala virus (CLCuBuV), Cotton Leaf Curl Multan virus (CLCuMuV), and Cotton Leaf Curl Kokhran virus (CLCuKoV) (Hina *et al.*, 2012). CLCuD is characterized by a bipartite genome consisting of two smaller, circular, single-stranded DNA molecules named DNA 1 and DNA β. These molecules belong to the category of satellite molecules because they rely on a helper Begomovirus for certain stages of their infection cycle, such as movement and insect transmission for both molecules, and replication in the case of DNA (Afzal *et al.*, 2023). A noteworthy feature of DNA is its ability to modulate symptoms, and typical symptoms of cotton leaf curl disease appear only when this molecule is present. In the absence of

DNA, viral DNA (DNA A) concentrations are low, leading to moderate symptoms of infection (Afzal *et al.*, 2023).

Taxonomic Tree

Kingdom - Shotokuvirae
Phylum - Cressdnaviricota
Class - Repensiviricetes
Order - Geplafuvirales
Group - ssDNA
Family - Geminiviridae
Genus - Begomovirus
Species - CLCuV

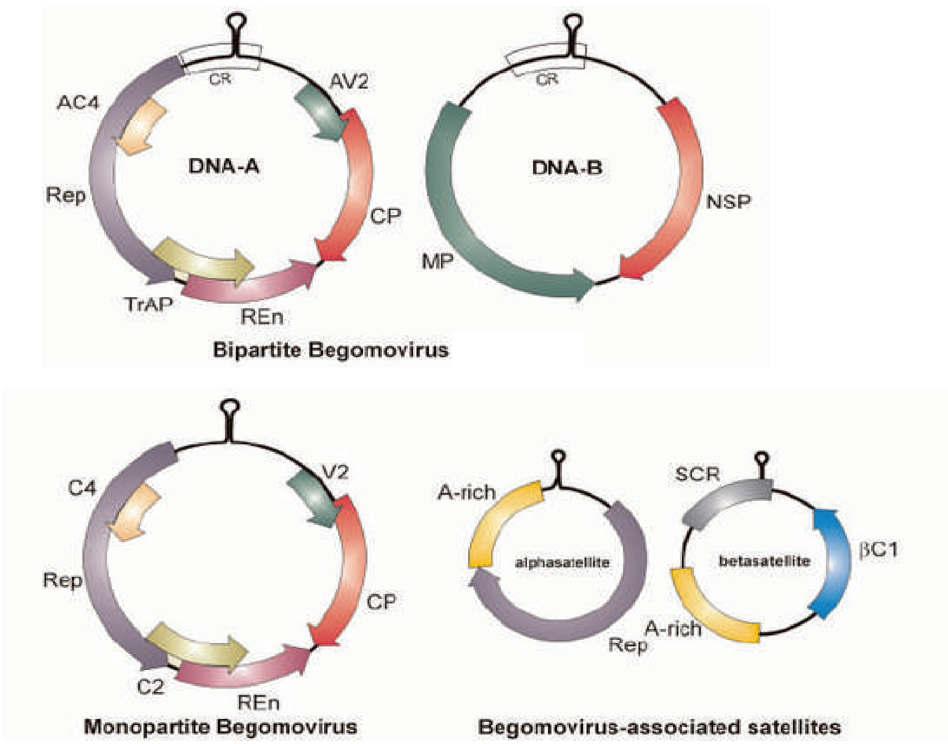

Fig. 1 Bipartite (consist of two genomes DNA-A and DNA-B) and monopartite (consist single genome with associated satellite) begomoviruses

Early CLCuD infection causes larger output losses, resulting in a 14.9 to 87.4% reduction in harvestable bolls and a 38.8% loss in boll weight. It lowers seed cotton yield by 10.5% when restricted to apical leaves only, 58.1% while infecting the upper plant canopy, and 68.7% when infecting both the upper and lower plant canopies (Singh *et al.*, 1999).

