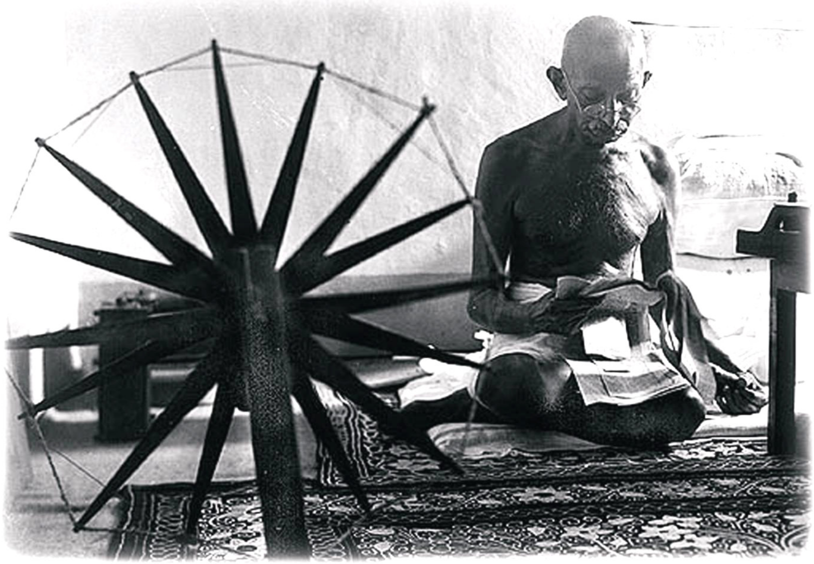

VISION 2025

CICR PERSPECTIVE PLAN

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ICAR

CENTRAL INSTITUTE FOR
COTTON
RESEARCH, NAGPUR

VISION - 2025

CICR PERSPECTIVE PLAN

CONTENTS

VISION 2025

CICR PERSPECTIVE PLAN

VISION

Improving production and quality of Indian Cotton (including the development of transgenics resistant to biotic and abiotic stresses) with reduced cost to make cotton production cost effective and competitive in the national and global market.

MISSION

To develop economically viable and eco-friendly production and protection technologies for enhancing quality cotton production by 2-3% every year on a sustainable basis for the next nineteen years.

PREAMBLE

Cotton plays a key role in the National economy in terms of generation of direct and indirect employment in the Agricultural and Industrial sectors. Textiles and related exports of which cotton constitutes nearly 65% account for nearly 33% of the total foreign exchange earnings of our country which at present is around 12 billion dollars with a potential for a significant increase in the coming year.

After independence, the erstwhile Indian Central Cotton Committee, one of the many commodity committees extant that time used to sponsor cotton research schemes on an adhoc basis till the work was taken over by the ICAR in 1966. Further the research efforts under All India Coordinated Cotton Improvement Project (AICCIP) was initiated by the Council in the year 1967. The establishment of AICCIP gave new fillip and direction in terms of multi-disciplinary and multi-centre approaches with the active involvement of Sate Agriculture Universities. The work in this project has contributed significantly in tackling location-specific problems in terms of varietal improvement and development of appropriate production and protection technologies. However, looking to the long term projections in respect of quantum and quality requirements of cotton and looking to the low level of productivity which is primarily due to the fact that the major cotton growing area is under rainfed conditions constantly exposed to vagaries and uncertainties of monsoon patterns in terms of total precipitation and distribution coupled with the varying level of pest and disease incidence, the necessity for expanding the research efforts in the spheres of basic and fundamental research and generate appropriate scientific data base for bringing in quantum jump in productivity through appropriately tailored applied approaches and technology was comprehended and accordingly the Central Institute for Cotton Research was established at Nagpur in the year 1976 by the ICAR. The erstwhile Regional Station of IARI at Coimbatore (Tamil Nadu) became a part of CICR simultaneously to cater to the needs of southern cotton zone. In the year 1985, the IARI Regional Station at Sirsa (Haryana) was transferred to CICR as a regional centre for the northern irrigated cotton zone.

CICR - MANDATE

Existing

- **To conduct basic and strategic research on cotton to improve yield, fiber quality and by-product.**
- **To create new genetic variability for location-specific adoption in cotton based cropping systems.**
- **To assist in the transfer of modern cotton production technology to various user agencies.**
- **To extend consultancy and link with international agencies to accomplish the above mandate.**

Proposed

- **To conduct basic and strategic research on cotton to improve yield, fibre quality and by-products.**
- **To create new genetic variability for location-specific adoption in cotton-based cropping systems.**
- **To manage the natural resources like soil, water and climate, more efficiently and to improve the efficiency of inputs for cotton, plus cotton based cropping system for reducing the cost of cultivation and to maintain the soil health for sustainable cotton production under eco-friendly environment.**
- **To extend consultancy and link with national and international agencies to accomplish the above mandate.**
- **To assist in the transfer of technology and to provide human resource development support at national and international level.**

AICCIP - MANDATE

- **To develop improved genotypes suitable for varied agro-climatic regions of the country in which cotton is grown.**
- **To develop production technologies to maximize yield from improved genotypes.**
- **To develop effective and economic insect pest and disease management practices.**

A multi-disciplinary (Breeding and fibre technology, Soil Science, Agronomy and Physiology, Entomology and Plant Pathology) and multi-location approach was envisaged to realize these objective quickly.

GROWTH

From a modest beginning the Institute has expanded considerably in terms of infrastructure and human resource development at all the three centres viz. Nagpur, Coimbatore and Sirsa.

Infrastructure

The Institute started functioning in 1976 in a small building provided by Punjabrao Krishi Vidyapeetb (PKV) but later on was shifted to rented buildings in the Nagpur city. The Institute was provided with two farms on lease by PKV at Phutala and State Department of Agriculture, Maharashtra State, at Panjri.

Nagpur : The main laboratory and administrative building was completed in the year 1986 and all the laboratories and the administrative wings were shifted to the new premises at Panjri Farm. Gradually over the years, good laboratories came into being in different disciplines with ample working space, sophisticated instruments centrally air-conditioned laboratories, good computer facilities etc. The Institute at present is having reasonably good laboratories, even though considerable scope exists for bringing about further improvement, keeping in view the emergence of some of the frontier areas of research such as genetic engineering, biotechnology etc. Pot house facilities in terms of glass house and three net houses were also constructed during the past.

Coimbatore : The laboratories in the initial stages were located in different buildings. After the construction of another laboratory building adjacent to the main building, most of the laboratories are presently functioning in these two buildings. Two glass houses, seed storage lab and insectory were also constructed in the recent past.

Sirsa : The laboratories inherited from the erst-while IARI Regional Station were strengthened with the provision of some sophisticated equipment and facilities including computer facility.

Library

Nagpur: From a modest beginning in 1976, the Institute has built up a reasonably good library facilities in terms of research journals (Indian & foreign), annual reviews, books, reports, reprints, proceedings etc. The library has a collection of about 3200 books, 3300 periodicals, 1750 reports & bulletins and 80 journals (30 foreign and 50 Indian) pertaining to various disciplines with special reference to cotton are being subscribed. Seven hundred reprints on cotton from the journals which are not being subscribed by the library have been collected.

Library has developed and designed 'Computerized Bibliographic Data-base on Cotton' to provide comprehensive and exhaustive information on cotton literature. Documentation services, such as Current awareness services, Retrospective search services, SDI service are being provided by using the data-base.

A quarterly abstracting bulletin entitled 'Cotton Research Abstracts is being brought out on a regular basis and circulated to all the cotton research centres in the country. At Coimbatore and Sirsa centres moderate library facilities are also available and which are being strengthened.

Liabray provides CD-ROM database search & retrieval service by using following databases. CAB Abstracts ; CROPCD; AGRICOLA; AGRIS;BIOTECH ABSTRACTS

Farm

Nagpur : In the initial stages the Institute had two farms for field research one of 41.77 hectares at Panjri and another of 20 ha. at Phutala on National High Way No.6. After shifting to the main building in 1986, the farm at Phutala was handed over to PKV. Simultaneously the Institute has acquired additional land of 134.32 ha. adjacent to Panjri Farm. Now a comprehensive block of 176.09 ha. is available for the institute needs at Panjri Farm. Concerted efforts were made within the allocated funds to develop the entire farm into a good research farm in terms of creation of blocks, levelling and digging of tubewells for providing irrigation to some specific areas etc. Labour sheds and farm buildings were constructed in each of the three blocks. Pucca roads are being laid to cover part of the farm area.

Coimbatore : The regional station has two farms, one farm of 18 ha. near TNAU where the regional station buildings are located. This is a well developed farm with good irrigation facilities for conducting research on irrigated cotton. Farm office building was constructed recently to accommodate the farm infrastructure. The other farm of 20 ha. is situated near the Sugarcane Breeding Institute and is nearly 6 km away from the main research farm. This farm has to be developed considerably in the coming years.

Sirsa : The regional station has 20 ha. well developed farm for research purpose with provision for irrigation facilities.
All the three research farms are well equipped with tractors and other farm implements and efforts are underway to initiate further developmental work in all the farms.

Buildings

Nagpur
The Institute at present is located in a spacious building accommodating administrative wings, laboratories, library, museum with ample working and sitting space for the scientists and other officials. Some of the laboratories have been provided with centralised air-conditioning facility. One glass house and three net houses were also constructed to meet the research needs of some of the disciplines. However, with the expansion of the Institute activities including the training programmes etc. the need arises for the construction of the following buildings in the coming years.

- Library cum museum building
- Auditorium
- Administrative block
- Scientist home cum Guest house
- Additional laboratory space, by constructing additional floors in the Annexe.

In addition to the laboratory building the Institute has one single storied farm building and ample godown space. In each of the farm block small buildings have been constructed for housing the farm offices, stores and implements in addition to labour sheds.

Residential Quarters
Nagpur : Twelve residential quarters have been constructed at Panjri farm to accommodate farm staff while in the city in the common ICAR residential complex along with NBSS & LUP, the Institute has 53 quarters of different categories. However, the need exists to construct some more quarters in all the categories (type I to VI) to accommodate the expanding requirements in the coming years.

Coimbatore : Initially the regional station had one main building and few tiled buildings accommodating the laboratories, administrative and farm wings. One additional laboratory building adjacent to the main building was constructed in the recent past. Recently, one farm building, two glass houses, seed storage facility and insectory were constructed. The need, however, exists to strengthen the building infrastructure at Coimbatore keeping in tune with the expansion of the R&D activities along with the construction of a guest house.

Sirsa : The regional station has one main building, housing all the functional units of the regional station. Nineteen (19) residential quarters are also available.

Other Facilities

Nagpur : The Institute is located 14 km away from the city and since public transport facilities are not adequate, the transport facilities have to be strengthened considerably to meet the growing demands. At present the Institute has one 52 seater bus, two mini buses, three jeeps and one staff car.

Coimbatore : To strengthen the transport facilities already available one mini bus and one jeep need to be provided .

Sirsa : Regional Station has one jeep catering to the requirements of the station. Looking to the expansion envisaged in the coming years one minibus needs to be provided.

Budget

(Rs. In Lakhs)

Plan period	Plan	Non-plan	Others (Plan Scheme)	Total
1981-85	319.04	199.82	70.78	589.64
1985-90	367.18	476.99	28.59	872.76
1992-97	500.00	1722.00	119.40	2341.40
9th Plan	841.10	3364.60	2648.20	6853.90
10th Plan	814.00	4769.11	4243.00	7826.11

Manpower

Plan period	Scientific	Technical	Administrative	Auxiliary	Supporting
6th Plan up to 1984	51	64	49	--	
7th Plan	88	84	57	17	
8th Plan	88	100	59	18	
9th Plan	88	99	54	-	138
10th Plan	88	95	53	-	132

SALIENT RESEARCH ACHIEVEMENTS

Crop Improvement

- **Cotton Gene Bank:** The National Centre for Cotton Genetic Resources with more than 9000 accessions of the four cultivated species of *Gossypium* and over 100 accessions of perennials including wild species and cytogenetic material *(in situ* in species garden) has been established at CICR, Nagpur. Germplasm lines were screened and a good number of lines with good agronomic based, superior fibre quality and resistant to pests and diseases were identified and distributed to end-users.
- **Varietal Improvement:** The Institute has released ten varieties of *G.hirsutum* (MCU 5 VT, LRA 5166, Supriya, Kanchana, Anjali, CNH36, Arogya, Surabhi, Sumangala and CNH 120 MB), five intra-*hirsutum* hybrids (Savitha, Surya, Kirthi, Omshankar and CSHH 198), two *hirsutum* x *barbadense* (inter- specific) hybrids (HB 224 and Shruthi), and one intra arboreum hybrid (CISAA 2). The variety LRA 5166 occupies the largest acrease in India (Table 1)
- Several multiple adversity resistant (MAR) lines having resistance to grey mildew, alternaria leaf spot and bacterial leaf blight have been developed.
- Study of different methods of breeding and selection for improvement of seed oil and lint characters resulted in the identification of high yielding early maturing cultures with improved oil content. Biparental section was found to be ideal for transferring high oil content. Crosses between genetically diverse parents had greater degree of hetrosis for oil.

