



Vision 2050



Central Institute for Cotton Research
Indian Council of Agricultural Research





Vision
2050



Central Institute for Cotton Research
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संदेश



भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो-तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट-परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान-जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन-2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से क्रिया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

राम मोहन सिंह

(राधा मोहन सिंह)

केन्द्रीय कृषि मंत्री, भारत सरकार

Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national programmes on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pest and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario.

Vision-2050 document of ICAR-Central Institute for Cotton Research (CICR), Nagpur has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.



(S. AYYAPPAN)

Secretary, Department of Agricultural Research & Education (DARE)
and Director-General, Indian Council of Agricultural Research (ICAR)
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Preface

Vision documents help us to prepare for tomorrow. They can hold light to the unfathomable and infinite realm called future. In short, they prepare us for a rainy day. The current document 'ICAR-CICR Cotton Vision 2050' is a collage of ideas that criss-cross each other but essentially define a path towards sustainable cotton farming to circumvent the enormous challenge of ever-increasing chemical dependence. The challenges are many. Over the past 10 years between 2003 and 2014, the cost of cotton cultivation in India increased three-fold, whereas the minimum support price only doubled. The cost on human labour increased four-fold during the decade, seed costs increased four-fold, fertilizer usage increased 2.5-fold and insecticide usage doubled over the past five years itself. We need to find solutions. The continuous increasing trend of chemical inputs actually leads any perceived success into an unsustainable and counter-productive quagmire. Many developed countries across the globe have realized this and started moving away from chemical intensive agriculture. How can we reduce the dependence on chemical fertilizers and pesticides in India, yet increase yields? This vision document attempts to find simple answers to the intractable problems. It is my firm belief as a cotton scientist that high yields are possible in marginal soils under rain-fed conditions as well, with high density planting of early maturing compact statured cotton varieties, sown early to escape bollworm attacks. Further, it is my firm conviction that a simple idea of strengthening cropping systems of cotton with nitrogen fixing legumes (fodder/pulses/oilseeds) dove-tailed with conservation agriculture and organic inputs can provide robust sustainable solutions not just for cotton but also to strengthen India's food security by reducing the import of pulses, oilseeds, fertilizers, pesticides and reducing fodder shortages. How well these ideas take shape over the next 35 years, only time will tell. But for the sake of posterity, these ideas will be in black and white for the next generation of young researchers to debate and decide the way forward.

Dr S. Ayyappan, Secretary DARE & DG, ICAR has always been inspirational with his down to earth saintly demeanour, yet technologically adept thinking. I express my heartfelt gratitude to him for encouraging all of us to think freely and

express frankly. I thank Dr J. S. Sandhu, DDG (CS), and Dr. N.Gopalakrishnan, ADG (CC) for the great support. I sincerely thank Dr C. D. Mayee, Chairman QRT for his ever-enthusiastic great guidance and solid support. Dr B. V. Patil, Chairman RAC and his team discussed the Vision document in great detail and provided valuable inputs. I thank them. Dr Prakash, Dr Blaise and Dr Sumanbala Singh, lent able support. Dr Sandhya Kranthi, Dr Monga, Dr M. V. Venugopalan, and Dr M. S. Yadav deserve special mention for being part of the think-tank. Dr Venugopalan provided specific inputs on climate change; Dr Monga and Dr Sandhya added new ideas and approaches on pest management; Dr Waghmare contributed his vision on the QTL mapping; Dr Singandhupe suggested novel inputs on natural resources management; Dr Loknathan, added new insights to technologies for genomics and breeding; Dr Wasnik provided valuable inputs on research for socio-economic welfare; Dr Annie Sheeba, Dr Balasubramani, Dr Santosh, Mr Velmourougane, Dr Raghavendra and Dr Santhy suggested new aspects related to their areas of expertise. I thank them for the timely inputs. All the scientists of CICR deserve appreciation for chipping in, as and when ideas came to them.

The Vision 2050 telescopes into the next 35 years with a dream that with technological support, the Indian cotton farmer will eventually produce the best ever quality cotton at the lowest ever production cost to get the highest ever yields in the world in the most sustainable manner imaginable in absolute harmony and consonance with ecosystems, to inspire rest of the world.

I wish you happy reading.

K.R. Kranthi
Director

Contents

<i>Message</i>	<i>iii</i>
<i>Foreword</i>	<i>v</i>
<i>Preface</i>	<i>vii</i>
1. Context	1
2. Challenges	6
3. Operating Environment	12
4. Opportunities & Strengths	18
5. Goals and Targets	25
6. Way Forward	28
7. Epilogue	36

Context



Cotton (*Gossypium spp.*) is the world's leading natural textile fibre crop and a significant contributor of oilseed. Cotton is one of the best gifts that nature bestowed on mankind. Cotton fabric is the most skin friendly of all natural fibres available on earth. Cotton contributes to 35.0% of the global fabric needs and 60.0% of clothing in India. It is estimated that in India more than 10.0 million farmers cultivate cotton and about 30 million persons are employed in cotton value addition.

Cotton is cultivated by about 80 countries. India cultivates cotton in 12 to 13 million hectares which is the highest cotton acreage in the world with more than 37.5% of the global cotton area in 2014. The estimated global cotton production in 2014 was 25.96 M tons (152.7 M bales of 170 kg/bale) from 34.14 M hectares (Table 1).

By 2050, requirement of total fibre may reach 85.26 M tons and the cotton requirement would be 33.15 M tons

The global production of all fibres including cotton increased from 52.0 M tons in 2000 to 72.5 M tons in 2010 at an average growth rate of 3.3% and if the growth rate continues to be 3.3%, it would reach 265 M tons by 2050. It is interesting that with the current fibre per capita availability of 9.0 kg fibre of which 3.6 kg is cotton, the requirement of total fibre by 2050 may reach 85.26 M tonnes and if

Table 1 Cotton production: Global Scenario 2014-15

	*Million hectares	*Million tonnes	*Lint kg/ha	Rainfed %
Australia	0.24	0.49	2038	26
Mexico	0.18	0.26	1476	12
Brazil	1.00	1.50	1524	98
China	4.40	6.53	1484	6
USA	3.93	3.50	891	60
Uzbekistan	1.29	0.87	678	10
Pakistan	3.05	2.28	750	0
India	12.70	6.64	523	60
World	34.14	25.90	760	27
World (excl. Indian data)	21.44	19.40	905	10

*Source: USDA -Cotton: World Markets and Trade. March 2015

cotton continues to cater to 40% of the total fibre requirement the requirement would be 33.15 M tons of cotton. However, at a modest average growth rate of only 1.6%, the fibre production may reach 136 M tons by 2050. With the rapid strides in technological advancement, it may not be very difficult to reach a cotton production level of 33.15 M tons by 2050, especially from the current production of 26 M tons in 2014.

Cotton – The Indian Context

Cotton in India is grown in eleven states under 40% irrigated and 60% rainfed conditions. The three states of north India, Punjab, Haryana and Rajasthan cultivate cotton in about 1.4 million hectares under almost complete irrigated conditions. Maharashtra has the largest area of 4.0 to 4.2 million hectares of cotton area with more than 90% under rain-fed farms. The cotton area in Gujarat doubled to reach 3.03 million hectares in 2011, from 1.57 million hectares in 2000. About 50% cotton area in Gujarat is irrigated. The newly formed Telangana state has 1.6 million hectares under cotton with almost 90% rain-fed. Karnataka, Madhya Pradesh and Andhra Pradesh have about 0.62 to 0.70 million hectares. While Karnataka has 14% cotton area under irrigation, Andhra Pradesh and Madhya Pradesh have 42-43% under irrigation. Odisha and Tamilnadu cultivate cotton in 0.14 million hectares each. The rain-fed regions receive 400 to 900 mm, but with uncertain and uneven distribution that affects yields.

India harvested a record production of 39.8 million bales from an area of 11.7 million ha with a productivity of 568 kg/ha in 2013-14

Cotton is cultivated by more than 10.0 million farmers in 12.7 million hectares in India (2014-15) that constitutes about 7.5% of

India's arable land and 37.3% of the global cotton acreage. India harvested a record production of 6.64 million tonnes (39.8 million bales) in 2013-14 from an area of 11.7 million ha with a productivity of 568 kg/ha, leaving behind the best ever historical record of 16.5 million bales before twelve years. Several factors have contributed to the increase in production. One major factor is the increase in cotton area by 66% from 7.8 million hectares in 2002 to 13 million ha in 2014. In contrast, over the past decade, the cotton area decreased in all the major cotton growing countries such as USA, China, Australia, Brazil and Pakistan.