Role of Whitefly as CLCuD vector

In 1930, Golding identified the vector responsible for transmitting the disease and termed it the "whitefly," belonging to the *Bemisia* species. A year later, in 1931, *B. tabaci* was specifically identified as the whitefly species responsible for transmitting the disease (Kirkpatrick, 1931). *B. tabaci* is a genetically diverse species that not only acts as a virus carrier but also hampers cotton plant growth through direct feeding. Over time, researchers have discovered at least 24 biotypes of the *B. tabaci* complex through the analysis of molecular and biological characteristics. These various biotypes and their variants are frequently found together as mixed populations in the natural environment (Rahman *et al.*, 2017).

Nature of damage

Whitefly takes the sap from cotton leaves and produces a lot of honeydew. The sap is the nutritious liquid that flows through the plant's phloem and gives nutrients to the leaf for photosynthetic activities. When the whitefly begins to consume the sap, a scarcity of critical nutrients is noted, resulting in a reduction in the amount of photosynthetic chemicals synthesized. Cotton leaves turn yellow as photosynthesis decreases, develops, and falls off the plant prematurely. With a strong infestation, branches might typically die. Small plant mortality is common, while plant death caused by whitefly attack is rare. Whitefly causes the plant to become weaker and less productive.

Economic Threshold Levels (ETL) for whiteflies are defined as if there are 6 or more adults per leaf in the upper canopy of plants, or if more than 10 whiteflies are found in the middle region of the plant in more than 50% (two out of four) of the plants.

Regarding the sources of CLCuV inoculum, it has been confirmed that Okra (*Abelmoscus esculantus*) and the weeds *Sida sp., Abutilon indicum, Xanthium strumarium* serve as sources of CLCuV inoculum. Additionally, CLCuV has been successfully inoculated in *D. metel* and tomato (*Lycopersicum esculantum*) plants using whitefly as vector, resulting in the development of CLCuV symptoms.

Leaf curl disease symptoms and effects in cotton

- Cotton Leaf Curl Disease (CLCuD) can lead to various symptoms depending on the severity of the infection (Fig. 2). Typical signs of the disease include the thickening and yellowing of small veins on the undersides of young leaves.
- In more severe cases, the leaves may exhibit downward or upward curling, resulting in reduced plant growth due to a decrease in inter-nodal space. Additionally, the disease's severity can lead to the formation of cup-shaped outgrowths called Enation on the undersides of the curled leaves.
- At the seedling stage, the presence of CLCuD significantly delays blooming, boll formation, maturation, seed cotton yield, and fibre quality, as highlighted by Farooq *et al*. (2011).

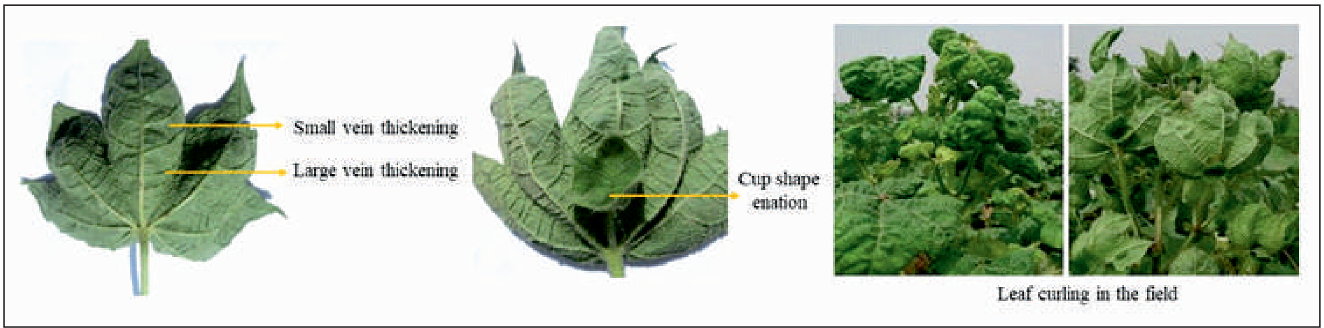

Fig. 2 Symptoms in cotton leaves and plants affected with CLCuD

Management of whiteflies

We cannot control whitefly with a single control technique effectively. Integrated pest management is very important for management of whitefly. We need to use all the techniques in combination at a right time to control whitefly effectively.

1. Monitoring of whiteflies

Monitoring is the primary tool for controlling it. It is the first and most basic step in controlling whitefly. Regularly or weekly (depending on the infestation), monitor the population of adults and nymphs in the field. After 50 to 60 DAS, whitefly monitoring should be done on a regular basis, or twice a week (Sattar *et al*., 2013).