Labour intensive hand picking

- Two promising semi dwarf cultures (CNH 123 and CNH 155) with high yield potential and with amenability to closer spacing have been developed and are in advanced stages of testing in All India Coordinated Cotton Improvement Project trials.
- Few male sterile plants have been identified in the derivatives of multispecies hybrids involving wild species *G.raimondii*, *G.thurberi* and cultivated species *G.hirsutum* and *G.barbadense* which are cytomorphologically stable.
- Wild species were used for introgression of useful characters and also for identifying new source of CMS. Elite lines with economic attributes and marker genes were isolated in the inter-specific hybrid derivatives. Gene for immunity to bacterial blight was introgressed into G.*hirsutum* from G.*anomalum* and dwarf early maturing bacterial blight immune variety NISD-2 was evolved.
- Factors associated with drought tolerance were assessed and promising drought tolerant cultures CNDTS-2, CNDTS-3, CNDTS-5 and CNDTS 23 were identified.
- By anatomical and biochemical studies it was deduced that gossypol content in the ovary was the most important deciding factor associated with bollworm tolerance.

- Breeder seed production is being taken up in this Institute. Useful information on seed production technology have been generated. Hard seed coat in H4 was found to have been inherited from female parent. Exposure of seed to 90 ^{0}C in water or soaking the seed in ethyl alcohol for 10 minutes helped in overcoming hard seed coat.

- 20 ppm NAA and 2% DAP sprayed four times during crossing period improved hybrid seed yield. To overcome the adverse effect of injury during emasculation, 50 ppm GA_3 application helped in improving boll setting and hybrid-4 seed yield and not in any other hybrid tested.
- Topping 30 days after square initiation and foliar application of Lihocin 50 ppm improved the seed quality. By crop trimming of parents of GMS based hybrids three crops could be taken up with 30 to 40% reduction in seed production cost. Higher dose of nitrogen followed by boron and zinc foliar spray improved seed quality and yield. Use of honeybee for hybrid seed production was found to be useful.

Table 1. List of Varieties/ Hybrids Released by CICR

Varieties/ Hybrids	Year of release	Spinning potential (counts)	Area of adaptability	Remarks
G.hirsutum				
MCU5VT	1982	60s	Verticillium wilt prone tracts of Tamil Nadu	Verticillium wilt tolerant
LRA 5166	1982	30s-40s	Rainfed and irrigated tracts of southern cotton zone & Vidarbha (Maharashtra)	Drought tolerant & adaptable to different agro-climatic conditions
Supriya	1984	40s-50s	Irrigated tracts of southern cotton zone	Whitefly tolerant
Kanchan	1988	40s	Whitefly prone area of southern cotton zone	Whitefly tolerant
LRK 516 (Anjali)	1992	40s	Rainfed and irrigated conditions of Maharashtra, Gujarat and south Rajasthan	Early maturing, compact & semidwarf, suited for closer spacing
CNH 36	1993	40s	Irrigated areas of western Maharashtra and southern and middle Gujarat	Dwarf early maturing
Arogya	1995	12s	Rainfed areas of central zone	Bacterial blight immune
Surabhi	1997	50s-60s	South zone	Verticillium tolerant, extra long

				staple, high yielding than MCU 5 VT
Sumangala	2000	30s-40s	South zone	-
CNH 120 MB	2001	30s	Irrigated areas of south zone, also suitable for rainfed condition.	Compact, early maturing, medium staple with high fibre strength.
Intra-specific hybrid (Intra *hirsutum*)				
Savita	1987	60s	Irrigated tracts of southern cotton zone	Intra-*hirsutum* hybrids of MCU 5 quality
CICR HH1 (Kirti)	1992	40s	Rainfed areas of Marathwada region of Maharashtra	Early maturing hybrid
TM 1312 (Surya)	1994	50s-60s	Southern zone	Presence of genetic marker character
OM- Shankar	1997	30s-40s	Northern cotton belt	Early maturing, high yielding hybrid
CSHH 198	2004	50s	Northern cotton belt	ClCuV resistant
Interspecific Hybrid (*G.hirsutum* x *G.barbadense*)				
HB 224	1989	80s	Irrigated tracts of southern cotton zone	Extra long staple hybrid
Shruthi	1997	80s	Southern cotton zone	Compact, short duration hybrid
Intra-*arboreum* Hybrid				
CISAA2	2004	10s	Nothern cotton zone	GMS based hybrid

Some unique cultures/lines were registered with NBPGR as Indian National Genetic Resource Table 2.

Table 2: Genotypes registered with NBPGR

Name of the material/ designated material	Genera and species	Race	Registration No.	Year of Registration/ Patent	Unique characters
G 135-49	*Gossypium arboreum* L.	Bengalense	INGR No.00017	Notification date 10.5.2000	Immune to all Grey mildew (*ramularia areola* Atk.) disease isolates existing in nature at present.
30805	*Gossypium arboreum* L.	Cernuum	INGR No.00018	Notification date 10.5.2000	-do-
30838	*Gossypium arboreum* L.	Cernuum	INGR No.02020	Notification date 22.5.2002	-do-
CNH 123	*Gossypium hirsutum* L.	Latifolium	INGR No.02021	Notification date 22.5.2002	Resistant to Cotton Leaf Curl Virus (CLCuV)
CINA 316	*Gossypium arboreum* L.	Bengalense	INGR No.04079	Notification date 31.5.2004	High locule retentivity and low short fibre content
LRA 5166 (GMS)	*Gossypium hirsutum* L.	Latifolium	INGR No.02012	Notification date 22.5.2002	Converted into GMS line.
CNO 131	*Gossypium hirsutum* L.	Latifolium	INGR No.00010	Notification date 10.5.2000	Earliness and high seed oil content.

Biotechnology

- Bt cry genes producing 44 M Da and 97 M Da from Bt – KHD-1 were cloned into pUC18 and recombinant were screened for production of toxins by bioassays against *Helicoverpa armigera.*
- Using shoot tip or meristem explants a protocol was standardized for direct shoot organogenesis. This protocol curtailed genotype dependent regeneration in cotton.
- A simple, reproducible protocol for Genetic Transformation and direct shoot organogenesis was standardized with Indian Genotype. Elite Indian cotton *G. hirsutum* CV viz, LRA 5166, Anjali (LRK 516) and *G. arboreum* CV viz, RG-8, PA 255, PA 402 were transformed with Bt cry I Ac and cry I Aa3 genes. The transformed plants were analysed for the Bt genes integration by PCR and Southern blot technique and the expression was assayed by ELISA test.
- Proteinase inhibitor gene was amplified and isolated from *G. hirsutum* CV LRK –516 by polymerase chain reaction. The gene was characterized by sequenced analysis and confirmed the expected fragment size as full-length gene of 0.650 Kb. Drought resistant genes such as dehydrin and osmotin were isolated from drought resistant genotypes. The dehydrin gene was amplified as 1.2, 0.7 and 0.5 kb and it showed that dehydrin gene might be a multigene family.

- Cotton plants were subjected to root nodule induction by *Rhizobium fredii,* which is isolated from *G. max.* Six individual plants of Anjali and two of LRA 5166 produced nodules in their root system. Nodules were characterized and nitrogenase activity was estimated by AR-method. Although the nitrogenase activity was found nil, the Bacteriods were present in the nodules. However, this result opens up the possibility of nodulation and nitrogen fixation by virulent Rhizobia, in non-legume plants like cotton.

- Identification of molecular polymorphism among the parents (CLCuV resistant (CNH 123, CNH 1012) and susceptible lines (CNH 1020, CNH 120) was carried out with 80 primers. The F_2 mapping population was developed. Ten resistant and susceptible F_2 DNA were pooled for bulk segregant analysis and amplified with the primer OPC 02, which produced the 1700 bp fragment and confirmed it repeatedly. This fragment has been converted into SCAR marker and the primer pair designed was 5' GTGAGGCGTCAGAGGGAT-3' (forward) and 5'-GTTGCCGTGCACTAGGCT-3' (reverse). The F_2 segregating RAPD loci were mapped using Mapmaker programme into ten groups. The primer sequence was designed for marker-assisted selection for screening the segregating population.
- Eletrocphoretic studies revealed the polymorphic bands in wild species. Polymorphism indicates a higher degree of diversity amongst wild species.

Crop Production

Nutrient Management

- Sulphur coated urea and neem cake coated urea improved the efficiency of applied nitrogen as compared to normal application of urea under irrigated condition, while for the rainfed conditions urea + FYM followed by neem cake treated urea were found to be efficient.

- Sprays of diammonium phosphate in low concentration (0.2 %) during active phases or reproductive growth significantly increased the yield of seed cotton.
- Supplementing half the recommended dose of fertilizer N with FYM viz. N_{30} P_{30} K_{30} + 5t FYM/ha and N_{45} P_{45} K_{46} + 7.5 t FYM/ha significantly increased seed cotton yield over N_{60} P_{30} K_{30} and N_{90} P_{45} K_{45} besides improving the soil organic matter status in rainfed cotton grown in vertisols.

- Sulphur application @ 10 kg ha significantly increased the seed cotton yield and dry matter production in LRA-5166 while in H4 (an intraspecific hybrid) a linear response upto 20 kg/ha was observed.
- Hybrid-4 (an intraspecific hybrid) was found to be more nutrient efficient and less exhaustive of soil nutrients as compared to varieties (SRT-l and AKH-4).
- Cotton under rainfed conditions responded to phosphate application at 40 kg P_20_5/ha placed at 7.5 cm depth in vertisols.
- Foliar application of 2 % urea or DAP at 60 and 80 DAS improved the seed cotton yield by 15 % in cotton varieties and hybrids.
- In the studies on long term effect of nutrient management, cotton - sorghum rotation out yielded cotton monocrop by 38%. *G.arboreum* out yielded *G.hirsutum* by 32-35%. Significant build-up in soil organic carbon was seen with FYM application.
- Alternate sprays of potassium at 1 % and DAP at 2% concentration (two to three sprays each at 15 days interval from first blooming) was beneficial for high yielding and high strength, higher count cottons.
- Vertical and horizontal stratification of ammonium-N available P and exchangeable-K was observed by placement of fertilizer in row and minimizing tillage operations in vertisols.
- Yields equivalent to N_{90} P_{20} K_{38} could be achieved with N_{30} P_{13} K_{25} + 5 tonnes FYM.
- Seed treatment with biofertilisers (*Azotobacter chrococcum* and *Azospirillum brasiliense*) with half the recommended nitrogen dose gave seed cotton yield more than the recommended dose of fertilizers

- Micro nutrient application (Zn_{10}, Mn_{10} and B_3 kg/ha 75 % soil and 25 % foliar spray) improved seed cotton yield by 25 % under two supplemental irrigations.
- Chelated sprayable micro nutrient concentrates were developed and found satisfactory in farmers' field trials.

Nitrogen Use Efficiency (NUE)

- Use of Neem cake coated urea and 5% gypsum coated urea was found to increase seed cotton yield and NUE.
- Nitrogen application in 3 splits half as basal, ¼ at 45 DAS and ¼ at boll development is for varieties as well as hybrids under rainfed conditions.
- Application of N_{60} P_{13} K_{25} helps to stabilise productivity at around 1000 kg seed cotton/ha.