India has a unique distinction of being the only country in the world to cultivate all four cultivable *Gossypium* species, *Gossypium arboreum* and *G. herbaceum* (Asian cotton), *G. barbadense* (Egyptian cotton) and *G. hirsutum* (American upland cotton) besides hybrid cotton. *Gossypium hirsutum* represents 99.9% of the hybrid cotton in India and all the current Bt cotton hybrids are either *G. hirsutum* or inter-specific hybrids with *G. barbadense*. *G. hirsutum* L. (American cotton) and *G. barbadense* L. (Egyptian cotton) have superior fiber quality. *G. hirsutum* L. is most widely cultivated because of its wide range of adaptation and high yield potential, whereas *G. barbadense* L. has fine and unique fiber quality. The near saturation of Indian cotton area with hybrid cotton resulted in significant changes in the species composition. The area under hybrid cotton increased from 40% in 2001 to 98% in 2015. As a result, the area under *G. barbadense*, *G. arboreum* and *G. herbaceum* which was 6.6%, 25% and 13% during 1995, has now declined to less than 2.0% for the three species together.

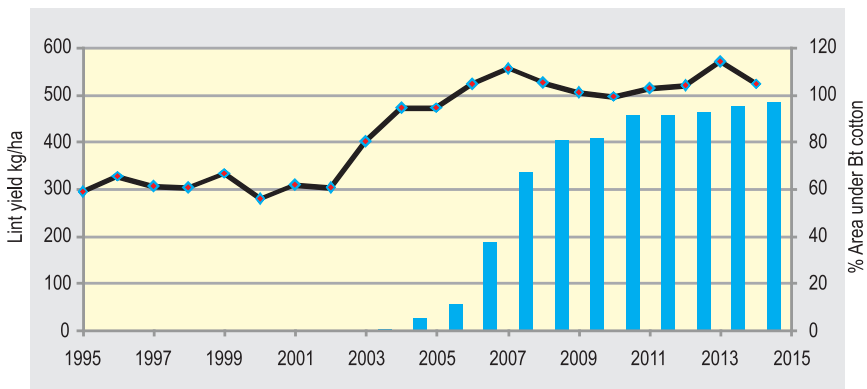
Factors such as favorable weather conditions, extremely low bollworm infestation and good market price for the cotton have contributed to the phenomenal increase in area and production. Bt cotton which was introduced in 2002, contributed immensely towards stability in Indian cotton production over the past decade. The area under Bt cotton increased from 6.3 million ha in 2007-08 to over 11.6 million ha during 2014-15. The quality profile of Indian cotton changed significantly. Long staple cotton which constituted 20% in 2000, increased to more than 88% of the total cotton produced in 2014 because of the Bt cotton hybrids, most of which are of the long staple category.

There has been a significant increase in the Indian cotton productivity levels over the past decade owing to several technological advances. The main factors for yield enhancement are:

1. Introduction of Bt cotton technology that efficiently protected the

crop from bollworms and thus prevented yield losses of 15-50% each year

2. Increase in hybrid cotton area from 40% in 2000 to 98% in 2015 that ensured growth of the Indian seed industry with competition amongst them to invest on R&D for the development of new hybrids and production of quality seed
3. Significant improvement in the seed quality and hybrid traits due to high commercial competition between the 46 'Bt cotton sub-licensee' seed companies
4. Introduction of several novel chemistries such as chloronicotinyls, oxadiazines, spinosyns, avermetins, diamides which enable effective pest management of a range of insect pests including the spectrum of sap sucking insects that generally get accentuated in the input-responsive hybrid varieties such as those prevalent in India
5. Increase in irrigated area under cotton especially in Saurashtra of Gujarat
6. Implementation of water saving technologies such as drip and sprinklers along with fertigation
7. Regulation of seed quality based on CICR technologies through regulatory agencies
8. Fertilizer use on cotton in India constantly increased over the past 10 years from 96 kg/ha in 2002 to 222 kg/ha in 2011 (Source <http://eands.dacnet.nic.in>). The increasing trend is continuing
9. Efficient delay in bollworm resistance development to Bt cotton through the insect resistance management (IRM) technologies developed by CICR based on the continuous 14 year monitoring carried out by the institute



20 years of Cotton Productivity in India

10. Effective utilization of the CICR strategies to combat Parawilt, Mealybugs, Mirid bugs, Thrips, CLCuD and leaf reddening
11. Wide spread use of LRA 5166, Anjali and Suraj in the development of the most popular private sector hybrids which resulted in the development of Bt cotton hybrids that were widely adaptable and tolerant to biotic and abiotic stress
12. Technological back-stopping provided by AICRP on Cotton-CICR by evaluation and identification of suitable hybrids for specific regions
13. Development of input-optimized package of practices & production strategies by AICRP on Cotton-CICR to enhance yields



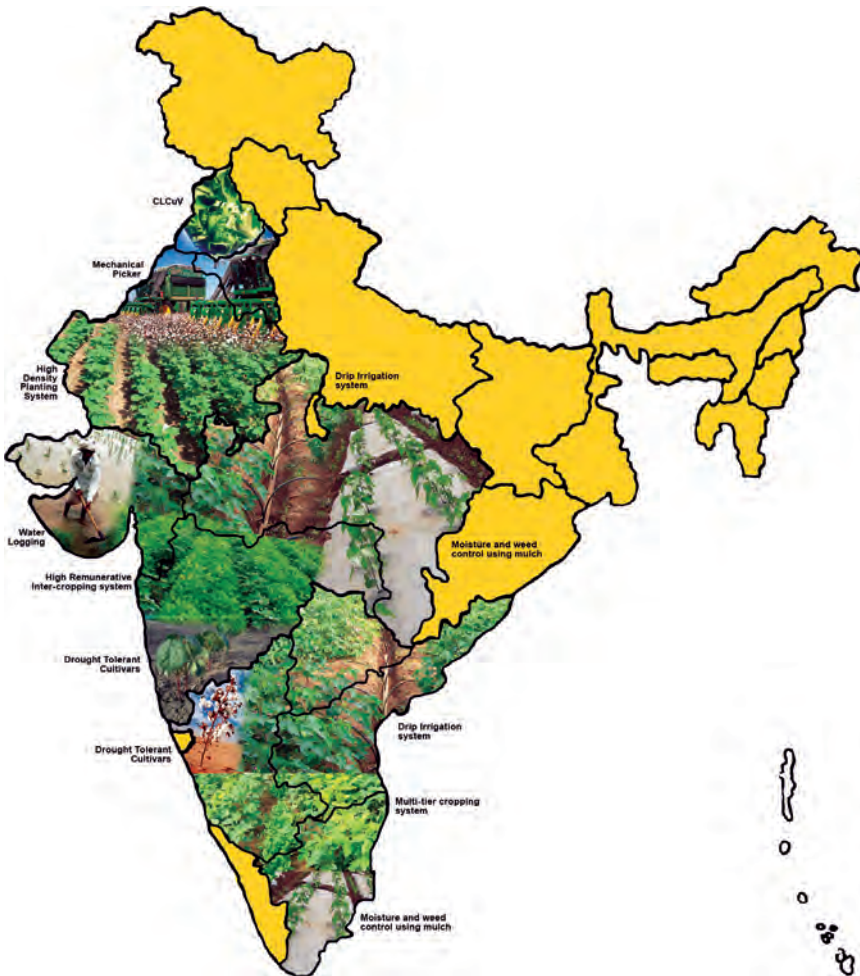
Challenges

COTTON is a commercial crop that provides livelihood security to farm families in India and several countries. Cotton production influences the lives of millions of persons. The textile industry provides livelihood to an estimated 40 million persons in India and 150 million across the globe. Cotton economy is influenced by a wide variety of factors. Farmer livelihood depends on yields, production costs and market price that determine the net profitability. The value-chain industry depends on raw cotton at an affordable price to enable them produce yarn, fabric and apparel in a global-competitive environment. The technology and input providers exercise enormous influence on inputs, generally orienting market demands that ensure reasonable profits. Consumers expect good quality products at affordable prices. All the stakeholders eventually get benefitted if the production costs are lowered and yields get enhanced. Some of the main challenges are listed below:



1. **Genetic erosion** and narrowing of genetic diversity in cultivated varieties/hybrids
2. **Non-availability of public sector GM cotton varieties** mainly Bt cotton
3. **Indian cotton productivity levels are 30-50% below world average** of the leading countries (Table 1)
4. **Insect Resistance development** to Bt cotton and insecticides
5. **Spurious inputs** such as GM seeds and pesticides
6. **Significant decrease in fertilizer factor productivity** of Indian soils from 20 kg grains/kg fertilizer in 1980 to 8 kg grains/kg fertilizer in 2010
7. **Low soil organic carbon content**
8. **Fertilizer usage doubled** to 28 million tons in 2014 over the past 20 years
9. **Imbalanced fertilizer usage and micro-nutrient deficiencies** in soils are resulting in increased insect pests, insect resistance to insecticides and concomitantly increased insecticide usage