2. Resistant plant material

The Indian upland cotton varieties LRK 516, LK 861, CSH 15, CSH 19, H 1156, CNH 154, CNH 1018, HH 62, HH 70, HH 75, HH 76 and *G. hirsutum* cotton hybrids LHH 144, Kasturi 2, Kasturi 18 remained free from CLCuV symptoms. Upland varieties H-1180, HS-90-80, LRA 5166, RS 875, RS 2013, CSH 10, CSH 11, CSH 20, Kanchana exhibited 20 to 43 per cent infection with mild CLCuD symptoms.

3. Cultural control

To effectively combat the spread of CLCuD, implementing a series of proactive measures is crucial. Firstly, reducing or eliminating alternative host plants before sowing cotton can break the cycle of disease inoculum availability. Additionally, uprooting and destroying infected cotton plants over a wide area should be seriously considered to limit the disease's spread. To create an environment less conducive to whitefly infestations, maintaining optimal plant-to-plant spacing of 60-75 cm and row-to-row spacing of 67.5 cm is essential, ensuring the crop is not overcrowded. Furthermore, avoiding intercropping cotton with susceptible plants like chilli or okra, which attract whiteflies, is advisable. Controlling and eliminating weeds from both the field and its surroundings is essential since weeds can act as hosts for whiteflies. Finally, minimizing the use of nitrogenous fertilizers, such as urea, can help reduce whitefly populations (Monga *et al*., 2011). By employing this comprehensive approach, farmers can better protect their cotton crops from the devastating effects of CLCuD and promote healthier, more resilient yields.

4. Chemical control

Another method of controlling the illness is to treat the seeds with systemic insecticides in the early stages. Seed treatment with chemicals like imidacloprid 600 FS, thiamethoxam 70 WS, carbosulfan 25 DS, and imidacloprid 70 WS has been found to effectively reduce whitefly populations. Opting for biopesticide-based insecticides during the early part of the season is also a viable option for managing the vector as they pose less harm to natural enemies. To minimize vector populations in later stages, a judicious application of triazophos @ 1500ml/ha (AICCIP 2009) and Ethion @ 2000ml/ha can be employed. In a study conducted by Ali *et al*. (2005), it was found that buprofezin was effective against nymphs, while acetamiprid, diafenthiuron, and imidacloprid were effective against adult whiteflies. However, it is crucial to avoid the use of synthetic pyrethroid pesticides when combating whiteflies. Neonicotinoid pesticides like thiamethoxam and imidacloprid should also be avoided. It is advisable not to use commercially marketed insecticidal mixes and mixing insecticides in tanks should be avoided as well. Before combining insecticides, always check to ensure that their tank mix is compatible.

5. Recent advances to combat CLCuV through biotechnological tools

Biotechnology and genetic diversity offer a valuable source in the fight against CLCuV. Some cotton varieties display greater resistance to CLCuV, making them suitable candidates for studying allelic variation. This information can then be used to design novel and efficient gene combinations. The progress in biotechnological tools has simplified the process of combating CLCuV through virus cloning.

Molecular markers also play a vital role in fighting this viral disease, and gene mapping using these markers can be easily accomplished. *Gossypium arboreum* has been utilized for isolating resistance genes, which can then be altered to induce susceptibility against CLCuV through the application of genetic engineering and other biotechnological techniques (Farooq *et al*., 2011).

Furthermore, transgenic approaches have been explored in multiple endeavors to develop resistance against the causative agents of CLCuD. Genetic engineering plays a crucial role in these efforts. Such approaches to disease control involve using conserved portions of genomes from similar species (pathogen-derived resistance) or genes sourced from distantly related hosts or non-host genetic sources to establish disease resistance (non-pathogen-derived resistance).