Stabilising productivity : Resource poor soils

- Application of FYM @ 5 t/ha, soil incorporation *in-situ* grown fodder legume and further addition of 10 t/ha subabul or sesbania lopping at 45 DAS supplied available nutrients and also helped in conserving 2% additional moisture, resulting in increasing seed cotton yields by 15-20% over the recommended N_{60} P_{30} K_{30} in resource poor soils.

Water Management

Nagpur

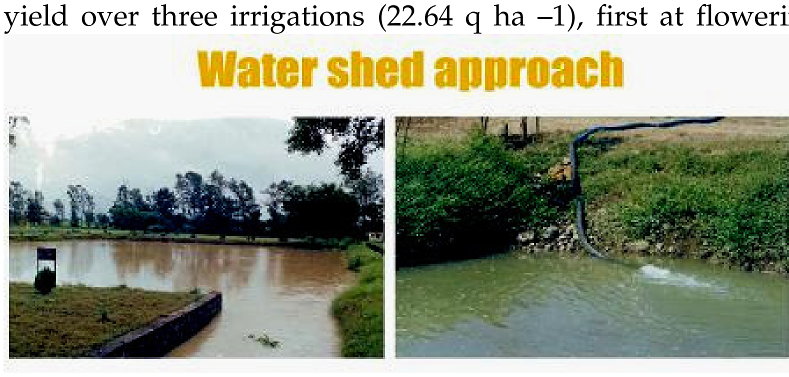
- **Ridge and furrow system :** Out of the various moisture conservation practices, tested over the years in 40 farmers' field on upper, middle, lower and bottom toposequences, ridge and furrow moisture conservation practice across the slope was evaluated as the best system and effective in reducing runoff, increasing percolation, conserving water and improving the recharge capacity of irrigation wells.

Rain Water Management – Watershed approach:

- About 4-5 lakh litres of excess run- off water can be harvested from one-hectare catchment area, which can be stored in field ponds of size 18x18x3 m.
- 0.7 to 1.0 ha area in medium deep and deep soils could be irrigated at early boll to peak development stage using harvested rainwater.

Recycling of harvested rain water

- Two irrigations of harvested rain water, first at flowering and second at boll development stage has given maximum (23.30 q ha-1) seed cotton yield over three irrigations (22.64 q ha –1), first at flowering, second at early boll development and third at peak boll development stage.



However, instead of giving two and three irrigations, one irrigation at peak boll development stage was found economical. One protective irrigation to cotton @ 4 ha cm of water maintained superiority over in-situ moisture conservation and enhanced seed cotton yield morethan a q/ha.

Micro Irrigation Management

The harvested rainwater was utilized for providing one or two irrigations to cotton crop. More than 90 % irrigation efficiency has been recorded with improved yield and quality of fibre.

However, with the use of drip irrigation following benefits have been recorded:

Water saving	-	About 50 – 53 %
Fertilizer saving	-	30 – 50 %
Water application efficiency	-	69 %
Water storage efficiency	-	83 %
Water distribution efficiency	-	17 %
Coefficient of uniformity in moisture distribution	-	98.2 %

- Skip row (2:1) irrigation and alternate furrow irrigation have proved most profitable in saving irrigation water without affecting seed cotton yield.
- Drip irrigation with 70% of water and 50% of the nutrients used in flood method was found better with higher yields.

Coimbatore

- Fertigation saved 50% water and 25% fertilizer compared to conventional practices.
- Paired row technique with drip and cowpea intercrop resulted in 50% saving of laterals cost for drip system in addition to additional income through cowpea and effective weed control.

- To reduce the cost of drip irrigation system, poly tube laterals (600 gauge) were used, which was found to give maximum gross return (Rs.47951/ha), net return (Rs.17151/ha) and benefit cost ratio (1.56).
- Growing cotton under polymulch enhanced seed cotton yield by 2.32 fold besides 40% water saving and complete control of weeds.

Soil Depth

- Soil depth plays an important role in yield maximisation of rainfed cotton. Seed cotton yield was increased with increasing soil depth. Maximum seed cotton yield has been recorded in deep (> 90 cm) soils and the minimum in shallow (< 45 cm) soils. However, the optimum soil depth for rainfed cotton cultivation was evaluated in between 67 to 110 cm soil depth.

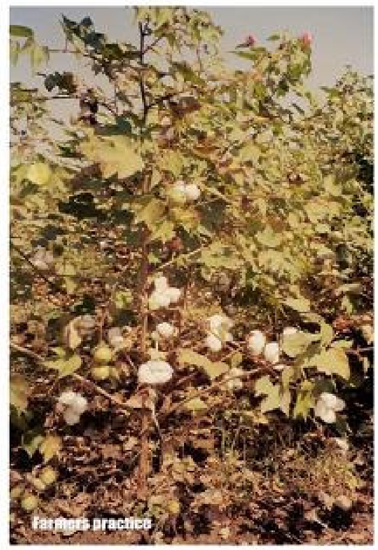
Cropping systems

- LRA 5166 was more amenable than LRK 516 for intercropping. PUSA 16,

PK 472, PKV l, Soybean genotypes showed better complementarity in inter cropping

Efficient cropping systems
Nagpur

- Green gram and black gram were identified as suitable intercrops for varieties grown in wider spacing (90 cm) and hybrids. For irrigated southern region, cowpea and small onion were found to be best suited for intercropping.
- Of the several soybean genotypes, five were identified compatible for intercropping with cotton Punjab 1, TAS 40, Pusa 16, PK 472 and PKV 1.
- Cotton intercropped with cowpea harbours more of coccinellids and in addition to higher parasitization.
- Intercropping of greengram with cotton enhanced maximum WUE of cotton by 2.46 kg ha^{-1} mm^{-1}, while blackgram (2.40 kg ha^{-1} mm^{-1}) and the minimum (2.01 kg ha^{-1} mm^{-1}) under control. Similarly, two irrigations, first at flowering and second at boll development stage has given maximum (3.20 kg ha^{-1} mm^{-1}). WUE closely followed by (3.11 kg ha^{-1} mm^{-1}) one irrigation at peak boll development stage and the minimum (2.20 kg ha^{-1} mm^{-1}) under control.



Coimbatore

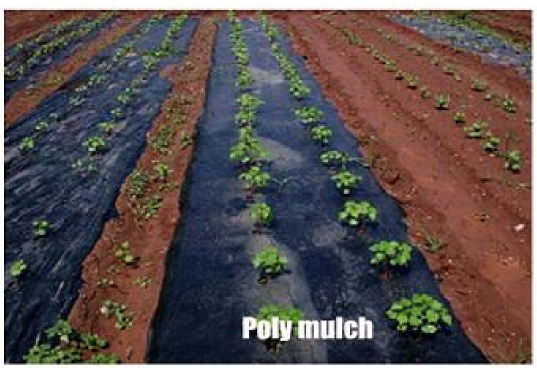
- Maize, when grown as a rotation crop after cotton in the same polymulch sheet with zero tillage, gave 2.78 tonnes/ha of additional yield than conventional system.

- The highest seed cotton yield (14.21 q/ha) and the maximum gross return (Rs. 23445/ha) was obtained with intercropping of one row black gram between cotton rows which was closely followed by cotton + green gram intercropping system (14.19 q/ha) and cotton + soybean system (13.88 q/ha) under rainfed condition.

- Multitier intercropping of radish and amaranthus planted between cotton rows under normal planting method registered the higher gross return (99%), net return (252%), benefit cost ratio (81%) and seed cotton equivalent yield (99%) than sole cotton crop.
- Diversification of cotton by rotating with jowar (*Sorghum bicolor*) for both grain and fodder has substantial benefits in terms of quantity and quality of outputs besides improvement of soils.

Tillage and residue management

- Reduced tillage system comprising pre-plant herbicide application and one pass of harrow and two inter-row cultivation for early and late season weed control, respectively, was found to be a viable technology to cotton growers of Central India.



- Deep ploughing once in two years before cotton sowing was found effective in increasing the yield of irrigated cotton – wheat system
- Conventional tillage (one time disc + two time cultivator) for irrigated wheat was found beneficial in increasing the yield of irrigated cotton – wheat system.
- Cotton stalk and wheat straw shredded and incorporated in the soil after crop harvest was found helpful in improving soil fertility and yield of cotton-wheat system under irrigated conditions.

Biofertilizers

- Application of Azotobacter, in combination with Azospirillum + PSB without organic manure and fertilizers has been found to result in a 50% saving of nitrogenous fertilizers bill without any reduction in yield.
- Bio-inoculants tolerant against synthetic and adverse climatic conditions were identified for use in cotton-wheat/soybean based cropping systems with 11-15% improved yields. Liquid Bio-inoculants were tested and found suitable in farmers fields.
- Pink pigmented facultative methylotroph (PPFM) isolated from cotton phyllosphere has improved the vigour index of cotton and helped in sulphur oxidation and P solubilization.

Mechanization

- Imported cotton picker was evaluated at CICR for a its performance under Indian conditions.
- Bullock and tractor drawn cotton planters were developed.

Cotton picker

Organic cotton production

- Institute developed a technology for organic cotton production using organic soil amendments and biocontrol based pest management with the following key inputs.

Organic soil amendments	Biocontrol based pest management
Farm Yard Manure @ 5 t/ha	Release of *Chrysoperla* sp @ 500-1000/ha 20-25 DAS and at 35 DAS.
In-situ green manure with fodder cowpea at 40 DAS	Release of *Trichogramma* @ 5 cards/ha at 45 DAS.
Spreading loppings from Sesbania spp. obtained from 2m dense rows after 10 cotton rows.	Spray of H-NPV @ 250 LE for young bollworms of *H. armigera.*
Vermicompost prepared from farm waste including cotton stalks and weeds @ 2 t/ha	Alternate spray with B.t formulation @ 1.5 l/ha.
Seed inoculation of *Azotobacter* @ 500 g/ha seed.	Release of *Bracon hebator* to kill bollworm larvae. Bird perches @ 4/ha.

Abiotic Stress Management:

- **Drought tolerance:-** The drought tolerance in Asiatic cotton was found to be associated with deep root system, higher root/shoot ratio and leaf transpirational cooling, whereas in American cotton enhanced leaf water status due to higher stomatal resistance led to dehydration avoidance. Tolerant genotypes possessed higher antioxidant enzymes viz. catalase and peroxides. Application of pix (25 or 50 ppm) at floral initiation stage and Kaolin (12%) one month after cessation of rains was found to enhance the water use efficiency.
- **Salinity tolerance:** Most of the cotton cultivars and germplasm lines could with stand salinity levels of 7 to 8 ds/m without significant reduction in growth and yield. Asiatic cotton show better tolerance to salinity compared to upland cotton. The leaf area expansion is more sensitive to salinity compared to photosynthesis. Tolerant genotypes could maintain cellular osmotic potential by accumulation of osmolytes such as proline and k+. They had higher K/Na ratio in roots and leaves.
- **Water logging tolerance:** Cotton is very sensitive to waterlogging at early seedling and squaring stages with drastic yield reduction. As a morphological adaptation, plants produce specialized cells known as hypertrophoid lenticels at the zone of submergence which facilitates the transfer of O_2 from shoot to root to maintain root

activity. At the metabolic level tolerant genotypes possessed higher Alcohol dehydrogenase (ADH) enzyme activity. Response of plants to waterlogging was again found to be genotype x environment specific. Genotypes with large canopy and heavy boll load show wilting known as parawilt under bright light and high temperature.

- **Anatomical changes due to water logging:**The anatomical change in the collar region of the stem-root during water logging was studied in detail. The lenticels formation, its rate of development and production of newer roots in cotton genotypes formed the basis for adaptive response under water logging situation

Physiological disorder:

- **Bud and boll shedding:-** Nearly 70% of squares and bolls are shed either due to physiological reasons or entomological factors. The exact cause of physiological shedding is not clear. However, studies revealed that the environmental factors such as cloudiness, high and low temperature, rains during squaring and flowering, water deficit, water logging and nutrient limitations aggravate the shedding of squares and bolls.

Management

- Low concentration sprays of Napthalene acetic acid (NAA) and DAP
- Application of pix (25 or 50 ppm) at floral initiation.
- In irrigated condition application of cycocel 40 ppm.
- Growing of tolerant genotypes.