10. Ever increasing cost of inputs such as seeds, fertilizers and pesticides and non-commensurate market price of cotton is lowering down profitability over time.
11. Cotton seeds costs increased constantly over the past 10 years from ₹ 1058/ha in 2002 to ₹ 3594/ha (Source <http://eands.dacnet.nic.in>)
12. Despite the introduction of Bt cotton, which was expected to reduce the need for insecticide use, the expenditure on insecticides on cotton increased constantly over the 10 year period from ₹ 1385/ha in the year 2002 to ₹ 2429/ha in 2011 (Source <http://eands.dacnet.nic.in>)



Constraints and Solutions

13. **Lack of irrigation facilities** in more than 60% of cotton area
14. **Non-availability of small scale low cost machines** for sowing and picking
15. **Labour shortages and enhanced wages**, which doubled over the past 7 years are resulting in delayed crop operations and diminishing profits.
16. **Erratic monsoon, droughts and extreme temperatures**
17. **Chemical influenced soil degradation, water pollution and poor microbial diversity**
18. **Reducing ground water levels** by 2-4 mbg within one decade in North and Western regions of India
19. **Climate change:** Climate change and global warming are serious challenges to agriculture. The atmospheric changes can result in fragile unpredictable ecosystems that extend vulnerability to many cropping systems. The Intergovernmental Panel on Climate Change (IPCC) projections estimate that atmospheric CO₂ concentration would rise to 450-500 ppm by 2050 and 575 ppm by 2080's along with increase in the mean temperature by more than 2°C. Cotton crop is generally resilient to several abiotic stress factors, but needs support systems to enable them mitigate the additional stress imposed by climate change. It is important to breed for climate resilient varieties and ensure conservation of natural resources to improve the resilience. Nevertheless, cotton crop can be affected by the unpredictable environmental stress inducing variables depending on the critical window, which affects production. However, cotton cultivation and processing also contribute to green house gas emissions, albeit to a lesser extent. The entire process of cotton crop production, fibre processing and maintenance of clothes contributes to less than 1.0% of the total greenhouse gas emission. Much of the CO₂ and NO₂ emissions are actually from irrigated cotton in developing countries. It is estimated that chemical inputs in cotton cultivation cause an emission of about 1200 kg/ha of CO₂ and 1800 kg/ha of NO₂. Irrigation pump sets were found to contribute to 642 kg CO₂ per hectare. Over the past few years there is wide spread awareness on the need to reduce chemical dependence that in turn can minimize the climate change impact. While elevated temperatures and CO₂ induced more feeding in insect pests such as the leaf eating caterpillar, *Spodoptera litura*, the cotton sap-sucking pests whiteflies, thrips, aphids, mealybugs etc. were found benefit by enhanced survival and reproduction. The whitefly, *B. tabaci* B biotype causes huge economic yield losses to cotton, apart from

transmitting the cotton leaf curl virus in north India and Pakistan. Elevated temperatures can lead to increasing populations of the whitefly thereby increasing infection of the cotton leaf curl virus. Simulation studies on cotton under projected climate change scenarios indicate a reduction in cotton yields in Haryana, Gujarat, Punjab and Rajasthan and an increase in cotton yields in the central and southern region provided the water resources are effectively utilized.

20. Need to enhance funding on cotton research to fill the critical gaps

Critical Gaps in Research

1. Characterization of genetic resources

- Need for Rain-out shelters & Phenotypic platforms to characterize genetic sources for resistance to biotic & abiotic stresses

2. Biotechnology – Critical Gaps

- IPR protected indigenous genes and promoters
- IPR protected genetic transformation constructs and genetic engineering technologies
- Novel technologies of RNAi and site directed gene integration
- Platforms for Bioinformatics and Molecular software application
- Indigenous gene data banks, molecular and microbial resources

3. Crop Improvement – Critical Gaps

- Genetic enhancement with reference to climate change
- Breeding for Multi-Adversity-Resistant hybrids/varieties
- Consolidation of genetic sources of resistance to cotton leaf curl virus (CLCuV) disease and bacterial blight
- Intensification of research on heterotic pools and development of hybrids with high harvest index and boll development synchrony
- Markers for major economically important traits
- Marker Assisted Breeding initiatives for pest & disease resistance
- Exploring the possibility of harnessing stable epigenetic variations across generations to improve adaptability of cotton to changing environments, hybrid vigour and productivity
- Developing epigenetically engineered cotton by chemical treatments and/or spontaneous/environmentally induced epimutations for higher productivity
- Early maturing varieties for rainfed regions
- Robust genetic sources for abiotic resistance (salinity, drought and heat tolerance)

4. Crop Production – Critical Gaps

- Conservation Agriculture Technologies and soil moisture conservation
- Intensive research to identify cropping systems of cotton with Nitrogen fixing crops (fodder and pulses) and microbial bio-fertilizers (*Azolla*, *Anabaena*, *Azotobacter*, Phosphorus solubilising microorganisms (PSM), Arbuscular Mycorrhiza (AM) etc.) also to ensure self sustaining IPM ecology and Integrated farming systems with animal husbandry
- Biological Weed Management Technologies
- Combined effective water-nutrition management
- Mechanization of operations to substitute labour drudgery
- Studies on the possible impact of technologies on labour displacement
- Real-time analysis of micro nutrient disorders and crop-specific formulations
- Standard package of practices for organic production
- Pollination ecology in enhancing productivity
- Research to mitigate the impact of climate change on crop productivity
- Secondary Agriculture and waste utilization

5. Plant Protection - Critical Gaps

- Robust research on components of IPM & IRM Integrated Pest Management (IPM) and Insect Resistance Management (IRM)
- Research on host plant resistance to whiteflies and CLCuD
- Addressing the challenge of insect pests and diseases that are common to many crops such as- Borers, viral diseases, virus vectors –whiteflies and thrips that have impact on cotton pest management
- Documentation of molecular diversity of cotton insect pests, parasitoids, predators, pathogens and economically important microbial populations in the cotton cropping systems
- Bio-security & planning for invasive pests such as whitefly B-biotype and Mealybugs
- Rapid diagnostic tools especially for cryptic insects and diseases

6. Seed Science & Technology – Critical Gaps

- Package of practices exclusively for cotton seed processing production
- Simple cost effective nurseries for hybrids
- Diagnostics – Critical for seed borne diseases

-
- Simple and cost effective genetic purity testing method for commercial hybrids (other than that for the transgene)
 - Research on pollination for seed production and quality

7. Social sciences – Critical Gaps

- Research on Market Intelligence methodologies for yield and price forecast
- Research on integrating novel ICT tools for precision farming
- Research methodology in extension, e-extension, crop specific portals, field guides and expert systems
- Research on welfare schemes such as MNREGA (Mahatma Gandhi National Rural Employment Guarantee Act), MSP (Minimum Support Price), input subsidies, and their impact on agrarian welfare and cotton production
- Partial factor productivity and Total factor productivity

8. Co-ordinated Projects – Critical Gaps

- Overhauling evaluation systems for technology validation, varietal suitability and release for specific agro-eco zones
- Removal of redundancy and over-lap in experiments



Operating Environment

THE Central Institute for Cotton Research (CICR) is a premier institution of cotton research in India under the aegis of Indian Council of Agricultural Research (ICAR), New Delhi. It was established in 1976 with headquarters at Nagpur (Maharashtra) and two Regional Stations at Coimbatore (Tamil Nadu) and Sirsa (Haryana). The institute has a total sanctioned 271 staff strength, with 81 scientists, 72 technical staff, 48 administrative staff and 70 supporting staff. The institute has a 425 acre research farm at Nagpur, 55 acre farm at its regional station Sirsa and 88 acre farm at regional station Coimbatore.



CICR, HQ, Nagpur



CICR, RS, Coimbatore



CICR, RS, Sirsa

The institute has a major mandate to conduct basic and strategic research for cotton improvement in the country. Over the years, CICR has emerged as a leader in science and technologies through its significant scientific contributions that lead to the spectacular progress of cotton production through public private partnerships. The role of CICR in solving various problems confronting cotton production in the country is widely acknowledged through the awards received by the institute.