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Breeding challenges for the development of new varieties/hybrids in Cotton

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Introduction:

Cotton is one of the most important fibre and cash crop of India and it plays a dominant role in the industrial and agricultural economy of the country. It provides the basic raw material (cotton fibre) to the cotton textile industry. There are four cultivated species of cotton *viz. Gossypium arboreum, G. herbaceum*, *G. hirsutum* and *G. barbadense*. The first two species are diploid (2n=26) and are native to the old world. They are also known as Asiatic cotton because they are grown in Asia. The last two species are tetraploid (2n=52) and are also referred to as New World Cottons. *G. hirsutum* is also known as American cotton or upland cotton and *G. barbadense* as Egyptian cotton or Sea Island cotton or Peruvian Cotton or Tanguish Cotton or quality cotton. Perhaps, India is the only country in the world where all four cultivated species are grown on a commercial scale. *G. hirsutum* (Upland cotton) is grown in more than 80 countries and produces 97% of world cotton due to its high yield and wide adaptation. Upon introduction of transgenic Bt cotton in the world most of the *G. hirsutum* cultivars is converted into bollworm resistant Bt cotton. India adopted hybrids Bt cultivars and the rest of the world adopted varietal cultivars. According to the studies, Bt cotton can dramatically lower bollworm attacks, cultivation costs, and boost crop output compared to non-Bt cotton (Mayee *et al*. 2002). The introduction of Bt cotton has made an efficient replacement for conventional cotton varieties by reducing bollworm attacks and boosting production and revenue.

Changed paradigm shift in Breeding Post Bt cotton era

The cotton breeding objectives changed soon after the introduction of Bt cotton first and second generations. Development of bollworm tolerant hybrids completely stopped as Bt cotton was resistant to bollworms. Focus started on solving sucking pest tolerance. A hairy bollworm-tolerant hybrid was not possible because of the negative linkage of bollworm tolerance with hairiness. The backcross method of breeding took centre stage and the molecular marker approach percolated into breeding programs. The exploitation of forward breeding methods got into the system. The use of ELISA and Zygosity tests were tools to confirm genes. Today all these are the routine of cotton breeding. Selections for the high boll number became a priority. The germplasm usage got shrunken due to more non-Bt lines and conversion of only selected restricted the working germplasm collections. This has led to reduced usable diversity in cotton as a large chunk of non-Bt lines are kept out of the main improvement programs. This is also one of the reason for the stagnation of the yield levels in India.

India is currently facing a hurdle as the pink bollworm has just broken out and begun causing serious economic harm to cotton. The only answer to this problem can come from transgenic or gene-edited approaches as there is no hope for conventional breeding.

Agroecology and Agronomic conditions versus Breeding

Cotton is cultivated in both irrigated and rainfed conditions and also in diverse agronomic conditions. There is very less utilization of selection environments for cotton improvement during the process of cotton breeding. However, these environments are utilized very well in the testing of hybrids. The variations like soil type, plant spacings, irrigations and thermos regimes. Due to these variations, there are dynamics of pest and disease situations also change. One of the reasons for the stagnation of yield in India is releasing hybrids for wide ecologies where hybrid performance varies erratically. With the introduction of Bt cotton, the cotton made inroads in sandy loam soils of Gujarat and Rajasthan and these selection environments during breeding are not utilized yet.

An emerging scenario in India is High Density Planting (HDP) systems to enhance the yields and there are plant types that are suited to these conditions but the introgression of such plant types with the Bt gene is very important. With HDP systems the farmers have to plant significantly more seeds, almost three times. In that case, hybrids or varieties will be a prominent question to be answered. With the HDP system increasingly adopted in India, then the challenges in crop improvement would be different.

This necessitates precision breeding for the right ecology and right environment which might lead to localized selections. For precision breeding, a varietal form of cultivar would become the best tool rather than hybrids.

Noises Negative Linkages in Cotton Breeding

There are negative linkages such as boll number and boll size, fibre length and ginning percentages, hairiness and white fly tolerance still play as hindrances in yield improvement and resistance breeding in cotton (Kumar *et al*., 2017). The famous negative linkage of hairiness and bollworm tolerance was broken by the introduction of Bt cotton. New tools like transgenics and Gene Editing should provide opportunities to break linkage barriers.