- **2-4D Effect:-** Cotton is very sensitive to herbicide 2, 4-D. Foliar sprays of 2, 4-D 5 ppm during flowering led to malformation of leaves and flowers.
  The appearance of the symptoms depends on the prevailing temperature, which in turn affected the growth and development of the plant.

Source-Sink alteration

Nagpur

Mechanical removal of early formed squares for few days subsequently led to sudden spurt in square production and synchronized boll bursting, resulting in higher yield. However, it is cumbersome and laborious. To overcome the above limitations, some action specific chemicals were evaluated to see their efficacy in delaying square production. Ethrel at low concentration found to mimic the effect of mechanical square removal, but it prolonged the duration of the crop. This under rainfed condition had an adverse effect of growing bolls in depleted soil moisture and resulted in reduced yield.

Coimbatore

- Foliar application of ethrel with an effective concentration of 30 - 45 ppm ethrel effectively controlled reproductive growth in the initial phase and produced profuse flowering leading to synchronous flowering and boll bursting. The yield realised was 25-30% higher than control without affecting the fibre quality.

- Maleic Hydrazide at 500 and 1000 ppm induced the axillary buds to sprout and break the apical dominance. The morpho-frame was altered with short stature, bushy growth. The yield enhanced by 30% with large number of small bolls.

Gossypol content

Wide variability in gossypol content in seed and other plant parts was noticed in about 300 working collections of cotton germplasm lines. Database for seed gossypol content has been established for approximately 500 germplasm lines which include the working collections and other genotypes of *G.hirsutum, G.arboreum* and *G.herbaceaum* and also will species. Wide variability have been observed and the germplasm lines have been categorized as low, (0-0.5%) medium (0.5-10%), high (1.0-1.5%) and very high (>1.5%) gossypol content lines. High gossypol content lines can be uitilised as sources for resistance in the breeding programme.

Cotton simulation model

- A generic model 'INFOCROP' has been calibrated and validated using crop weather, soil, genotypes, date of sowing, nitrogen level as basic inputs. The model has simulated the phenology more accurately and accuracy of simulated yield was 94% and biomass 89% across the agro-climatic zones. Using the crop model an integrated method was developed along with remote sensed area estimation and GIS techniques incorporating soil and weather parameters to predict the cotton production at the regional level.

Photosynthetic efficiency

- Asiatic cottons showed a better stability in their photosynthetic efficiency under adverse growing conditions. At flowering and early boll development stages transgenic cotton has higher stomatal conductance, photosynthesis and transpiration compared to non-transgenic counterparts.

Studies on CO_2 Enrichment

- Cotton plants grown under elevated carbon dioxide level of 650 ppm and temperature of 40 degree centigrade was found optimum for photosynthetic and nitrate reductase activities of the plant leading to improved productivity.

Fatty acid profile of cotton seed oil

In order to determine the nutritional value of cotton seed oil the essential fatty acids profile was estimated.

Fatty acid		Range (%)
Saturated	Palmitic	16-26
	Stearic	1-4
Unsaturated	Linoleic	41-52
	Oleic	16-28

The following lines containing high linoleic acid > 50%) were identified which offer potential in improving cotton seed oil quality.

G.hirsutum		G.arboreum
Devraj (52.6)	6088 (56.4)	AC 40 (54.8)
CH 900 (52.1)	Clarksville (57.9)	AKH 235 (58.1)
B-56-181 (54.9)	OCI 122 (55.5)	Cocanadas WH (56.8)
MA-7 (54.1)	B.Cot 100 (57.3)	Malsoni (54.6)
UPA 5717 (55.4)	IC-81 (58.6)	Malvi 20 (58.3)

Fatty acid profile with special emphasis on unsaturated fatty acids like oleic and linoleic acids has been documented in nearly 600 germplasm lines

Fibre Physiology

- Very high phenols coupled with higher IAA oxidase and Peroxidases and lesser fibre to seed reducing sugar ratio affected fibre elongation in short stapled genotypes.
- Under *in vitro* conditions, fibre length of 17 mm was achieved for the first time in fertilized ovule culture and 12 mm in unfertilized ovules.
- Parthenocarpic seedling with well differentiated root and cotyledonary leaves was obtained when unfertilized ovules were cultured *in vitro*

Efficient *G. herbaceum* genotypes with excellent adaptability in coastal areas

- Steady state maintenance of metabolic status was evident in *G. herbaceum* as compared to *G. hirsutum* genotypes
- Higher levels of soluble protein, reducing sugar and phenolics was maintained upto 150 days of crop growth.
- Metabolically important enzymes - Nitrate Reductase and Peroxidase had a significant role for efficient adaptability under adverse situation.
- *G. herbaceum* genotypes (RAHS 14 & G.Cot 21) and desi hybrids (G.Cot DH 7 & G.Cot DH 9) have been identified with yielding ability of 15-20 q/ha and better adaptability to adverse situations in coastal areas of the country.

Social Sciences

- The major risk aversion tendencies observed were varietal combination, use of F_2 seeds, use of less than recommended dose of fertilizers, more than recommended number of sprays, resort to natural farming and institutional credit shyness.
- Yield gap models showed that plant density gap in hybrid and soil dummy in variety were the major significant variables responsible for the yield gap while nutrient gaps is common to both.
- A regression model estimated with all India productivity as dependent variable and the percentage of irrigated area and dummy for hybrid indicated that both have contributed significantly to cotton productivity. However, instability has increased simultaneously particularly during the post hybrids phase mainly because of hybrids calling for intensive crop management being cultivated under all situations particularly resource poor conditions leading to violent fluctuations during adverse years and thereby affecting the average performance.
- The major constraints reported were the incidence of pests especially bollworm (62%), poor quality/ineffective chemicals (51%), non availability of canal water on

time (48%), non-availability of power supply (48%), tied up credit (39%), non-availability of quality seed (37%), use of non-notified varieties (41%) improper use of chemicals mixing/cocktailing chemicals on own or at the advice of the dealers (35%) and loss due to leaf curl virus (12%), though seem to be less in magnitude is undoubtedly increasing.

- The extent of use of non-notified varieties in vogue was to the extent of 33% ranging from 15% in Bhatinda and 55% in Hisar. Concomitant to this was the varietal proliferation in all the sample farms. More than 80% of the respondents under cotton-wheat system have resorted to closer spacing unlike in their counterparts in Central India where wider spacing and reduced plant density particularly in varieties is the major constraint to productivity.
- The higher rate of output efficiency of cotton production is appreciable, but to achieve this farmers using inputs at an inefficient level is matter for concern from profitability, sustainability and environmental health points of view. The output efficiency was inversely proportional to size of farming. It can be inferred from the results that natural resource conservation (resource use efficiency) is required in irrigated cotton production.
- There is a linear and significant relationship between yield and up to four genotypes per farm on an average. The varietal multiplicity is through a sort of varietal combination in which some robust and proven hybrids are always cultivated with LRA 5166 and one or two research varieties for experimentation, so that the average yield is ensured. Thus variety (here LRA 5166) is used as a yield stabilizer in hybrid cultivation. Totally rainfed farms showed more varietal discipline and yield stability than the farms with borrowed or purchased sources of irrigation.
- Bt cotton has recorded significant increase in yield (2-5 q/ha), savings in plant protection expenses (Rs.16000 – Rs.4000/ha), additional returns (Rs.2800 – 15000 /.ha). The awareness and adoption level has increased with seasons. RCH-2 Bt has performed better than MECH Bt. There are many unapproved Bt hybrids in cultivation in A.P. and Gujarat performing better, but are causes for concern from management point of view.
- Historical data collected from 40 organic cultivators revealed that organic cotton production is a mode or risk aversion, cost reduction motivated by premium prices and cash payment. Though the yield after stabilization period was only 5.63 q/ha against the 7.14 q/ha in synthetic farming, the loss was more than compensated by the price premium of Rs.230-700/q and cost reduction of Rs.1900/ha. Further, the yield and price stability were high among organic farms. It has to be localized and cannot be a substitute for intensive farming.
- Commodity diversion model results indicated that delay in cash payment and improper grading were the inducing factors for cotton diversion from the monopoly procurement than price difference and avoidance of credit recovery.
- Criteria for research problem selection among cotton scientists in India were studied and it was found that priority of the organization set by various mechanisms has emerged as the most important criteria followed by foreign collaborations, feedback from clients, current hot topics, and contribution to scientific theory and publication probability.
- High degree of alienation from land was observed among cotton growers and perceived quality of life has become somewhat worse for majority of cotton growers.

- Current financial condition of a family has become a serious problem for more than half of the cotton growers and seventy per cent of cotton growers are very concerned about returning the loan they have taken for agriculture.
- A major portion of variance in technology adoption behavior of cotton growers related to adoption of hybrid cotton is explained by the Model which includes variables like spatial distribution, availability of the technology, marketing strategy, pricing, and promotional communication.

The macro level constraints to cotton production identified were:

Macro level constraints in cotton production

Constraint	**% of cotton area**
Unsuitable soils	20
Non-certified seeds	60
Non-recommended seed rate	30
Delayed sowing	70
Multiplicity of genotypes	25
Non-recommended genotypes	15
Non-descript cultivars	10
Improper spacing	30
Subdued inputs use	40
Endemic to pests	2
Competition from	
Sunflower	3
Soybean	5
Groundnut	4

Crop Protection

Changing pest scenario in cotton

Occurrence of three species of mirid bugs belonging to genus *Ragmus*, family Miridae of the order Hemiptera on cotton has been recorded since 2001.

Emerging pest status of thrips and mirids among sucking pests, and pink bollworm attaining the status of key pest in cotton were established.

Dynamics of cotton insect pests and natural enemies
Crop Pest Interactions

Developed and validated Genotypic Resistance Ratio (GRR) technique to evaluate cotton breeding materials against bollworms that quantifies the combined plant resistance mechanisms to cotton insect pests including the tolerance trait of 'compensatory growth' in response to bollworm damage.

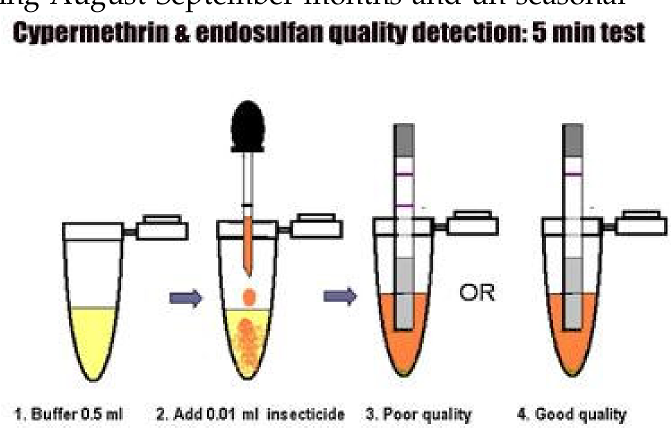
Loss assessment

Avoidable losses due to sucking pests in cotton variety LRA 5166 and hybrid NHH 44 ranged between 15-22% and 5-18% respectively whereas due to bollworms ranged between 30-35% in hybrid and between 25-30% in variety.

A linear relationship and significantly positive correlation was observed between bacterial blight intensity and losses in seed cotton yield. On susceptible cultivar a potential loss vary from 9.1 to 32.29% with an average loss of 18.07%.

Development of weather-based forewarning systems for crop pests and diseases

Greater than 70% relative humidity during August-September months and un-seasonal excess rainfall during the season distributed on many rainy days and rainfall amount more than 50 mm during October results in outbreak of *H. armigera*.



Maximum temperature greater than 33^{0}C, morning relative humidity less than 70%, evening relative humidity more than 40% and minimum temperature less than 12ºC during standard weeks of 40, 41, 43 onwards, 48 and 49, respectively led to the severity of *P. gossypiella* attack..

Factors affecting disease onset and development were identified in order to develop prediction and forecasting models for bacterial blight. High disease intensity was favoured by Maximum temperature of 29.4 – 34.9ºC, Minimum temperature of 21.7–24.2 ºC, Maximum relative humidity 81-93%, Minimum relative humidity 55-87% and 1-6 rainy days.