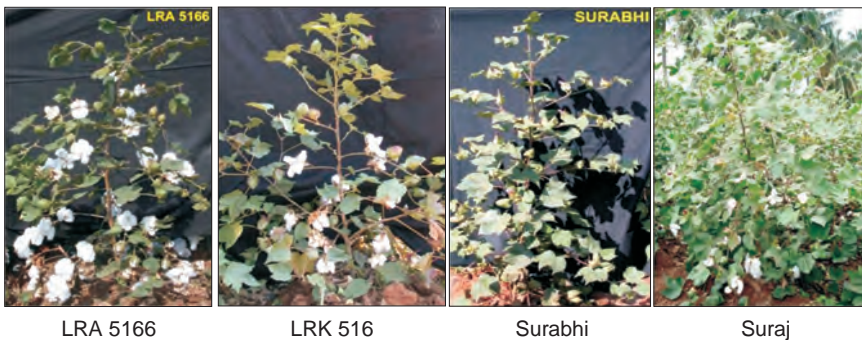
CICR has close collaborative linkages with ICAC (International Cotton Advisory Committee, Washington), ICGEB, ICRISAT, CIRCOT, IARI, NBRI, NCL, PPV&FRA, NBA, DBT, DST, RCGM, GEAC, Ministry of Environment and Forest, APEDA, NHB, DAC and DCD (Directorate of Cotton Development), seed industry and the pesticide industry. The institute has close linkages with Agricultural Universities located in the cotton growing regions of the country through its All India Coordinated Research Project on Cotton.

The Central Institute for Cotton Research takes pride in the four international patents in South Africa, China, Uzbekistan and Mexico,

several Indian patent applications, significant technologies that were disseminated to lakhs of farmers and the large number of training programmes conducted on different aspects of cotton production for Indian and foreign scientists/extension personnel.

The institute has been recognized all over the world for its outstanding work on plant breeding, crop improvement, crop production technologies, development of Bt-cotton, development of immunological diagnostic kits, basic research on insect resistance to insecticides. Cry toxins and xenobiotics, development and dissemination of IRM (Insecticide Resistance Management) and IPM (Integrated Pest Management) technologies for conventional and Bt-cotton. A few notable achievements of the institute are listed below:

- The institute partnered in the 'International Cotton Genome Initiative ICGI' programs and has contributed to the development of cotton genome -published in the world's leading journal 'Nature'.
- The institute is widely acknowledged for its basic research that led to the development of several processes, products, technologies and pre-breeding advanced genetic stocks that are either highly adaptable to biotic and abiotic stress or excellent in fiber quality attributes. Recently a new *G. arboreum* genetic stock was developed with the highest ever fiber strength of 29 g/tex.
- The CICR varieties, LRA 5166, LRK 516, Surabhi, Suraj and many others possess excellent adaptability characteristics and are being commonly utilized in majority of the highly adaptive commercial private hybrids that are grown across the country.



- CICR has developed and released 30 improved genotypes including **twelve** varieties of *Gossypium hirsutum* (MCU 5 VT, LRA 5166, Supriya, Kanchana, Anjali, CNH 36, Arogya, Surabhi, Sumangala, CNH 120 MB, Suraj, CNHO 12, CSH-3129 and CCH 2623), **three** varieties of *G. arboreum* (CISA 310, CISA 614 and CNA 1003 (Roja)), **one**

variety of *G. barbadense* (Suvin), **nine** intra-*hirsutum* hybrids (Savitha, Suguna, Surya, Kirthi, Omshankar, CSHH 198, CSHH 238, CSHH 243 and CSHG 1862), **two** interspecific (*G. hirsutum* x *G. barbadense*) hybrids (HB 224 and Shruthi) and **one** intra-*arboreum* hybrid (CISA 2).

- The World's best extra-long staple variety 'Suvin' was developed by CICR.
- The recent variety Suraj has excellent fibre quality (length 31.7 mm, strength 25.9 g/tex with 3.8 mic) and is now being promoted for High Density Planting Systems (HDPS).
- Forty (40) genetic stocks (*G. hirsutum*-24, *G. arboreum* - 10 and Introgressed - 6) have been registered for their unique, novel and distinct characteristics. These would serve to generate important cotton genotypes with economically important traits and unique morphological markers.
- The institute has one of the world's largest germplasm collections of 11,345 belonging to four species of cotton (*G. hirsutum*-8265, *G. barbadense*-305, *G. arboreum*- 1936 and *G. herbaceum*- 565) besides a number of land races (*Hirsutum*-7, *Barbadense*-1, *Arboreum*-6 and *Herbaceum*-1), wild species (26), interspecific derivatives (40) and perennials (193). These serve as valuable resources of biodiversity with innumerable economically important traits.
- To reduce the cost of hybrid seed production, a Thermosensitive Genetic Male Sterile line (TGMS 1-1) was identified and characterized in *desi* cotton (*G. arboreum*). It produces completely fertile male flowers at minimum temperature of less than 18°C and produces completely sterile male flowers at minimum temperature more than 24°C with continuous good sunshine. Complete male sterility could be obtained only during summer flowering (i.e. month of May) for consecutive four years. This line could be successfully employed for hybrid seed production in summer with 30% boll setting efficiency.
- Several other innovative aspects of useful research include the discovery of apomixes trait, cleistogamy, temperature sensitive male sterility and five-loculed genotypes. Under the Diversification and utilization of male sterility system, 82 genotypes were converted under CMS background, 66 genotypes were converted



under GMS background. 12 GMS based hybrids were found to be promising in multi-location trials.

- CICR developed, patented and commercialized ‘farmer-usable’ kits to detect Bt cotton. The kits are being used on a large scale by farmers and seed testing agencies in the country since 2002 to curb the spread of illegal and spurious Bt cotton seeds.
- The institute has developed ‘PCR based Kits’ to detect various pathogens including the dreaded cotton leaf curl virus.
- Over the past few years, the institute has been successfully promoting *Desi* cotton varieties which require low production cost for high yields to enhance sustainability in the Melghat tribal tract of Amravati District of Vidarbha. The programmes have become very popular with increased adoption levels and generated new hopes to cotton farmers in the region.
- The institute is known for its pioneering work on fundamental research on insect resistance to insecticides and Bt toxins. Scientists of the institute developed stochastic models and developed IRM (Insecticide Resistance Management) strategies for the country. The institute provided leadership for national dissemination of the IRM and IPM (Integrated Pest Management) technologies for conventional and Bt-cotton.
- Recently, three novel lectins have been identified by the institute as promising candidate genes for the control of sap-sucking insect pests (aphids, leaf hoppers, and whiteflies).
- Two new bio-pesticide formulations, mealy-kill and mealy-quit were developed for the control of mealybugs and sucking pests.
- New Bt genes were designed indigenously, synthesized into gene constructs and are being used in the genetic transformation of cotton. The institute has developed several other transgenic events with Bt genes in *G. hirsutum* cotton. The institute played a stellar role in supporting research for the introduction and popularization of Bt-cotton in India.
- The institute developed several package of practices, poly-mulch techniques, multi-tier cropping systems, innovative inter-cropping





Multi-tier cropping system



Inter-cropping system

systems, and several other crop production strategies to optimize input use and maximize benefits from Bt-cotton.

- The institute developed and demonstrated a new concept of 'High Density Planting Systems' (HDPS) that has potential to improve yields of rainfed cotton, especially in Maharashtra, Madhya Pradesh and Andhra Pradesh. More than 5000 one acre frontline demonstration trials were conducted with HDPS over three years. Results showed that the productivity of cotton in HDPS with straight varieties was found to be a viable option to improve the



High Density Planting Systems (HDPS) field view

productivity of cotton particularly under rainfed conditions at reduced production costs

- The institute has developed many implements and devices and has filed patent applications for 'solar powered knapsack sprayer' and 'bullock drawn planter' that have been developed and commercialized.
- CICR has recently established a 'voice-mail' weekly advisory system called 'e-kapas' network to connect 100,000 farmers for technology dissemination and backstopping. Advisories and alert services are

being issued to the registered cotton growers in 8 local languages so as to enable them initiate proactive measures.

- The institute has won national and international awards for its outstanding work in development and dissemination of IRM strategies in about 200,000 hectares in 30 districts of nine cotton growing states in fields of about 90,000 farmers, resulting in net financial benefit of ₹ 500 million per year due to 50-60% reduction in pesticide use and enhanced yields.
- Recently the Central Institute for Cotton Research, Nagpur was conferred the 'National Award 2014- Best Research Institute – Krishi Sansthan Samman' by Mahindra Samridhi India Agri Awards 2014.
- CICR hosted 'KrishiVasant 9-13 February 2014', the country's biggest ever Agricultural Exposition in which an estimated 8 to 10 lakh farmers attended from all across India.
- In addition to the research programmes, the Institute is engaged in first line transfer of technology. These include Frontline demonstration (FLD), On-Campus/Off-Campus demonstrations, Seed Village Programme and IPM/IRM demonstrations. Farmer-Scientist Interaction programmes are organized periodically for enabling in-depth interaction between farmers and researchers.
- The Institute undertakes regular technical training programmes for 2-8 weeks for specialists and on-farm training courses for cotton growers usually of one to two days duration. The Govt. of India recognized the institute as the centre for conducting National/Model Training Courses on Cotton Production Technology. More than 1500 senior level extension functionaries belonging to all major cotton growing states of the country have been trained in these mediums to long-term programmes. In addition, the institute undertakes short term sponsored training programmes by the State governments, NGO's private companies/corporations and other organizations. Periodic International training programmes are also organized for cotton professionals from other cotton growing countries of Africa and south and south-east Asia such as Vietnam, Myanmar, Indonesia, Sri Lanka, Bangladesh etc.