Wild Species utilization in cotton Breeding

About 50 species of the cotton genus (*Gossypium*) are found in Africa, Australia, Central and South America, the Galapagos Islands, Hawaii, the Indian subcontinent, and Arabia. These species include five allotetraploids. Upland cotton and Sea Island cotton are the primary sources of textile fibre in the globe. Based on meiotic chromosomal pairing behaviour, diploid *Gossypium* species split into several genomes labelled A-G and K (Wendel and Cronn, 2003). The hybridization of “D-genome” diploid species *G. raimondii* Ulbrich and G. *gossipioides* L. (2n = 2x = 26) with “A-genome” diploid species *G. herbaceum* and *G. arboreum* (2n = 2x = 26) produced the new global tetraploid species about 1-2 million years ago (Wendel and Cronn, 2003). Currently, a variety of *Gossypium* germplasm from around the world's national germplasm banks is being preserved. This germplasm includes wild species, races and seed stocks. There are between 53,000 and 63,946 world cotton accessions conserved in the major cotton-growing nations, according to the World Cotton Germplasm Resources inventory (Abdurakhmonov, 2014). Cotton breeders can use the rich diversity of wild and domesticated cotton species as a significant resource to speed up the selection of characteristics with key agronomic functions. Even though transferring advantageous features from wild diploid species into domesticated tetraploid cotton is a difficult endeavour, numerous researchers have had success in creating interspecific hybrids involving the genotypes of the donor and recipient. These interspecific hybrids have been developed through bridge crosses or other means, including finding genetic recombinants between donor and recipient genotype chromosomes using cytogenetics and other techniques.

Bacterial blight, caused by *Xanthomonas axonopodis pv. malvacearum*, is a key disease in many parts of the world. *Gossypium* taxa harbouring A-genome were shown to possess near-immunity for this pathogen and, therefore, these sources are valuable for introgression into cultivated tetraploids. The bacterial blight resistance gene, *B6*, found in *G. arboreum* was successfully transferred into *G. barbadense* (Zafar *et al*., 2009). Cotton leaf curl virus (CLCuV) is the widespread and most damaging disease in northern India and is capable of causing yield loss of up to 90%. Since none of the existing *G. hirsutum* varieties has recorded resistance to CLCuV, wild relatives have been explored. *G. arboreum*, was used as a donor of CLCuV resistance to transfer it to *G. hirsutum* using conventional hybridization and backcrossing. In another effort, resistance to CLCuV from *G. stocksii* was successfully introgressed into "MNH-786," a *G. hirsutum* cultivar, through interspecific hybridization (Mammadov *et al.* 2018).

G. tomentosum, a wild cotton species, is host to many unique agronomic traits, including drought tolerance, salt tolerance, heat tolerance, nectarilessness, insect-pest resistance and lint colour. *G. darwinii*, another wild allotetraploid species, with AD_5 genome has many useful traits, including drought tolerance, fibre fineness, Fusarium wilt, and Verticillium wilt resistance (Liu, *et al*., 2015).

Contemporary cotton breeding objectives

Higher yields

With the Breeding of Bt cotton cultivars, there are a set of objectives that are to be looked into from different angles. Earlier Cotton was considered a Source rich crop, but now with Bt cotton, it is no longer so. There is a need for more amount of sources to set more bolls in the varieties which can increase the yields. This source build-up has to be done in a fixed window of the crop. This necessitates morpho physiological selections for high relative growth rates. This will help in increasing the yield.

Better fibre quality

In India, the majority of farmers grow upland cotton which is in turn a medium staple (26 to 28 mm) and easy for harvesting. Whereas ELS cotton (32-36 mm) is specific to geography and not entertained by farmers due to its shy yielding. However, there is a great amount of demand for ELS cotton in the textile industry. But in India, of the nearly 33 million bales produced in the 2022-23 season. In India, the domestic consumption is around 31 million bales, ELS cotton accounts for just around 1 million. But here too the domestic production of ELS cotton, according to industry players, is 350,000-400,000 bales. This means 600,000 bales need to be imported annually. This shows the gap in our textile to raw material and we are importing ELS cotton from USA with more cost.

There is a need for long and extra-long staple cotton, the demand for this cotton is high as middle-class income groups of the world wish to have better clothing requirements. *G barbadense* is the source for such a staple length. However, this species of cotton is not possible to cultivate in wide ecologies due to their susceptibility to sucking pests. The options to produce longer and more extra-long staple cotton is to develop barbadense suitable for cultivation in wide ecologies or increase the fibre length in *hirstutm* cotton either conventionally or with the aid of biotechnologically.