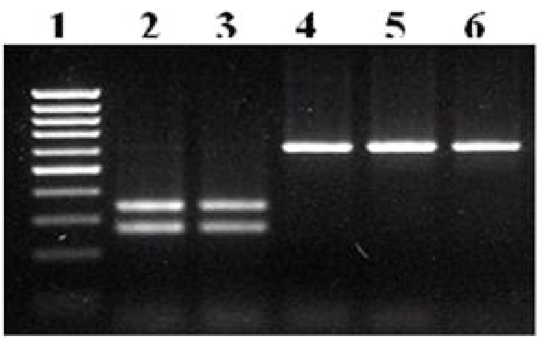
An Expert System for Indian Cotton Insect Pest Management (ICOTIPM) for diagnosis of insect pests was developed to determine the population size or damage through sampling methods to use with ETLs and select ETL based insecticidal control measures.

Variability among the pests

Mitochondrial DNA studies revealed the presence of 18 haplotypes in Indian *H. armigera.*

PCR RFLP with Rsa 1 was able to distinguish *H. armigera* from *H. assulta* in their morphological indistinguishable stages.

PCR tool to distinguish between H. armigera and H. assulta



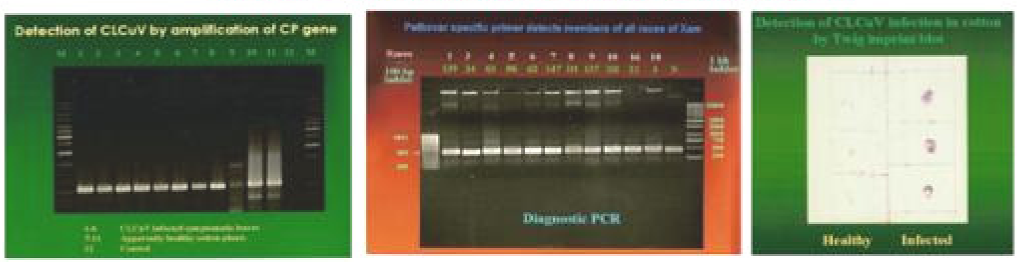
The non- cotton strains of *H. armigera* preferred to feed on red gram and chickpea over cotton and in inter strain crosses the female moth influences the feeding preference of the progeny.

Host Resistance

A total of 3000-5000 *Gossypium hirsutum* and *G. arboreum* lines have been screened against insect pests and diseases and many tolerant, resistant and immune lines were identified.

PROMISING TECHNOLOGIES

DISEASE DIAGNOSTIC MOLECULAR KITS



Xanthomonas axonopodis pv malvacearum (Xam)

Fifteen races of *Xam* on the basis of differential host reaction have been recorded in India. Races 10 and 18 are most virulent and predominant.

First molecular evidence of biotype variability within race 18 has been observed.

Pathological evidence - At least ten biotypes evolved based upon growth curve analysis, rep-PCR, RAPD, plasmid profiles and RFLP analysis

Bacterial blight

Use acid delinted seeds. Soak in 0.1% streptocycline. Spray 0.01% streptocycline + 0.2% copperoxy chloride

Ramularia areola
Variability in *R. areola* was recorded on the basis of morphological or cultural characters host response to cross inoculation and polymorphism in RAPD-PCR profiles.

Resistance to insecticides
Resistance to Cry 1Ac has not been recorded from any of the Indian populations of *H. armigera* or *Earias* sp despite cultivation of Bt cotton for the last three years.

Development of detection kits

Bt detection kits
Six kits namely: Bt-Express, Bt-Quant, Bt-Detect, Bt-Zygosity, Bt-Express-II and Bt-Elisa II have been developed and commercialized. A Bt referral lab was opened by Government of India in the Institute.

Insecticide Resistance Detection kits
Eleven kits to detect resistance to pyrethroids, endosulfan and methomyl were developed which include 4 scar markers, 3 ELISA kits, 2 dot-blot and 2 immunochromatographic dip-sticks. The immunochromatographic kits were distributed to entomologists of State Agricultural Universities for field validation.
Resistant strains selected with Cry1Ac exhibited a broad spectrum resistance, to a variable degree, to almost all the Cry1 toxins tested but showed an unchanged susceptibility pattern to Cry2Ab. A near-isogenic Cry1Ac-line exhibited some amount of cross resistance to Cry2Ab. Joint toxic action studies indicated that none of the Cry1 toxin combinations displayed any significant synergism.

Kits to detect quality of spurious insecticides formulations
Eight kits, which include ELISA as well as dip-stick to test the quality and residue of pyrethroids and endosulfan have been developed.

PCR Detection of leaf curl virus

Three genomes of 0.7, 1.2 and 2.7 kb were amplified and cloned. These have been used to detect the leaf curl virus from symptomless cotton and weed plants using dot blot method. ELISA method was also developed and used for detection of CLCuV.

PCR Detection of *Fusarium oxysporum* f. sp. *Vasinfectum*

PCR method was used for detection of *Fusarium oxysporum* f.sp. *vasinfectum* from cotton seed. This method can be used in quarantine testing of seed material.

PCR Detection of bacterial blight pathogen

PCR can detect *Xam* by amplification of 0.4 kb DNA fragment.

Biological control

The mass multiplication protocols for HNPV, *Crysoperla carnea* and *Trichogramma* were standardized. Further the institute facilitated and supported the establishment of biocontrol factories in Vidarbh region of Maharashtra.

A multi cell plastic tray for mass handling of *H.armigera* larvae was developed.

Semi-automatic units were designed, fabricated and installed which are working well and the production of *Chrysoperla* has become quite economical.

Full fledged world – class insectary set up for the first time where rearing of bollworms has been successfully carried out for more than 20 generations. The insectary maintains up to 53 cultures of *Helicoverpa* and 20 cultures of spotted bollworms.

Near isogenic lines of *Helicoverpa* with reference to specific insecticide groups such as endosulfan, methomyl, quinalphos, Cry 1 Ac etc. are being maintained. Insecticide susceptible reference strains of *Helicoverpa* are being maintained.

Out of 148 bacterial isolates 5 were found to be very inhibitor of Xam in vitro. Most promising isolates belonging to Pseudomonas fluorescens provides effective eradication of Xam, improves germination, increases root shoot length and reduces bacteril blight incidence.

Eight potential isolates of Pseudomonas fluoresces and one isolate of bacillus firmus isolated and evaluated against Xam. 9 selected isolates provided high levels of antagonism against Xam in vitro. Phloroglucinol gene fragment as ampliphied from strains of Pseudomonas that encode production of antimicrobial DAPG.

Of the 16 indigenous isolates of entomopathogenic nematodes belonging to *Steinernema* and *Heterorhabditis* spp. collected and evaluated against *H.armigera* , five were found to be effective against *H.armigera* at 10-15 infective juveniles per insect larva.

Two photorphabdus isolates symbiont of entomophogenic nematodes earlier recorded to be antagonistic towards sucking insect pests of cotton, were field tested. The results indicate that spray of photorhabdus sp. As broth as well as toxin extracted is effective against sucking pest.

Management of Stem Weevil (*Pempherulus affinis* Faust)

Several management strategies have been evolved to control the stem weevil incidence:

- Reduced cropping intensity
- Destroying affected and dried plants.
- High seed rate
- Earthing up to prevent the egg laying by adult weevils
- Application of Neemcake (150Kgs/ha) +Carbofuran (1.0Kg a.i/ha) at 15-20 days after sowing (DAS).
- Stem drenching with Neem seed extract 5% from 45 DAS,4 times at weekly interval or drenching with Chlorpyriphos 0.1%, 4 times at weekly interval from 45 DAS.

Pathogenic specialization in cotton pathotypes

- Based on the disease symptoms on the leaves and on the morphology of the pathogen on the host, *Ramularia areola* Atk. isolates have been classified in to four groups.

Biochemical mechanism of resistance to bollworms

- Squares of Bollworm tolerant genotypes possessed lesser protein, sugars and higher levels of secondary metabolites like condensed tannin, gossypol and phenolics as compared to susceptible cultivars.

Grey Mildew

Spray 0.2% wettable sulphur or 0.1% carbendazim. Use antagonistic bacteria. Destroy infected debris

Developmental biochemistry of cotton – pest/disease interaction

- Seed dressing insecticides imidacloprid and Chlothianidine helped in better metabolic status of cotton seedlings due to enhanced peroxidase, acid and alkaline phosphatase activities.

- Carbosulfan and Thiomethoxam helped in enhancement of Nitrate Reductase activity and soluble protein content.
- Variation seen in Polyphenol oxidase, Superoxide dismutase and Catalase enzymes during interaction of cotton genotypes with isolates of grey mildew is useful in diagnostic tool development.
- Farmers friendly Bt production technology popularly known as Bt bucket was developed which was subsequently converted to Bt drum .

Pesticide Application Technology

Pesticide application through a knapsack sprayer with hollow cone type of nozzle at the speed of 3.6km./hour and at 75 cm height above canopy with a pressure of 45psi, discharging 44cc/min of spray fluid was found to be the most effective .

IPM

Season long training on IPM were provided to 150 subject matter specialists of Department of Agril. Of different cotton growing states.

Established nucleus and cluster villages for promotion and implementation of IPm practices.

Imprementation of two pest management approaches viz., IPM with biocontrol options including ETL based insecticidal sprays and need based chemical sprays were undertaken in addition to IPM on Bt cotton.

Created awareness on fild scouting and need based chemical interventions through weekly visits and through on farm days.

Quantified the efficacy of individual components of IPM at research station using cotton cultivar NHH 44.

Evaluated the pheromone blends of BARC for *H.armigera.*

Crated off season management practices and refined the package for seasonal cotton pest management.

IRM

Strategies were implemented in an area of 59,233 ha in fields of 20,525 farmers of 444 villages in 30 districts of 10 cotton-growing states. The overall benefit due to the project implementation was estimated at Rs 4807 lakhs, accrued from Rs 3097 lakhs due to yield increase and Rs. 1710 lakhs from reduced insecticide usage.

IMPACT ASSESSMENT

- Cotton of all staple categories suitable for spinning yarn 6-120 count types are cultivated / produced in India. They belong to four *Gossypium* species and hybrids.
- India has achieved self-sufficiency in all quality staple types for internal consumption with surplus for export.

  Productivity has increased from 88 kg to 467 kg/ha lint after independences. Production has increased from 2.2 to 24.4 million bales of lint.
- Increase in productivity and production was due to development of improved varieties, hybrids and development of improved package of practices for crop production and protection, and effective transfer of technology.

Growth
This change in scenario was due to establishment of AICCIP in 1967 and subsequently CICR, Nagpur in 1976 and the regional stations at Coimbatore in 1976 and Sirsa in 1985. Their sustained research efforts in collaboration with CIRCOT, Mumbai and SAUs located in cotton growing areas and development efforts of Directorate of Cotton, GOI), and State Department of Agriculture and NGOs led to spectacular increase in cotton production.
Central Institute for Cotton Research, Nagpur has an excellent gene bank consisting of about 9708 accessions (*hirsutum* 5919, *barbadense* - 1049, *arboreum* - 1 774, *herbaceum* - 511 and wild species of *Gossypium,* perennials and races, synthetic polyploids and their derivatives - 451). The accessions were evaluated, multiplied and distributed to research centres for cotton improvement work.

Input/Output assessment
Sustained R & D inputs resulted in spectacular growth in cotton production, consumption and exports. India is earning valuable foreign exchange due to export of raw cotton, lint, yarn, textile and garments.

Short Comings

Varieties/hybrids
Though more than hundred varieties and hybrids have been developed and released in the country, only few are being grown in large areas. Some of these varieties hybrids have not shown stability in yield. Availability of certified seed has also been a constraint. In view of muiltiplicity of cultivars/hybrids, 99 varieties/hybrids have been recommended for denotification.

Productivity of some of the high yielding varieties and hybrids released so far has plateaued. This could be due to admixture of seeds, segregation, use of F_2 seeds, inadequate and improper cultivation practices and pest and disease control measures, loss of soil fertility etc.

Hybrids did not, until 1994, even make their appearance in the northern zone i.e. in Punjab, Haryana, Rajasthan and Uttar Pradesh.

Resistance breeding did not receive as much emphasis as it deserved. As a result jassids, whitefly, *heliothis* and pink bollworm developed resistance against use of pesticides. No conscious effort was made to develop varieties for abiotic stresses.

Varieties hybrids developed so far were suited for ring spinning. However, with high speed modern spinning like rotor, friction and air-jet spinning, we need to develop genotypes with desired fibre characters. Trash content of our varieties was also high. We have to breed varieties with low neps and mote content.