Opportunities & Strengths

Global commodity: Though cotton is cultivated in more than 34.0 million hectares in a total of about 80 countries, just about 7 countries occupy nearly 79% of the global cotton area. India has the largest area of 12.75 million hectares (37.3%), China has 4.4 million hectares (12.94%), USA has 3.9 million hectares (11.47%), Pakistan has 3.0 million hectares (8.82%), Uzbekistan has 1.3 million hectares (3.8%), Brazil has

1.0 million hectares (3.2%) and Burkina Faso has 0.6 million hectares (1.97%). Rest of the world depends on these seven and 4-5 other countries for cotton production. Though, cotton comprises only about 40% of the global fibre production, it is the most preferred natural fibre for clothing in every country of the world. It is a global commodity that caters to all the clothing needs of mankind. The main advantage of the commodity is that it does not spoil easily on long term storage and there is a perpetual demand.

High yields are possible: As many as 32 countries have a productivity level of more than 520 kg lint per hectare, which is more than India's average yield of 520 kg/ha. At least a dozen countries produce more than 1050 kg lint per hectare which is double that of India. In 2013, Australia produced more than 2000 kg lint/ha, China, Mexico, Brazil, Turkey and Israel produced more than 1500 kg per hectare. These statistics point out towards possibilities that India can also reach such higher yield levels by orienting its agronomic patterns that enabled these countries to obtain higher yields, since these countries produce cotton consistently at three times the yields of India, mostly under rainfed conditions with lesser chemical inputs.

India has the largest acreage in the world: India cultivates cotton in 37.3% of the global cotton acreage. Interestingly, over the past decade, India's area grew significantly by 60% while many major cotton growing countries such as China, USA, Brazil and Australia reduced their area. The biggest advantage unlike many major countries of the globe, is the



decentralized management of individual small-scale farms by farmers themselves.

Livelihood: Cotton is a very important commercial crop. In many parts of the country farmers prefer to cultivate cotton over any other crop because of a relatively better assurance of production compared to other crops. Cotton can be stored for a reasonable amount of time without any detectable change in quality parameters. This is seen as one of the main advantages, especially when farmers may have to wait for better market prices.



Climate resilient crop: Cotton is a semi-xerophytic plant that has immense capabilities to survive water stress and recuperate after prolonged stress. It is therefore innately tolerant to drought. It is basically a forced annual and has an indeterminate growth habit. Compared to any other crop, cotton germplasm pool is likely to have a wide range of genotypes that can survive extreme climate conditions. Thus there are enormous opportunities to select for varieties that can adapt to climate change with a good potential for high yields despite adversities. However cotton crop is sensitive to climate induced effects. Studies conducted by CICR and other institutions elsewhere in the world showed that cotton crop in some circumstances may benefit from higher temperatures and enhanced CO₂. Cotton is a C-3 plant and thus responds positively to higher levels of CO₂. Elevated CO₂ levels are utilized by the plant to produce larger leaves which result in enhanced photosynthesis and crop vigour. But, the enhanced vigour creates an inevitable demand for more fertilizers, pesticides and water for higher yields. The tap root system of cotton plants helps the crop to combat moisture stress and overcome drought in a comfortable manner with subsequent availability of water. However, productivity declines in the event of moisture stress during flowering and/or boll formation stage.

Strong science and technological back-up: India has the best of scientific manpower and is technologically as advanced as many developed countries. The Central Institute for Cotton Research has a sanctioned strength of 81 scientists. Additionally, the All India Coordinated Research Project on Cotton (AICRP on Cotton) network has about 120 scientists who are dedicated to cotton research on various aspects. The strong human and technological resources provide a great opportunity for the country to advance rapidly towards global leadership.

Proper prioritization of core focus areas and appropriate investment on R&D in the identified priority areas would hold the key as to how the country's cotton future would shape up in the next 35 years up to 2050.

Large Gene bank: India has one of the world's largest gene banks with an array of 11,345 accessions of all the four cultivated species. India is the only country in the world that cultivates all the four

India has one of the world's largest gene banks with an array of 11,345 accessions of all the four cultivated species

species *Gossypium hirsutum*, *G. barbadense*, *G. arboreum* and *G. herbaceum*. The gene bank is an invaluable treasure of a wide range of economically important quality traits that can be sourced and pyramided

into cultivars with resistance to identified biotic and abiotic stresses and are suitable for specific agro-eco zones in the country. The gene bank provides a powerful opportunity to combat the challenges posed by climate change uncertainties. The recent techniques of fibre evaluation in the field provide new opportunities for plant breeders.

Low cost of production: Amongst the major cotton growing countries, India's average cost of cotton cultivation is considered to be less than the general average cost in the world. With proper science and technological interventions, it is possible to enhance productivity and further reduce the cost of cultivation by minimizing the dependence on chemical inputs in an eco-sustainable manner. This would easily place India as a front runner for global leadership with an advantage in cotton commodity trade over all competing countries.

Burgeoning population, manpower availability and employment opportunities: India's burgeoning population also provides an opportunity for a wide range of skilled labour and technical manpower. The labour wages and expenditure on technical manpower in India are amongst the lowest in the world. It is estimated that every bale (170 kg lint) provides employment for at least one person in the value chain. Thus cotton provides an immense opportunity for the country not only to provide employment but also utilize its population in the best possible manner to add value to cotton and its by products for domestic and export purposes. If India succeeds in a modest manner by doubling the production from the current 40.0 million bales to 80.0 million bales, the additional commodity thus produced would provide an additional employment for another 40 million persons.

Strong Trade & Textile background: Indian has the longest history and heritage on textiles. In the non-SSI sector, there are 1961 non-SSI mills, 1340 spinning mills, 173 exclusive weaving mills and 0.312 million power loom units. India has an installed capacity of 4.86

million spindles, 0.78 million rotors, 52,000 organized sector looms, 2.316 million power looms and 2.38 million hand looms. India has a demonstrated annual capacity for yarn production of 3.49 million tons and fabric production of 32 billion sq metres. The ministry of textiles states that the per capita cloth availability in India is 43 to 44 sq metres. Historically, India was known for its amazing skills and technical expertise in spinning and weaving. With good policy support in labour management, electricity and water, the textile industry can easily catapult India into a global power by generating employment and foreign exchange.

Value addition & Foreign exchange earnings: Currently, India is exporting raw cotton to an extent of 10 to 12 million bales, which would have otherwise provided employment for at least 10 to 12 million persons apart from creating value added exportable surplus good such as yarn, fabric and apparel, which would be worth at least US \$ 20 billion. China presents an interesting case study of being the world's largest importer of raw cotton despite being the world's largest cotton producer. As a policy, the Chinese Government paid 50-60% higher than the Cotlook-A price and ensured that farmers were not negatively affected because of the huge imports of raw cotton. The cotton processing and value chain industry stood to gain because of the low cost of raw material and high value addition from the phenomenal textile exports worth US \$ 188 billion in 2010 compared to the Indian textile exports



worth US \$ 26.5 billion and other competing countries such as US, Hong Kong, Italy and Germany with textile export earnings worth US \$ 21 to 30 billion. With immense resource advantages at hand, India should seriously consider strengthening the textile and trade industry and emulate China's success story of importing raw cotton without affecting farmer interests, build cotton reserves to provide consistent employment, produce huge value added goods and earn tremendous foreign exchange.

Oilseed and Seed cake: Every year 12 to 13 million tonnes of cotton seeds worth ₹ 24,000 to 26,000 crores (₹ 240 to 260 billion) are produced in India. The oil extraction efficiency is about 10-11% which provides 1.2 to 1.3 million tonnes of cotton seed oil worth ₹ 12000 to 13000 crores (₹ 120 to 130 billion) and an equally worth seed oil cake. Reports indicate that with good scientific methods, the extraction efficiency can be enhanced to 16-17%. Thus it is estimated that every year nearly ₹ 70 billion are wasted due to improper seed and fibre processing in India. Currently, India is importing edible oil worth ₹ 68000 crores (₹ 680 billion). Increasing cotton production and enhancing the oil extraction efficiency can reduce edible oil imports significantly.