Biotic stress resistance

Numerous pests are attracted to cotton, and morphological and biochemical features such as hairiness, okra leaf shape, nectariless, and polyphenol chemicals that may impart broad-spectrum insect tolerance can be used to improve host tolerance (Indrayani and Sumartini, 2012). Breeding for sucking pests is a challenging part as whitefly tolerance comes from glabrous leaves, but the same will be susceptible to jassids and thrips. These create a time lag for the development of new varieties. In addition to this, there are no genetic sources identified for pests like Mealy Bug or pink bollworm which need different strategies (Mammadov *et al.* 2018).

Wilts are more prevalent in cotton ecologies and the best way to find a solution to these is through gene editing followed by breeding. Most recently, through a genome-wide association study (GWAS) on 290 Chinese cotton accessions followed with a CRISPR/Cas9- mediated knockout, Gh_D03G0209 (named GhGLR4.8) on D03 encoding a GLUTAMATE RECEPTOR-LIKE (GLR) protein was identified as the candidate gene for the resistance gene Fov7 (Liu *et al.*, 2021) confer resistance to *Fusarium oxysporum* race 7 in the Upland cotton.

Abiotic stresses

In India, 65% of the cotton area is under rainfed conditions which range from 450 mm to 1200 mm of rainfall. This poses a challenge coupled with diverse soil types for rainfed reasons. Breeding tolerance either to moisture stress or flooding, plays an important role in yield improvement. The only way to bring yield improvement in these ecologies is to classify them with soil and rainfall situations and create four to five selection environments and screen germplasm to identify the best homeostasis lines that can ensure better average yields in wide environments. Another option is to increase the localised selection and make adaptability tests to release under these conditions (Anandan, 2010). In addition to conventional breeding, biotechnological interventions such as molecular markers or gene editing might help in creating elite genetic pools. A temperature increase of 2-3°C above the ideal can reduce biomass and yield while increasing fibre micronaire (Majeed *et al*. 2021). The quantity and quality of cotton fibre are also affected negatively by salinity and drought.

Challenges in seed production

Breeders biggest problem is to develop hybrids, but producing high-yielding parents, also play crucial role to meet supply chain demands. Seasonal issues and labour issues are the main issues that the production sector is experiencing. The key to solving the issue is obtaining male sterility. Nevertheless, obtaining appropriate male sterility is difficult. The industry relies on the Genetic Male Sterility (GMS) system to remain competitive. However, when it comes to breeding, various features, such as Bt genes and male sterility, are stacked together, making it take a while for the product to reach the market.

Developing and commercializing Bt cotton varieties involves complying with strict regulatory guidelines and safety assessments. The regulatory process for genetically modified organisms (GMOs) can be time-consuming and costly. Breeders must navigate through the regulatory framework to gain approval for the release and cultivation of Bt cotton varieties, adding complexity to the breeding process.

Use of speed breeding technique in cotton

Since cotton is a long-duration crop, it is exceedingly challenging for breeders to advance the material to suit consumer demand. Its biggest detriment for breeders is that it takes 140 to 180 days to complete the life cycle. Therefore, generation advancement is crucial for completing the life cycle as quickly as feasible. The process of “speed breeding” involves influencing many variables to hasten plant growth and development. Speed breeding can be employed on other plants, such as cotton, though it has mostly been utilized on cereal crops like wheat and barley.

Speed breeding can be used in cotton to speed up the breeding process and create new cotton varieties more quickly by using light, temperature and plant hormones. Some private firms are working on speed breeding in India.

Conclusion

Upon the introduction of Bt cotton, the usable diversity has been reduced to a significant extent which can only be diversified through Public-Private sector participation as public-sector hold germplasm of high importance. Extra Long staples are to be made prioritized and improve the overall textile performance. Pink bollworm has been damaging economically which can only be solved through transgenic and gene editing mode of strategies. Whiteflies and thrips are also damaging the crop where sustainable resistant lines development is essential which needs additional genetic resources. Wide hybridization, pre-breeding and line development need a partnership with the public sector. Yield stagnation in India will continue to be there for the next five years and elevating the yields can be possible first through agronomic manipulations and development of hybrids/varieties suited to new agronomic practices.