We do not have varieties specifically bred for salinity, water-logging or high rainfall areas.

Quality seed supply

This has been a major constraint in the field extension and spread of varieties and hybrids. Hardly, 10 to 30% area is covered under certified seed in different states. This situation was due to inadequate agencies for the production of certified seed, inadequate monitoring and lack of coordination. Distributors often indulge in supply of spurious seed and supply of F_2 seed, resulting in low productivity at the end.

Soil Productivity

Similarly, growing of cotton year after year on the same field, resulted in poor crop productivity. Cotton is grown on alluvial, sandy, black and red soils which are generally low in organic carbon, N, P,K,S and Zn. Cotton cultivation in shallow soils results in poor yields due to lower profile moisture and nutrient storage. Farmers are not adopting recommended fertilizer practices.

Irrigation

Only about 35% area is under irrigated cotton. Irrigation efficiency is hardly half to one third. Indiscriminate use of water resulted in rise of water table and salinity problems in the North. In severe cases, farmers had to abandon such areas for cotton.

Pesticidal use

Indiscriminate use of pesticides i.e. large number of sprays, supply of spurious insecticides, incorrect sprayer and droplet size resulted in development of resistance in cotton pests as well as resurgence problem. Soil conservation and pest control measures have not been promoted on community basis.

Grading pricing and marketing

Cotton being a commercial crop, proper pricing is key for cotton growth and marketing. However, due to various reasons, farmers were selling mixed cotton with high trash content with colour of cotton yellowish or dull white. This type of cotton was fetching them lower price. Marketing practices in different states were also different, However, due to its export potentiality, the situation is gradually changing.

Lessons learnt, suggestions and options for future

Some of the shortcomings in earlier work and the lessons learnt have already been mentioned above. Accordingly, research efforts (basic, strategic and applied) have been taken up to mitigate the problems. These have been mentioned under programmes. Options for future are indicated in our Perspective Plan in suitable time frame.

SCENARIO

India has the largest acreage under cotton, has the lowest productivity at global level and ranks third in production after China and U.S.A.. If we increase the productivity in India, we can increase our export quota and earn valuable foreign exchange, after meeting the internal demand for cotton.

Cotton is inherently a semi-xerophytic perennial crop. However, it is being grown as an annual seasonal crop. India is unique to grow all the four cultivated species (G. *hirsutum, G. barbadense* G. *arboreum* and G. *herbaceum)* and inter and intra specific hybrids (HxB or HxA) under diverse agro-ecological conditions.

Northern zone comprising Punjab, Haryana and parts of Rajastban and UP., where cotton is grown under irrigated conditions on alluvial and sandy soils. The region is known for growing *hirsutum-arboreum* type of cottons, though efforts are underway to produce HxH or Hx B-hybrids. This zone has the highest productivity (around 485 kg lint per hectare). Cotton in this area is grown adopting farm mechanisation due to shortage of labour. Presently short and medium staple cotton is grown but there is scope for growing extra-long staple *barbadense* varieties and or its hybrids. Pest and disease problem is generally less in this region. There is a need to evolve day neutral, photoinsensitive -medium duration varieties with synchronous flowering. Problems of salinity, alkalinity and rise in water table are often encountered. Cotton-wheat is the predominant cropping system.

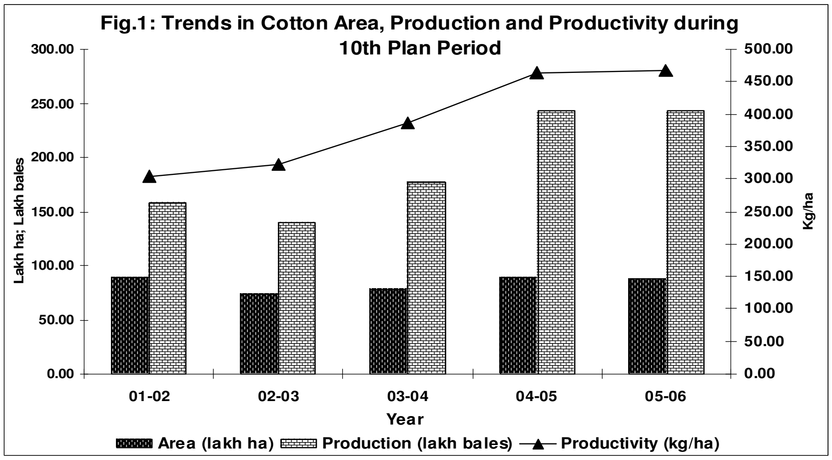
Central zone comprises primarily rainfed tract of MP., Maharashtra and Gujarat. Predominant area is under black soil, which is subjected to runoff, erosion, soil and nutrient losses. Soils are poor in fertility. Cotton productivity is the lowest (around 437 kg lint per hectare) due to uncertainty and vagaries of monsoon, This area is known as' Central *hirsutum-arboreum-herbaceum* and hybrid zone. Moisture stress, salinity, soil degradation problems are often encountered. Farmers in this area are resource poor and therefore not in a position to invest more. Cultivation is done traditionally with bullock drawn implements and by manual labour. There are more weeds, pests and disease problems due to uncontrollable rain and soil problems. The area is more suitable for '*desi*' cottons. Hence *arboreum* cotton improvement can be strengthened for this area, besides other cotton improvement programmes. Cotton is grown as a mono-crop or as an intercropping system.

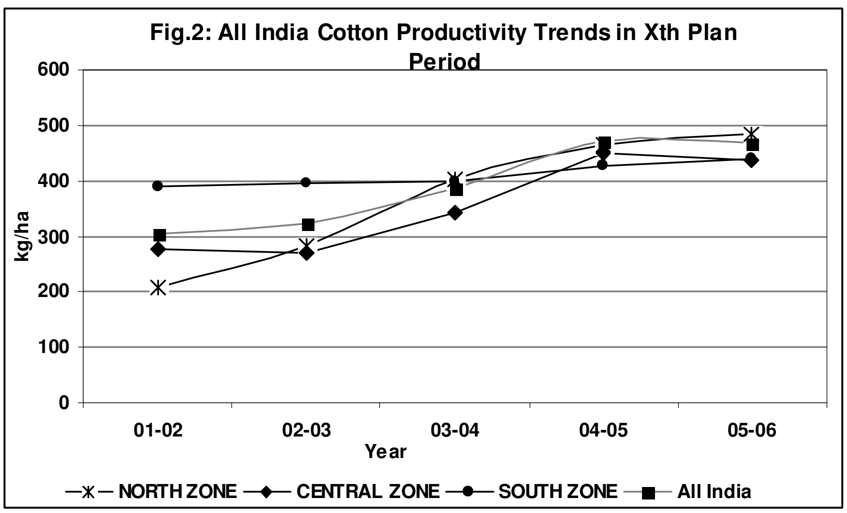
Southern zone comprising of Andhra Pradesh, Karnataka and Tamil Nadu is a zone for growing *hirsutum-arboreum-herbaceum-barbadense* and hybrid cottons. Soils of this zone are both black and red and poor in fertility. Cotton cultivation is done both under irrigated and rainfed conditions. This zone has the productivity of around 440 kg lint per hectare. The area is well known for growing long and extra long staple *barbadense* cottons and hence may be encouraged for growing export oriented cotton. Pest and disease problems are more. Due to type of climate available, cotton can be grown through out the year. Cotton is grown in south as sole crop or in intercropping system with onion, chilli, cowpea, maize etc. Cotton-rice rotation is also followed in this area.

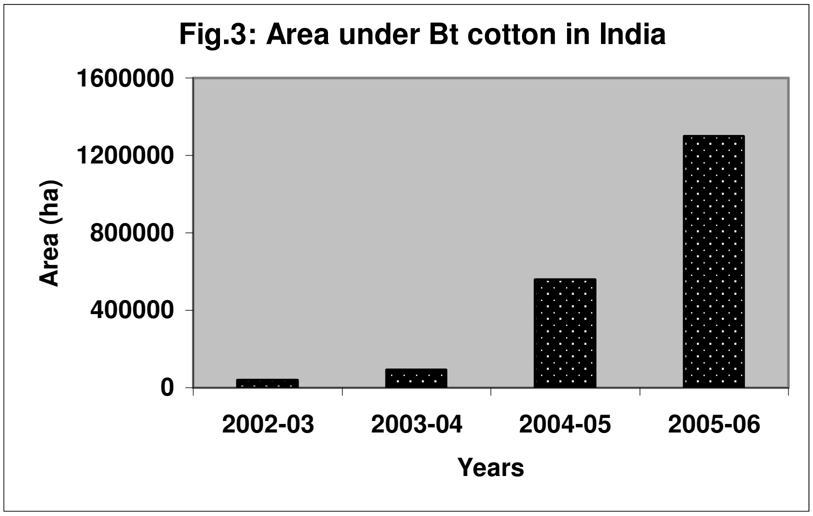
Details of the area, production and productivity profiles of the country (over the years) as well as in the three zones, are indicated in Figs 1 and 2.

The production trends as depicted in Fig.1 clearly indicate that the overall increase in production over the last 5 years in India is mainly contributed by the increased productivity of North and Central cotton zones. In south the productivity remained more or less constant (Fig 2). Ideal weather across Northern zone for the last few years contributed to record yields (616 kg/ha) in some of the cotton growing states like

Punjab. In Central India, Gujarat has rapidly emerged as India's largest cotton producing state. The adoption of Bt cotton by farmers in this state is believed to be the dominant contributing factor for yield increase. However, yields in some of the states like Maharastra which has maximum area under cotton cultivation (33 %) and Karnataka are very low (271 and 328 kg/ha respectively) that led to poor national average productivity.







State-wise adoption of Bt cotton in India

State	2004 (ha)	2005 (ha)	2006 (ha)
Maharastra	200,000	590,000	200,0000
Gujarat	130,000	150,000	330,000
Madhya Pradesh	85,000	145,000	310,000
Andhra Pradesh	80,000	280,000	676,000
Karnataka	18,000	30,000	80,000
Tami Nadu	10,000	25,000	-
Northern Zone	N/A	60,000	
Punjab			281,000
Haryana			42,000
Rajasthan			2,000
Total	**500,000**	**13,00,000**	**372,1000**

Cotton is hand picked by women labour. Due to plant type, picking and storage methods that are prevailing in the country, there is generally higher trash content in Indian cotton. The cotton which comes to market is a mixed one (both in terms of picking and mixtures of varieties or non-descript cotton). Instead of bright white lustrous colour, it is often dull yellowish and blackish in colour. Due to these situations, cotton fetches lower price in the market. Marketing system in different states is different. It varies from unorganised market in the villages to organised monopoly cooperative marketing system. In most of the states except Maharashtra, there is free market. Marketing Federations are also operating in different States, undertaking the purchase and supply of cotton to Mills and Textile Industries.

Cotton and cotton industry provides employment to millions of people, contributes substantially to GDP and foreign exchange earnings. Centre and States are both involved in Textile Policy of the Country. In seed industry, Public and Private Sectors are participating in enhancing the supply of certified seed. National and State Seed

Corporations and Private Companies are playing a pivotal role in this direction.

Linkages are effective among the research organisations like CICR, CIRCOT, AICCIP, SAUs and Public and Private Seed industries and the development agencies like Cotton Directorate, GOI., State Department of Agriculture, N.G.Os and user industries like EICA, CAB., CCI., ICMF, SITRA, BTRA, SIMA, ALCOTTON and many others. It is implicit here, that there is also closer coordination between Ministry of Agriculture and Ministry of Textile, GOI.

SWOT ANALYSIS

STRENGTHS

- Largest cotton area in the world.
- Diverse agro-climatic conditions and growing of all the four cultivated *Gossypium* spp.
- Well established cotton research network, comprising National Institutes, State Agricultural Universities and Private Sector R&D establishements.
- Availability of trained scientific manpower and skilled technical personnel in research institutions.
- Long experience of developing commercial hybrids and their production technology.
- Wide range in quality among cultivars (6s-120s) and diverse species/hybrids under cultivation and availability of vast variability and genetic resources of cotton.
- Availability of new tools and techniques such as biotechnology for varietal improvement.
- Well-established domestic textile industry with good export earnings and seed industry.
- Information network and extension machinery for fast and efficient transfer of relevant technologies.