Cotton stalks: Every year 36 to 40 million tonnes of cotton stalks worth about ₹ 1800 to 2000 crores (₹ 18 to 20 billion) are produced in India. Cotton stalks are very high in calorific value at 18 MJ/kg only next to soybean amongst the crop residues generally used as bio-fuels. Interestingly, cotton stalks possess cellulosic fibre that is equivalent to most hardwood species. Therefore, the stalks are considered as ideal raw material for the manufacture of particle boards, hard board, corrugated boards, hand-made paper. The stalks are also used in the manufacture of micro-crystalline cellulose and to grow edible oyster mushrooms. However, as much as 85 to 90% of the cotton stalks are wasted in India. The stalks provide a good opportunity for small scale industries. With proper planning and technologies that are available with ICAR institutions, cotton stalks can be used to provide employment for about a million persons and generate substantial revenue through value added goods.

The resilience of *Desi* cotton: India has a distinct advantage of being the centre of origin and diversity of the *Desi* cotton species *Gossypium arboreum*. For at least more than 5000 years, India was known for its finest fabrics made out of the *Desi* cotton. The *G. arboreum* *Desi* species is known for its robust adaptability. Unlike the American cotton species *Gossypium hirsutum* which is susceptible to a wide range of biotic and

abiotic factors, the *Desi* species is highly tolerant to insect pests, diseases, salinity, drought, water-logging and the changing climate. Varieties of the *Desi* species are known to get easily acclimatized

By 2050, It may be possible that *Desi* cotton *G. arboreum* could replace majority of the area that is currently under *G. hirsutum* in light of climate change related weather vagaries

to marginal soils and adverse environments. They can be good yielders even with minimum fertilizers and pesticides. Though less than 5.0% of Indian scientists work on the species, India has developed excellent varieties that produce cotton with fibre properties and yields equivalent to that of American cotton. The varieties are highly adaptable to any region in the country. Thus *Desi* cotton varieties represent a treasure and insurance for the future of cotton cultivation in the country. Thus India has a great advantage in *Desi* cotton species especially with reference to climate change. By 2050, it may be possible that *Desi* cotton species *G. arboreum* could replace majority of the area that is currently under *G. hirsutum* in light of climate change related weather vagaries and focussed systematic breeding efforts for fibre quality improvement in *Desi* cotton.

GM technologies: Thus far only one GM technology in the form of 'Bt cotton' which expresses genes from the soil bacterium *Bacillus thuringiensis* (*Bt*) has been approved for commercial cultivation in India. Within 6-7 years of its introduction the technology spread to more than 95% of cotton area in the country. Bt cotton successfully controlled the bollworm and is estimated to have prevented yield losses to the extent of 30-60% every year. However, the biggest gain from the technology has been in the form of reduced insecticide usage from 1.53 kg insecticide per hectare in 2001 to 0.53 kg/hain 2008. However, insecticide usage gradually increased over the past 6 year period to reach 0.96 kg/ha in 2013, mainly due to the introduction of a large number of susceptible hybrids and increase in the area under these hybrids susceptible to sap-sucking insects. There are good opportunities for several useful GM traits such as resistance to drought, salinity, water-logging, resistance to viral diseases and premium fibre qualities. New technologies such as RNAi based gene silencing provide immense opportunities to explore enormous possibilities to equip the crop to combat biotic and abiotic stresses. Development of next generation GM cotton varieties for prioritized target traits by precise integration of target genes through plant genome engineering tools has the potential to transform the field of 'GM cotton'.

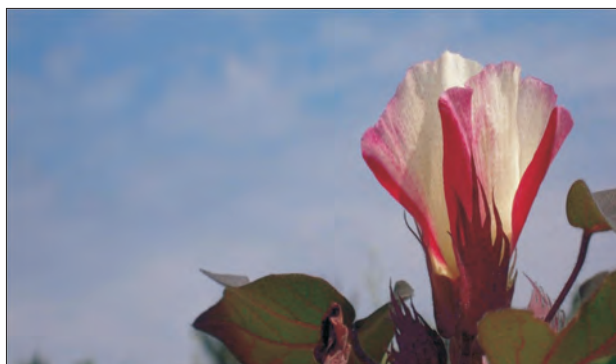
Diagnostic technologies: Diagnostic technologies such as biochemical assays, immunoassays, PCR, real-time PCR, LAMP (loop-mediated isothermal amplification) have greatly enhanced the speed to

detect proteins and specific genes in an accurate and precise manner. Such technologies have great potential in assisting in the detection of cryptic insects, latent infection of dreaded diseases, thereby contributing immensely to effective crop protection and yield enhancement.

Genomics: Cotton comprises of total 50 species of which only four are cultivated commercially. The recent advances in sequencing platforms and bioinformatics have resulted in a wealth of information available as expression profiled data, waiting to be exploited. The complete annotated genome sequences of *Gossypium raimondii* (D genome) and *Gossypium arboreum* (A2 genome) were made available in the public domain. Additionally, the publicly available resources include 49 genetic maps, 24,000 markers, more than 1,000 quantitative trait loci (QTLs) representing more than 30 agronomically important traits, phenotype data from thousands of germplasm accessions, about 6,50,000 NCBI sequences, 18,000 genes and gene products and 4,60,000 expressed sequence tags (ESTs). The cotton genome sequence database provides a major source for cotton improvement. Diversity Array Technologies (DArT) provide new opportunities for whole genome profiling and to develop molecular markers.



Goals and Targets



Cotton is a commercial crop. The main goals of R&D are as follows:

- 1. To attain productivity levels - equivalent to the best in the world:** Compared to the current Indian, average yields of 500 kg lint/ha, Australia and Israel produce cotton at more than 2000 kg lint per hectare, Mexico, China and Brazil produce 1400 to 1600 kg/ha, while Uzbekistan, USA and Egypt produce about 1000 kg/ha. At the current growth rate, it is possible that by 2050 these countries may easily double the productivity which would mean 3000 to 4000 kg lint per hectare. India should plan its research with an aim to reach a productivity level of at least 2000 kg per hectare by 2050, if possible more.
- 2. To produce premium quality cotton:** Indian plant breeders need to develop varieties that have the premium fibre qualities as per the dynamic technological changes in textile-machinery. Apart from the needs of the textile industry, varieties must have the best possible fibre qualities for the non-spinning sector such as absorbent cotton, surgical cotton, mattresses etc. The immediate plant breeding goals would be to develop climate resilient varieties with premium fibre traits, high harvest index, high ginning out-turn, early maturing, that can withstand biotic stress factors such as insect pests, nematodes and pathogens.

India should plan its research with an aim to reach a productivity level of at least 2000 kg per hectare by 2050, if possible more.

- 3. To reduce cost of cultivation by reducing the dependence on chemical fertilizers, pesticides and labour:** Establishment of input-use-efficient sustainable cereal-legume based cropping systems integrating INM, IWM, IPM technologies for self sustaining sturdy ecology based agriculture with a potential to reduce urea application in cotton at least by 50% (1.5 million tons) worth ₹ 600 billion at current price. R&D efforts should develop cropping systems comprising of cotton with nitrogen fixing legumes fodders (alfalfa, berseem, stylosanthes etc.) pulses (peas, beans, lentils, Guar bean, mung bean, black gram, red gram, *Phaseolus* spp, *Vigna* spp., *Vicia* spp., *Cajanus* spp., *Pisum* spp., *Cicer* spp., etc.) and oilseeds (soybean and groundnut) that do not depend on chemical agriculture. Multiple abiotic/biotic resistant varieties and Integrated Pest Management (IPM) can reduce pesticide use immensely thus resulting in increased food and environment safety and export. Science based eco-friendly IPM and Insecticide Resistance Management (IRM) have the potential to reduce chemical pesticides at least by 50% (20,000 metric tons) worth ₹ 3000 crores (₹ 30 billion). Integrating legume fodder crops into cropping systems with cotton has the potential of enhancing milk productivity at least by 10% (13 million tonnes worth ₹500 billion). Integrating legumes/pulses into cropping systems with cotton has the potential of enhancing productivity of pulses to reduce imports by 20% (0.76 million tons, worth ₹ 24 billion). Enhanced production of pulses, oilseeds and fodder will result in increased livelihood and nutritional security.
- 4. To produce cotton for employment generation and earn foreign exchange:** Enhancing cotton production even by 10% (4 million bales raw cotton) will generate employment for additional 1.0 crore persons if converted to fabric and earn at least ₹ 400 billion through exports. The increase of 10% production will result in 0.1 million tons oil worth ₹ 10 billion. Increase in self reliance by enhancing the production of cotton seed oil and reducing of vegetable oil imports by about 1.2 million tons will be worth about ₹ 120 billion.
- 5. To reduce the area under cotton in favour of food crops:** Over the past 12 years, India's cotton area increased from 7.8 million hectares in 2002 to 12.75 million hectares in 2014. Thus 5.0 million hectares of other crops were converted to cotton. It would be important to reduce the cotton area to about 8.0 million hectares and double the cotton productivity, so as to ensure that the 5.0 million hectares are cultivated for India's food security.