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Challenges in Cotton Seed Production and The Way Forward to Meet Farmers' Demand

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Cotton is a major fibre crop of global significance. It is grown in tropical and sub-tropical regions of more than 80 countries. India and China are the two largest seed cotton producers countries. Cotton seed production is a critical aspect of the cotton industry and ensuring an adequate supply of quality seeds to meet farmers demands and sustainable cotton cultivation. However, there are several challenges that the industry faces in Hybrid Cotton seed production. Here are some of the key challenges and potential ways forward:

High Cost of Cultivation

The cultivation of hybrids is input intensive and pollinations depends on manual labour. 60% of the cost incurred by the seed producing farmer is by employment of manual labour for the pollinations. The high cost of cultivation cannot be offered by small and marginal farmers due to high input cost and pollination charges. The high cost of cultivation act as barriers in the expansion of area under hybrid cotton.

High Risk of Cotton Seed Production

Farmers must invest more than 1 lakh Rs. per acre towards cultivation of hybrid cotton seed production. At times due to untimely rainfall & poor quality of pollination work by the labourer quality of seed get deteriorated and the farmers do not get their remuneration for their seed. Such farmers incur heavy losses hence farmers step back to take up hybrid cotton seed production.

Non Availability of the Skilled labour

There is scarcity of skilled labour in the hybrid cotton seed production, labours from other location use to migrate to the cotton seed production areas for pollination work during the crop season. Childrens of below 15 years age used to come with the migrated family to work in the cotton seed production. After the government strict regulations as use of child labours, migrated labours stopped migrating for this kind of work hence farmers have to shift the crop from cotton seed production to other commercial crops. Recent example of Banas kantha, Gujarat where big farmers use migrating labours most of them are child labours, because of strict regulation as per child labour act 1986 employment of children are prohibited in the Hybrid cotton seed production work there by acute shortage of skilled labour for this purpose.

Constraints in Seed Production

Hybrid cotton seed production is highly labour intensive as emasculation & pollination is done manually by labours. Rainfall during the pollination period will impact both quality and quantity of seed, which ultimately increasing the cost due to increasing in the pollination period. GMS lines have replaced to some extent to mitigate the risk of employing more no of labour for crossing work. However, performance of GMS hybrids in the commercial cultivation are not superior over conventional hybrids. Below are the major constraints of hybrid cotton seed production:

1. A large number of varieties/hybrids are grown creating problems in the production of adequate quantities of good quality seeds. The multiple varietal scenario, also complicates the insect pest problems.
2. Regular occurrence of cyclones in October-November in the coastal AP belt resulting in adverse abiotic stress.
3. Excessive use of nitrogen fertilizers leading to heavy pest incidence in certain pockets.
4. Acute labour shortage in certain productive irrigated areas.
5. Soils are sandy loams, with low water holding capacity, thus inadequacy of stored moisture profile results in poor yields of rain fed cotton.
6. Excessive and indiscriminate use of pesticides has resulted in the development of a high level of resistance to insecticides by pests, leading to resurgence, increased expenditure, low productivity and frequent crop loss.
7. Non-availability of suitable cultivars for rice fallows in coastal Andhra Pradesh.
8. Leaf reddening.

Economics

Farmers to meet their high cost of cultivation borrow money from local money lenders which attract high interest cost resulting in decrease in their profit margins. Banks should fund the hybrid seed production farmers in the form of loan with low interest rates which can prevent them to go the money landers, by this way farmers can get additional profit margins by 10 to 15 thousand Rupees per acre due to lowering the interest rates and by eliminating middle men in the system.

Since there is price cap on sale of cotton seed, seed companies are unable to pay attractive procurement price to the farmers or incentives to encourage good quality cotton seed production.

Pest and Disease Management

Cotton plants are susceptible to various pests and diseases that can significantly impact seed quality and yield. To address this challenge, need to breed varieties which are resistant to biotic & abiotic stress and also promoting integrated pest management practices are essential (pink boll worm). This can reduce the reliance on chemical pesticides and ensure healthier seed production.