WEAKNESSES

- About 65% of the cotton growing area is rainfed with low productivity and high year-to-year variations coupled with risk induced low input usage.
- Inadequate fibre strength in majority of cultivars/hybrids.
- Proneness of present day cultivars to damage by varied insect pest and diseases throughout the crop period and the consequent yield losses.
- Resource poorness and institutional credit shyness of rainfed farmers and the risky nature of the crop result in low-input use and tied-up credit.
- Non-availability of appropriate farm machinery for timely and efficient cultural operations, where seasonal labour shortage is recurrent.
- Multiplicity of varieties/hybrids.
- Cultivation of unidentified and non-notified hybrids/cultivars.
- Non-availability of sufficient certified seeds.
- Lack of advance training of International standard to many scientists.
- Genetical improvement in productivity has reached a plateau.
- High cost of production.

OPPORTUNITIES

- Ample scope for earning foreigh exchange by export of row cotton, cotton yarn, fabric and garments.
- Sufficient scope for organic cultivation.
- Exploitation of genetic engineering and bio-technology in developing transgenic against biotic and abiotic stresses.
- Improvement in diploid cotton for fibre strength, length and yield.
- Molecular characterization of germplasm accessions, gene-tagging, genome mapping, will enable patenting of valuable genes on time.
- Strong domestic demands for cotton by textile industry, viz., mill powerloom and handloom sectors.
- Low yield base offers ample scope for yield improvement by resource integration.
- Scope for employment generation through hybrids seed production, mass multiplication of bio-agents for crop protection, by-product utilisation, etc., through rural small scale/cottage industries.
- Opportunities for horizontal expansion into non-traditional areas e.g. Orissa, Wes Bengal, North Easter State, Uttar Pradesh and Jammu and Kashmir.

THREATS

- Competition from manmade fibres which are cheaper and offer wide quality options for blending.
- Shrinking quality of natural resources under major cotton based cropping systems due to indiscriminate exploitation leading to decline in factor productivity.
- Excessive and indiscriminate use of pesticides in certain hot spot areas, causing pesticide resistance, ecological imbalance and environmental pollution.
- Decline in profit margin, unstable prices and risk prone nature of the crop leading to sub-optimal input use.
- Competition of crop substitution e.g. soybean, sunflower etc, in rainfed areas and sugarcane, paddy, banana etc., in irrigated areas.
- High competition in international market.
- Proliferation of research varieties and spurious seed and chemicals enhance the rate of crop failure and hindrance for technology transfer.
- Some of the emerging problems such as leaf curl virus, resurgence of minor pests posing threat to cotton cultivation.

ISSUES AND STRATEGIES

Total fibre requirement for 2010 A.D. and 2025 A.D.

Presently average cloth consumption per year is 30 sq. meters per person. Marginal increase is expected by 2010 AD. Rate of annual mill consumption increase is 5% and thus would reach 350 lakh bales. In our total foreign exchange earnings, 30-35% is from export of yarn, sewing threads, fabrics, made-ups, garments etc. Hence, demand for cotton will increase. At least 15-20 lakh bales of raw cotton per annum may be kept for stable exports. Non-mill consumption is of the order of 15 lakh bales (stuffing, surgicals, absorbent cottons). Small scale spinning units installed since recently consume about 15 lakh bales per year. This non mill consumption and small scale spinning would increase to 30 lakh bales. Thus for 1.16 billion population, we will need 350 lakh bales.

Assuming 5% consumption growth rate we may require 525 lakh bales by 2025 AD., including non mill consumption and exports.

Staple wise and count wise requirement of cotton : Research Priorities

- Yarn production in 1-10 counts (coarse) has shown declining trend. But with denim (Jeans) etc. on the rise 7-14s are now in higher demand especially for denim export and local use.
- Production of fine and superfine counts (41s and above) has increased. Also 31-40s has shown increase. 11 - 40s count group represents 71% and hence greater efforts are required in this category.
- The use of cotton and synthetic fibre blends will increase as it rose to 13% in recent years. MCU5, MCU 5 VT, Surabhi, Suvin, DCH 32 are useful for blending. But fibre maturity and trash content requires attention. Good fibre strength and extensibility are important for blending to get good yarn properties.
- Modernisation of spinning system for higher production rates, productivity and automation for cost reduction of yarn.
- Open end (OE) spinning systems - Rotor spinning, Friction or DREF spinning and airjet spinning which ensure high rate of production and large size of yarn and package are coming into existence. Ring spinning for all counts with wide adaptability, rotor (upto 24s), DREF (upto 30-45s coarse counts) and airjet for finer counts (50s and above) and also for man-made fibres and blends including combed cotton. For the new systems, high fibre strength and fineness are now more important.
- Often raw material economy in mill is achieved by mixing few varieties to spin the required count. Sometimes mills also underspin.

- Wide variation in fibre quality in the same lot and different lots of same variety, admixture in cultivation marketing centres, poor cultivation practices, are the lacunae in the present system. Improvement of fibre strength 25-30 g/tex for 3 mm gauge, 75-80% mature fibres, reduce stickiness and motes (neps and naps) in interspecific hybrids, low short fibre content/lowered trash content seed coat fragments etc. and improvement in ginning aspects etc,, and optimum micronaire value without affecting maturity are some of the desirable traits to be looked at.
- Rotor spinning - (BN. GNA, F414, F505, Juhrar, H 777, Khandwa 23, Vikram, Sanjay, AHH 468, NA 247, Laxmi, Sharada, MCU 7, LRA 5166, etc.). Airjet spinning- (H6, Varalaxmi, DCH 32, MCU5, MCU8, Suvin, Surabhi etc.).

Export Quality/Quantity

- Establish firm basis for regular stable export of raw cotton (no adhoc export policy).
- Export of value added items like yarn, sewing thread, fabrics, garments, furnishings, handlooms and others.
- Regular, stable and assured export policy will help to stabilise cotton price to the

growers and industry ensuring remunerative price to the cotton growers.

- 1986-87 (1 3.8 lakh bales), 1989-90 (13.7 lakh bales), 1990-91 (11.9 lakh bales) export of cotton.
- Export oriented production programme for export demand varieties.
- Quality standards stipulations to be adhered to whether it is raw cotton, yarn or textile goods.
- Concentrate on export of long and extra-long staple cotton and value added items like yarn in medium staple category and medium count groups.

Uzbekistan, Turkemania and Australia are emerging as major exporter of raw cotton. China, Taiwan, Pakistan, Indonesia, Bangladesh are competing in textile export.

Hybrid vs. Varieties

- Now hybrids occupy 45-48 % area out of 8.5 m.ha. and contribute to 55-60% of total production.
- Hybrids have contributed to higher yields, wider adaptation, yield stability in rainfed situations, higher quality cotton production, higher seed output and seed oil output, improved labour economy, 100% improved seed coverage of hybrids, increased trade textile activity, increased seed production and seed industry.
- Quantum jump with hybrids in north zone is visualized and several new *intra-hirsutum,* interspecific and desi cotton hybrids have been identified.
- Cultivation of Bt hybrids will lead to increase productivity and reduction in pesticide use.
- The cost of hybrid seed has increased and there is need for reducing the cost of production by various means and offering at lower prices.
- Hybrids under good management should yield at least 30 to 40% more than varieties.
- There is need for strong complementary research development programmes for both hybrids and varieties so that the full potentials and practical advantages of both can be harmonized.
- Hybrids perform better under higher input technology conditions and superior management.

Arboreum vs. hirsutum

- G.67, Khandwa 2, SRT 1, Laxmi, MCU 5, LRA 5166 etc. varieties became so popular changing the species composition
- Development of intra-*hirsutum* hybrids (F_1) since 1970s and their popularity in commercial cultivation even under assured rainfall condition in Maharashtra, Andhra Pradesh, Madhya Pradesh etc. caused further replacement of *desi* cottons particularly *arboreums.* lntra-*hirsutum* hybrids and high yielding varieties with higher yield level and premium price in the market also provided impetus to replacement of traditional Asiatic cottons.
- *Arboreums* got confined to marginal lands, moisture stress a drought prone areas and only consumer oriented production for such end use requirements.
- *Arboreum/ herbaceum* have additional advantage of resistance tolerance to sucking pests including whitefly, new leaf curl virus and tolerant to moisture stress.

- In Tamil Nadu, staple improvement was achieved to superior medium long staple Karungannies *(arboreum)*, but not matched by high yield. In Maharashtra State, PKV developed long staple *arboreum* A 8401 with high yield potential but has not become as popular expected. At Parbhani, MAU has developed long staple varieties PA 255 and PA 402.
- Good Asiatic cotton hybrids developed could not spread duet problems in seed production.
- There is need for improvement of *desi* cottons for plant type, reducing duration, increasing the boll weight, non shedding locules, fibre density and fibre length besides micronaire to required level besides yield.
- Give new weightage in breeding programmes to high biomass with high harvest index, higher boll weight, seed and lint indices in both *arboreum*/ *hirsutum*/ hybrids. Agronomic differentials may be introduced early in the selection stages.
- Transfer of some useful *arboreum* characters to *hirsutum* to be considered through appropriate interspecific hybridization technology,
- Genes from wild species for abiotic and biotic resistance and other desirable traits be transferred into both *arboreum* and *hirsutums.*
- Development of varieties of *arboreum* and *hirsutum* with higher oil content may also be given importance in breeding.

Breeding Strategies

- Development of long linted *G. arboreum* with high yield potential.
- Gene pyramiding of insect resistant genes especially the bollworm complex.
- Development of Multi-Adversity Resistant (MAR) genotypes.
- Pre-breeding/conversion of unadapted germplasm in all the four cultivated species into usable and value added varieties.
- Improving fatty acid profile of cotton seed oil.
- Development of extra-long staple cotton.
- Identification and diversification of new sources of male sterility for hybrid seed production in cotton.
- Utilization of two-line and one-line method of hybrid seed production, fixation and exploitation of apomictic phenomenon for improving productivity and quality in cotton.
- Identification, characterization and conversion of photo-period (day length) sensitive germplasm accessions to make them suitable for north zone.
- Improvement of fibre quality (length and strength) of north zone cultivars.

Seed Technology

- Rediscovering self defense mechanisms in cotton seed against seed microflora (physical, biochemical and molecular levels)
- Development of farmers friendly diagnostic tools by dipstick method for seed viability (for dehydrogenase activity)
- Unraveling the scientific basis of indigenous technology know-hows . on cotton seed quality enhancement

Biotechnology

Targeted integration of economically important genes for cotton improvement

- Insect resistance genes available in public domain like Cry 1 Ac, Cry 1 Aa3, Cry I F, Cry I a5, Cry I Ac (Enc)
- Disease resistance genes like PDR based approach for virus diseases, Xa21 and NPR1 homologs, chitinases, glucanases and other novel genes for broad spectrum resistance
- For drought resistance DREB genes, dehydrin, osmotin genes
- Fibre quality improvement genes like cellulose synthase
- Oil quality improvement by targeted disruption of critical genes of fatty acid and metabolism
- Development of a repository of new gene construct for economically important traits
- Screening of cotton germplasm for somatic embryogenesis
- Selectable marker gene deletion in transgenics by recombination system

Organelles transformation

- Development of antibiotic marker free and environmentally safe chloroplast + transformation system in cotton

Structural Genomics / Molecular Breeding

- Molecular mapping of descrete traits on cotton map for biotic and abiotic stresses
- Mapping quantitative trait loci (QTLs) for fibre quality characters in diploids and tetraploids and marker assisted selection (MAS)
- Construction of molecular linkage map of diploid A genome and tetraploid AD genome
- Molecular basis of tissue specific gene expression for delayed morphogenesis of gossypol glands
- Molecular characterization of genes governing resistance against key diseases of cotton in NILs and other sources of resistance
- Investigations on evolutionary basis of fibre in *Gossypium*
- Identification of molecular mapping of apomictic genes and exploitation of apomictin and TGMS phenomenon, for improving productivity and quality in cotton
- Development of RILs and NILs for fine mapping of economically important traits in cotton
- Molecular characterization of core collection / germplasm of upland and *desi* cotton
- Development of molecular markers to identify economically important traits in cotton
- Development of molecular markers for identification of essentially derived varieties

Functional Genomics

- Identification of transcripts governing tolerance
- to important pests, diseases and drought
- Construction of cDNA library for ESTs expressed in response to biotic and abiotic stresses
- Construction of genomic DNA library in BAC and YAC for cloning genes of economic importance

- Microarray, development and analysis for mapping genes specifically expressed during biotic and abiotic stresses and fibre development
- Molecular basis of cotton seed invigoration
- Characterisation, isolation and transfer of fibre quality genes in cotton
- Geminiviruses based gene silencing vectors as a reverse genetics tool for identification of gene function

Bioinformatics

- Development of database for cotton germplasm accessions
- Cataloguing of accessions based on morphological, phenotypic and genetic characterisatics
- Development of data base of cotton DNA markers and gene sequences useful in comparative and functional genomics of cotton

Innovative and sustainable Cotton based cropping systems

Cropping systems in various forms, like mixed cropping system, are adopted in traditional dryland agriculture which act mainly as risk cover against crop failures due to vagaries of monsoon or pest attack: Mixed cropping with sorghum, arhar, maize or pulses in central India, and with groundnut, ragi or millets in parts of south India is a common system followed. In Punjab and Haryana, mixture of moth and guar with cotton was in vogue before the advent of short duration cultivars,

Cotton based cropping system on new approaches could be considered depending upon the rainfall (amount, distribution and length of season) and type of soil. Profitable intercropping systems are possible with range of rainfall between 600-750 mm and on soils with moisture storage capacity of 100 upto 150 mm. With rainfall upto 900 mm and soils with moisture storage capacity upto 200 mm, relay and sequence cropping systems can be developed. Cropping systems for different zones (inter and sequence cropping) may be evolved, taking into account cost of cultivation, higher productivity and land equivalent ratios (LER).