6. **To develop technologies that can reduce labour drudgery and create comfortable machine based farming systems:** Greater use of information and communication technologies can contribute to rapid dissemination of technology at least cost. Accurate, quick diagnostics contribute to efficient IPM and management of invasive pests.



Way Forward



The roadmap for India's cotton future should be necessarily based on sustainable practices that ensure high productivity at low cost. The crop production practices must incorporate inputs in consonance with the ecosystems to make it ecologically and economically as sustainable as possible. With good science this should not be difficult. The table below highlights the current challenges posed by increase in chemical dependence for cotton cultivation over the period 2003-2011.

	Actual 2003	Actual 2011	*2011	x-fold increase	Strategies to combat the challenge
Human labour ₹/ha	5858	19423	13752	2.35	Develop small scale planters & pickers
Seed mean ₹/ha	1086	3594	2544	2.34	Indigenous GM variety
Fertilizer mean kg/ha	98	222	222	2.26	Cotton cropping systems with nitrogen fixing legume crops (fodder, pulses & oilseeds) to strengthen INM & IPM at low production cost
Fertilizer mean ₹/ha	1769	5641	3884	2.26	
insecticide mean ₹/ha	1708	2429	1719	1	Early sowing of early maturing Bt varieties resistant to sap-sucking insects in HDPS
Cost of cultivation ₹/ha	23351	59051	41810	1.79	
Insecticide Mt for sucking pests	2909	6599	6599	2.27	Encourage domestic textile industry
Insecticide Mt for bollworms	6372	222	222		
Cotton Market value ₹/ha	29322	69679	49335	1.68	High density planting systems (HDPS) with compact varieties to obtain high yields
Yield mean kg lint/ha	362	506	506	1.39	
Net profit ₹/ha	5971	10628	7525	1.26	Develop India-specific IRM strategies and implement to delay resistance
% Bt area	1	92			

Source: <http://eands.dacnet.nic.in/>(*2011 ₹ data calculated at 2003 constant prices based on consumer price based on index <http://databank.worldbank.org/data/views/reports/tableview.aspx>)

STRATEGIC PLANS

Strategic plans to circumvent the challenges posed by chemical intensive cotton cultivation.

Plant Breeding Research for Yield Enhancement

- Enhance indigenous and exotic diversity of crop genetic resources in gene banks
- Phenotypic platforms for biotic and abiotic stress
- Breeding for marginal ecologies
- Breeding for climate resilient multi-diversity resistant varieties
- Breeding for resource-use-efficiency
- Breeding for organic agriculture
- Breeding for premium quality such as Extra Long Staple 38 mm, Strength 32 g/tex and Long Staple 30 mm, Strength 30 g/tex
- Focus on improvement of *Desi G. arboreum* and *G. herbaceum* varieties
- Marker Assisted Breeding (MAB) for validated markers. Multiple resistance breeding using Marker Assisted Selection (MAS) and marker assisted inter-specific trait introgression
- Centralized PGR (Plant Genetic Resources) management with Public-Private-Partnership (PPP)
- Development of heterotic pools and MS lines for hybrid development
- Indigenously developed GM (Genetically Modified) cotton for resistance to prioritized biotic and abiotic stresses using IPR protected genes.
- QTL pyramiding for Next-Generation varieties
- Enhance genetic variability, conservation of gene pool and germplasm enhancement
- Collection and characterization of germplasm of North East
- Sturdy Compact Early Maturing Varieties for low inputs and amenable for High Density (20 times the existing)

Strategic Research for Sustainable Resource Management

- Strengthen seed production chain
- Production of quality seeds and development of package of practices
- Conservation agriculture and efficient resources management
- Management of salinity, drought, heat and moisture stress
- Development of package of practices for organic & integrated farming system
- Technologies to reduce cost of cultivation
- Development of solar energy based pesticide application technologies

- Systematic replacement of hazardous chemical pesticides and fertilizers with eco-friendly alternatives for sustainable farming
- Use of nano-technology and nano-biotechnology for environment friendly pest management and insecticide selectivity with effective delivery systems
- Enforcement of pesticide safety guidelines, with heavy penalties imposed in the wake of evidence of undisclosed adverse effects on human health and environment
- Robotic approaches for efficient pest and nutrient management
- Technological interventions to make cotton seed suitable for edible purposes to be able to utilize the 22-24% seed proteins for human nutrition
- Cotton-legume rotations, intercropping, bio-fertilizers and microbial resources
- Cropping systems for nutritional security & comprehensive food security
- Technologies for water conservation and enhancing water-use-efficiency
- Remote sensing and GIS application to identify the magnitude of abiotic & biotic stresses
- Identification of length of growing period (by considering ETo, rainfall and water storage capacity of soils of different cotton growing region)
- Rainfall probability analysis and rainfall return period
- Conjunctive use of surface and ground water (for northern region)
- Cotton seed oil: enhancing nutrient quality
- Nanotechnology for enhancing chemical use efficiency
- Precision farming research
- Bio-fuels and energy from cotton cellulose especially farm waste utilization (fibre & stalks)
- Enhancing input-use efficiency of land, water, nutrients and labour
- Policy plans and perspectives for climate resilient crops
- Identification of most potent bio-pesticides and most effective strains for biological control
- Development of low cost, least energy intensive, bio-pesticide production technologies and eco-friendly formulations to enhance Bio-intensive IPM
- Identify ideal legume inter-crop systems to augment naturally occurring biological control
- Novel techniques for management of sucking pests - thrips, white fly, mealy bugs & vectors

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- Small-scale Mechanized cultivation and processing for small and marginal farmers
 - Bio-safety, Bio-security, food and feed safety

Strategic Research to Strengthen Socio-Economic Welfare

- Development of yield prediction and price prediction models
- Thrust on human resource development, sharpening the skills in newer techniques/technologies
- Utilization of high-tech devices for faster cotton based information dissemination through effective ICT interventions
- Studies on technology impact on behavioural changes of stakeholders
- Creating cotton based information network and farmer user-friendly decision support interactive systems in local languages
- Research on development of tools to identify priority based on needs of farmers and the cotton value chain industry
- Research on yield gaps and extension methods that can reduce the gap between technology development and adoption of technologies by farmers and the value chain industry
- Research on methods to strengthen public-private partnership involving farmers' groups, SHGs, NGOs at village level
- Development of curriculum and techniques for farmer training programmes to enhance awareness and skills of agribusiness entrepreneurship
- Research on gender issues in crop production, management and marketing
- Research on gender-specific resource use pattern and develop capacity development programmes for women
- Research on socio-economic dynamics of crop production and agrarian stress
- Research on small-scale farm entrepreneurship models
- Assessment and refinement of technologies in rainfed resource poor farming systems
- Development of technologies for market intelligence, marketing efficiency, technology impact, agri-business feasibility and returns to research investment

Focus on Basic Sciences

QTL and linkage maps

- From the Indian cotton research and improvement point of view, concerted efforts are needed to develop saturated genetic linkage map of diploid A genome and tetraploid AD genome cotton.