Climate Change

Changes in climate patterns, including extreme weather events and temperature fluctuations, can affect Cotton crops and seed production. Investing in climate-resilient cotton varieties and sustainable agricultural practices can help mitigate the impact of climate change on seed production.

Genetic Diversity

Maintaining genetic diversity in Cotton seed production is crucial to prevent the vulnerability of the crop to emerging pests, diseases, and environmental stresses. Implementing seed banks and promoting the cultivation of traditional Cotton varieties can contribute to preserving genetic diversity.

Quality Control

Ensuring high-quality seeds that are free from contamination and diseases is vital for successful Cotton cultivation. Strict field quality control measures throughout the seed production process, including proper seed storage and handling, are necessary to meet farmers' demands for reliable seeds.

Seed Availability and Timely Distribution

Timely availability of quality seeds is crucial for commercial farmers to plan their planting schedules effectively. Improving seed distribution networks, involving private seed companies, and encouraging public-private partnerships can help ensure timely seed availability.

Awareness and Training

Farmers need to be educated about the importance of producing quality seeds by adopting best practices from sowing to harvesting & ginning. Training programs and extension services can play a crucial role in enhancing farmers' knowledge and skills.

Seed Technology and Research

Continued investment in research and development for seed technology, including biotechnology and genetic engineering, can lead to the development of more resilient and productive Cotton varieties. However, it is essential to address potential concerns related to environmental impacts and farmers' rights when implementing new seed technologies.

Policy Support

Supportive policies from governments can incentivize private sector involvement in Cotton seed production, encourage research and development, and promote sustainable practices. Policy measures may include tax incentives, research grants, and regulations that foster responsible seed production.

Way Forward

In conclusion, meeting farmers' demand for Cotton seeds requires a multifaceted approach that addresses challenges across the entire seed production value chain. By implementing sustainable and innovative solutions, supporting research and development, solution for Seed grower concerns and involving stakeholders at all levels, the Cotton industry can enhance seed production and contribute to the growth and prosperity of farmers globally. Below are the suggestions for the way forward:

1. Popularization of integrated pest management strategies.
2. Delineation of areas for the cultivation of specific varieties and hybrids and restricting the number of varieties grown in a region.
3. Development of varieties suitable for double cropping system on rice fallows
4. Soil moisture conservation measures particularly for rain fed regions of Karnataka, Gujarat, Maharashtra, Telangana, Andhra Pradesh, Haryana & Punjab.
5. Development of suitable chemical weed management technology and selective mechanization for irrigated high productive areas.
6. Site specific productive and compatible intercropping systems, particularly in irrigated areas.

Suggestions for national approach to sustain the pre-eminent position of cotton in the country's economy and enhance profitability of cotton cultivation, total revamping on the policy front is required to meet the ensuing competition where price, phytosanitary standards, honouring the commitment, timely delivery and quick adjustment to the changing economic order are going to be the chief determinants of a country's standing in the international commodity trade. In relaxing the constraints and enhancing the cotton yield, suggested and identified remedies at research, development and institutional levels are:

1 Popularization of seed villages, varietal zomng and agropharmacy concepts.

2. Prevention of proliferation of genotypes and making available quality seeds.
3. Delineation of areas for different cotton species, varieties and hybrids for higher productivity.
4. Evolving shallow soil specific genotypes and production technologies. Micro irrigation has to be introduced through cheaper institutional credit.
5. Community wells for irrigation supplemented by seed villages atleast in case of varieties, will provide cheap and quality seed supply in the proximity with one variety villages.
6. Provision of community bore wells for irrigation wherever watershed development is not possible.
7. Developing and adopting appropriate soil and water conservation measures in central zone and cropping system based fertilizer/integrated management.

8. Mass campaigning of IPM through Biological control/Bio-labs at district level.
9. Compulsory comprehensive insurance delinked from credit (in selected cotton districts).
10. Organizing integrated cotton production and processing cooperatives for value addition at farm level.
11. Restructuring pesticide delivery system/district pesticide inventory scheduling and introducing agro-pharmacy.
12. Waste lands in vastness, can be let in long term lease for 'corporate farming' for individual mills or federation/association so that one variety uniform quality lint can be produced in larger tracts where individual farmers cannot venture.

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