- Fine mapping of major QTLs employing diverse approaches such as linkage mapping with the help of large size population of RILs and linkage disequilibrium (association mapping) would help in mapping important QTLs identified by tightly linked markers and facilitate application of MAS in cotton.
- Cloning of major QTLs in cotton using comparative genomics of *Gossypium* and biotechnological tools to identify major QTL sequences, develop construct and clone major QTLs
- Cloning of alien useful genes *i.e.* Genes known for high strength from other species, higher cellulose deposition, biomass production, abiotic and biotic stresses using comparative genomics of different crops and transformation techniques
- Pyramiding QTLs for desired traits like drought, water logging, salinity tolerance by combining transformation techniques and marker assisted breeding in widely adaptive genotypes
- Developing and characterizing immortal introgression populations to reduce complex morphology into defined constituents amenable to genomic analyses
- Developing/identification of trait specific lines to be used for comparative expression profiling and genetic networks involved in expression of traits and understanding gene regulation
- Developing insight into the gene functions and biological processes important in fiber development and agronomic improvement
- Information on the relationship between candidate gene diversity and cotton improvement

Molecular Sciences

- Integrate phenotyping platform with genotyping to identify useful molecular markers
- High throughput Molecular characterization and DNA fingerprinting
- Association mapping and molecular linkage maps. Molecular markers and gene tagging
- RNAi for fundamental studies and trait improvement through genetic engineering
- Identification of miRNA and siRNA for gene silencing
- Allele mining and bio-prospecting of genes. Discovery of novel genes and promoters
- Functional genomics for trait enhancement. Integrate genomics, proteomics and metabolomics to tag economically important alleles/traits
- Basic research on stress mitigation and metabolic pathways

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- Elucidation of molecular pathways in nutrient-use-efficient crops/varieties
 - Elucidation of molecular pathways, cell and molecular physiology of abiotic stress of drought and salinity tolerance
 - Elucidating molecular mechanisms of phentotyping and developmental plasticity in cotton in response to myriad environmental cues or stress

Fundamental Science

- Basic studies on the resilience of *desi* varieties and land races
- Apomixis research to fix heterotic vigour
- New transformation methods for GM crop development
- Nano technology for diagnostics and gene transformation
- Basic research on soil health, water–nutrient interactions

Molecular Ecology

- Pollination ecology for enhancing crop/seed productivity in cross pollinated crops
- Research on plant volatiles, allomones, kairomones and antioxidants
- Isolation, characterization and synthesis of allomones, kairomones for major insect pests
- Elucidate genetic variability of major insect pests, parasitoids, predators and pathogens
- Research on new races/recombinants/biotypes of various pathogens and insects
- Strengthen taxonomy of insects and molecular systematics
- Basic ecological tri-tropic interaction studies to strengthen IPM
- Basic research on insect resistance molecular mechanisms for the management of insect resistance to Bt crops and insecticides.
- Molecular characterization of species specific genes that confer polyphagy and survival advantage in bollworms, armyworms and whiteflies
- Molecular characterization of Cotton Leaf Curl Virus

Combating Climate Change

- Develop cropping systems through conservation agriculture, minimum tillage, crop residue recycling with soil conservation techniques with cover crops to enhance soil organic matter and better carbon sequestration
- Develop cropping systems oriented towards organic agriculture of cotton with nitrogen fixing legume crops that can assist for least

dependence on chemical inputs, replenish soil nutrients and minimize pest and disease infestation

- Identify and consolidate non-chemical eco-friendly options for all crop management and production practices in cotton to minimize the dependence on chemical inputs
- Redefine seasonal suitability window of varieties based on the changing climate to ensure better adaptability for high yields
- Optimize all inputs including water and chemicals to prevent wastage
- Develop robust varieties for rain-fed farming, with resilience to biotic (insects and pathogens) and abiotic stress factors (drought, salinity and water-logging) related to climate change
- Develop early maturing varieties that can escape drought stress
- Develop agronomic practices for better weed management, proper light interception, and enhanced nutrient and water use efficiency
- Develop cotton production systems with emphasis on low inputs and high productivity in rainfed regions

Co-ordinated and Network Projects

- Orienting all experiments towards agro-eco-zones
- Development of agro-eco zone relevant technology assessment methodologies
- Removal of redundancy in experiments across AICRP centres
- Development of field gadgets for efficient data collection, decision support software for efficient analysis and interpretation of multi-location data

New Infrastructure

- New 'Basic Research' & 'Centres of Excellence' on cotton
- Phenomic-platform infrastructure to characterize genetic resources
- Referral labs on GM cotton and pesticides
- Renewed missions on oilseeds, pulses, fodder and nitrogen fixing crops integrated with cotton

Consolidation of Linkages

International

- Linkages with IRRI, ICGEB, CIMMYT, ICRISAT, ICAC, IBPGR, Bio-21 Biodiversity International – Rome, International Food Policy Research Institute (IFPRI), Indo-American Knowledge Initiative, International Centre for Agricultural Research for Dry Area (ICARDA), IITA- International Institute for Tropical

Agriculture (legumes, cereals and pulses), CSIRO, Australia (cotton and pulses)

National

- Linkages with NBRI, NCL, PPV&FRA, NBA, DBT, DST, Ministry of environment and Forest, APEDA, NHB, DAC, IMD, ISRO/ Remote Sensing Application Centres and Crop Development Boards



Epilogue

A vision for the next 35 years is a huge challenge. A vision for a commercial commodity such as cotton in a country like India -which is a kaleidoscope of myriad hues in every stakeholder sphere, is a monstrous challenge. Given the resilience of the country, and the propensity to spring surprises in the form of scientific and innovative technological brilliance, a vision for 2050 has to be imaginative enough to capture the probable unexpected technological events. This vision presents a broad canvas that contains a spectrum of thoughts which can only serve as steps for the younger minds who can eventually give complete shape to the edifice of future. Can India ever emerge as the global leader with the highest global productivity level? With the immense strength of ideas, will power and talent available in the country, it would be surprising if that does not happen by 2050 at least.

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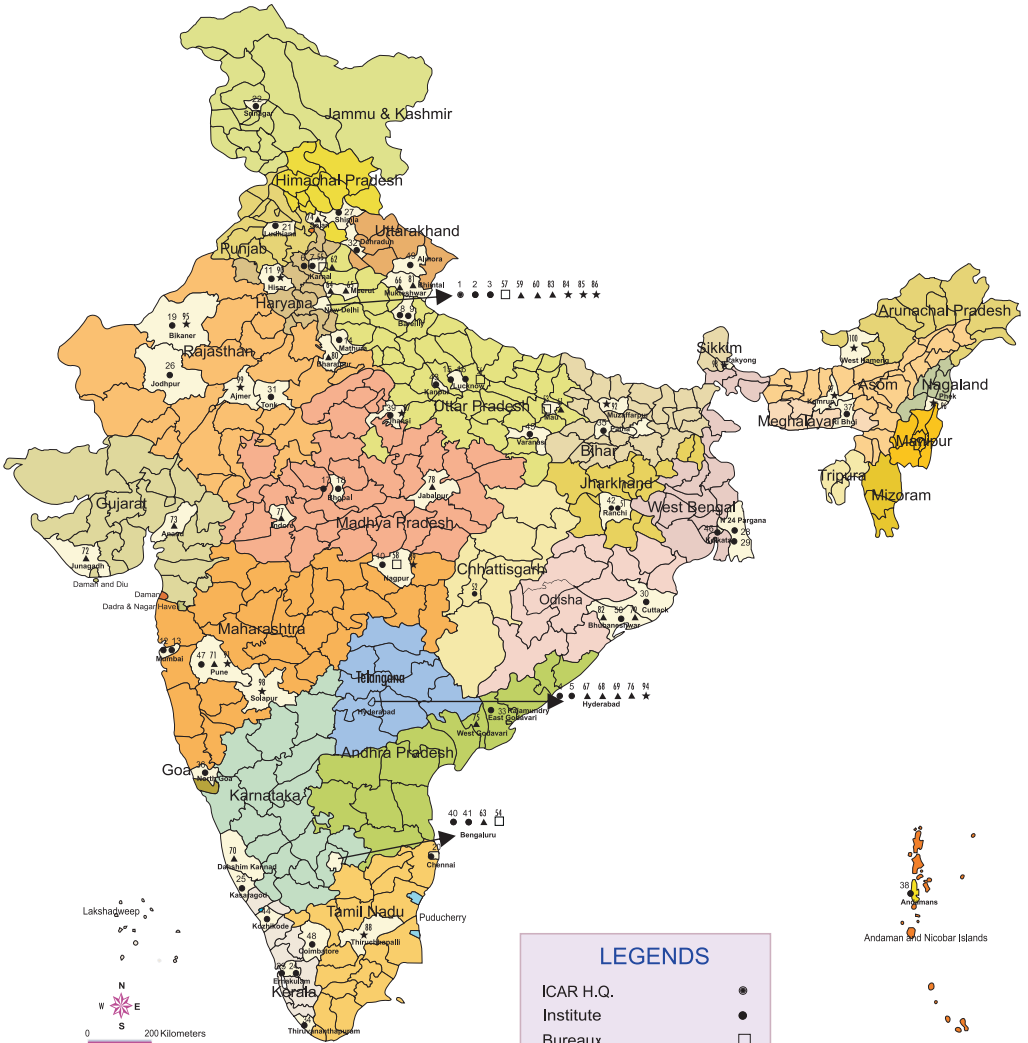
Agricultural Universities





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Institutes, Bureaux, Directorates and National Research Centres



● 64 Research Institutes ● 6 Bureaux ● 15 National Research Centres ● 15 Project Directorates



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