Precise nutrient supply systems

Cotton farming has extended to a greater extent to marginal ecosystems in the rainfed tracts of central India. In these fragile ecosystems, soil nutrient status is very poor. To realize potential yields, large amounts of fertilizers will be needed to meet crop demands. There is a large difference in demand and supply and is expected in the future too. Therefore, fertilizer economy for higher yields as well as effecting N economy by introducing suitable legumes and biological nutrient sources is needed. Core researchable areas are :

1. Identifying nutrient efficient genotypes and fitting plants to nutrient poor soils
2. Identification of genes for nutrient uptake and developing nutrient stress tolerant transgenics.
3. Developing novel fertilizer products and management strategies
4. Site specific nutrient management

Organic cotton

There is going to be greater scope for organic cotton in the world market. In centra and south zone, rainfed *desi* is predominantly organic with low level of inorganic fertilizers insecticides. Rainfed *hirsutums* in certain pockets and most *herbaceums* are organic. In Gujarat state, V 797, G.Cot 13, Dhumad are grown as organic cotton and are suitable for rotor spinning, blending for hosiery making and stuffing. We need to exploit these niche areas for producing organic cotton.

- Use of *Azotobacter*, *Azospirillum* alongwith organic matter, phosphate solubilizing micro-oraganisms (PSM) instead of inorganics, should be encouraged and production protocols need to be standardized.

Managing and protecting natural resources

There is growing concern of environmental pollution because of farming (increased C emissions through burning and oxidation of organic matter, fertilizers and pesticides contaminating the ground and surface waters, excess irrigation causing land degradation through salinization etc.). To protect and improve the resource base, developing sustainable conservation technologies are proposed.

- Loamy to sandy loam soil with effective drainage system in north zone is highly suitable. Soil temperature is high at sowing, while soils are low in nutrient status.
- In central and south zone, deep vertisols (black loamy soils) are good for hybrids and *hirsutums*, *Desi* cottons have now been confined to marginal and shallow soils. Red loamy soils are also good in south zone pockets.

Core researchable areas developing conservation technologies are :

1. Anti erosion measures
2. Anti emission/ climate protection methods.
3. Precision farming technologies to raise efficiency of inputs for lowering cost of production.

Drip Irrigation

Cotton on 65% of the rainfed area suffers from water stress at the crucial phase of boll development, and from inefficient water management on rest of the irrigated areas, facing problems of drainage and rising salinity. Drip irrigation system attains relevance here for saving in water consumption to the tune of 40% over conventional irrigation system, and with higher productivity of cotton, the water use efficiency is high. Other advantages, like fertilizer saving upto 30% through fertigation, uniform maturity with optimum fibre quality.

Secondly, due to at critical growth stages, cotton cultivation is to be discouraged on such soils. Reasonably good crop of cotton can be obtained from such soils with low water holding capacity of lighter soils and insufficient supply of plant nutrients with the use of drip system.

Large tracts under cotton are under saline soils, or under saline water use. Since root zone is constantly wet under drip system, soluble salts are pushed away from the zone, enabling a reasonably good harvest of cotton in these areas.

Decision support system

The development of simulation models in association with GIS (Geographical Information System) and remote sensed data to estimate cotton area, soil characterization and its suitability for cotton cultivation, identification of plant types for a particular agroclimatic zone, crop monitoring and forecasting of pest and yield. This is going to help the planners and policy makers to take appropriate marketing strategies.

Stress Management

- Plant responses to different environmental cues at signal perception and transduction level so as to better understand the functional genomic.
- Abiotic stress tolerance through phenotyping, marker assisted selection and transgenic approach.
- Improving the physiological efficiency of the cotton with emphasis on
  - Changing C_3 pathway to more towards C_4 pathway.
  - Use of nanotechnology in the development of stress monitoring devices
  - Development of biosensors to indicate stress and nutrient deficiency

Biochemical Mechanisms

The main mission of Plant Physiology and Biochemistry Program Area is to understand and improve the biochemical mechanisms that limit the stress tolerance and productivity of cotton. Heat stress reduces crop yield by inhibiting photosynthesis when leaf temperature exceeds 32°C. Increased production of 'Heat Shock Proteins' (HSPs) occurs when plants experience a gradual increase in temperature more typical of that experienced in a natural environment.
The mechanism by which heat shock proteins contribute to heat tolerance is still not certain. HSPs provide a significant opportunity to increase heat tolerance of crops. To elucidate their mechanisms of action and to exploit their potential contribution to increasing heat tolerance are needed.

Proteomic studies

Proteome differs from cell to cell and is constantly changing through its biochemical interactions with the genome and the environment.
Proteomics is essential for a better understanding of complex biological systems through isolation, identification, characterization and quantificatioin tiny amounts of almost limitless varieties of proteins.

Two-dimensional electrophoresis, matrix-assisted laser desorption/ionization–time of flight (MALDI-TOF) MS will be used for identification and characterrisation of proteins.

Fibre development

- Enumeration of processes and enzymes involved in the development of fiber quality

Mechanization of cotton production

- Sowing in Punjab is 80% mechanized. So also interculturing, control of weeds with weedicides (stomp), pest management with Tractor Mounted sprayers, self propelled sprayers etc. In other areas partial mechanization of field operations like ploughing, cattle drawn implements for sowing interculture etc., especially in central South zone.
- Machine picking was tested at Abohar (Punjab) but led to high trash and discolouration of lint etc. LH 900 appears suitable. Breeding better varieties suited

for mechanical picking, modification in pickers and defoliation research are needed.
- Hand picked cottons in India are superior to machine picked cottons elsewhere (cleaner with less trash and dust and good colour).

The following machinery need to be developed for efficient mechanized farming:

1. Automated Planting Machines: Computerised self propelled automatic carriers. Dimensions of the field (Length and bredth), spacing between rows and plants to be fed, the machine will complete the job of planting on its own, precisely without a fuss.
2. Weeders: Detect weeds by artificial vision and pattern recognition sensors and codes, activating rotary flails, flame to uproot or kill weeds.
3. Variable rate spraying: Detection of pests/weeds (by way of color, temperature or any other indicator) and delivering the correct dose of pesticide on target. Pesticide delivered only if pest detected e.g. a patch of grass. Thus saving not only pesticide but environment too by preserving flora and fauna.
4. Pickers: Robotic arm pickers with artificial vision to detect white color of cotton, directing the arms to pick cotton.
5. Completely automated system of monitoring, forecasting and decision making: The system will monitor the entire farm by way of sensors installed at various locations, and the data on weather parameters, soil moisture, fertility status, pest build up etc will be collected, fed to the centralized knowledge base, along with satellite data on weather forecast, pest movement etc. for processing by an expert system centrally and decisions made in real time to be implemented either by humans or automatic machines.

Marketing/Pricing of Cotton

- With increased access to global market following GATT, effect of quality parameters on market prices of cotton has to be monitored as in international market, quality will be stressed upon.
- Horizontal market integraton is needed to avoid wide fluctuations in prices within markets and crop seasons.
- Vertical integration of processing with production will facilitate enhanced the sharing for the producer in value added proceeds.
- The impact of changing technological of trade regime on-farm production and marketing has to be monitored.

Research – Client Linkages and Transfer of Technology

- Move from commodity centered approach of extension to a farming systems approach including audit of local resources, market segmentation, production planning, standardization and quality control, and post harvest technology.
- Using the power of online networks, computer communication and digital interactive multimedia to facilitate dissemination of cotton production technology and marketing information.
- Effective use of information and communication technology, TV, radio, national and international networks, internet, expert systems and computer based training systems to improve information access to the farmers, extension workers, research scientists and extension managers.

- Introduction of innovative and decentralized institutional arrangements to make extension system farmer driven and farmer accountable.
- With the private sector, NGOs and other entrepreneurs entering into the arena of transfer of technology in cotton production the issue of human resource development of therse agencies need to be addressed.
- Detailed Manpower profile of extension professionals engaged in transfer of technology which also include skill profiles and skill gap analysis.
- Strengthening of locally relevant innovation processes and knowledge systems.
- Better linking of cotton growers to input and output markets.

Quality Seed Requirements and Role of Various Agencies

- Hybrid seed (certified) is required for present need upto 7600 tonnès year.
- Stable varieties of upland desi cotton varieties are required (certified seeds) upto 75000 tonnes year.
- Now coverage is 100% for hybrids (both certified and truthful label seeds), but some spurious seeds F_2 s etc. are also reported.
- For improved varieties, certified seed use is ranging from 10 to 30% in different states. Inter farmer sales and farmers own seed are more now for varieties.
- There is need for
    - Better demand projection variety-wise BS, FS and CS.
    - Better monitoring of all these stages and timely effective certification.
    - Stricter quality control in the certified seed production and marketing.
- Better coordination between seed units of GOI/ICAR with SSFs –SCAs and private sector seed companies for timely availability of seeds after grow-out tests and certification.
- Need for a well defined seed production programme for hybrids and straight varieties by different state governments – SSC should produce cost efficient certified seeds, limit the number of varieties/hybrids to specific areas, greater involvement of SAUs in breeder foundation seed programmes, guard against import of contaminated seed, region-wise varietal preference, package of practices, certifying organic cotton.
- Better integration of GOI/ICDP in seed production. Some technical coordination agency to keep track of Breeder, Foundation and Certified seed production system. Control monitoring of fibre quality of varieties every year by testing to avoid wide variation in the yield and quality performance of certified seed crop and quick varietal deterioration.

Estimation of Area and Production

- There are conflicting interests in publicizing the estimated area, and particularly production.
- The GOI Ministry of Agriculture estimates are rather conservative and on the lower side.
- Cotton trade (EICA etc.) based on quick estimates of ginning and pressing data provide the production figures, but not always consistent.
- Cotton Advisory Board (CAB) provides consensus based estimate including trade and official data.

- Need for developing cotton yield models integrating all parameters of critical importance especially
    - Soil moisture budget.
    - Pests and disease incidence based on weather data.
    - Inputs from remote sensing data and time series analysis.
- Seventeen major cotton growing districts in five states are under cotton acreage and condition assessment project since 1990-91.
- For area assessment better coordination with State Agriculture Departments is essential including field data collection. More ground based experiments by CICR and SAUs are essential for basic conceptual inputs for this multiple pickings crop. Some limitations of spectral data for moisture stress and bollworms.

Cotton vis-à-vis Synthetic and other Natural Fibres
it is □rboretum□ that with the anticipated increase in the standard of living, the use of synthetic polymers is expected to enhance in the coming years, mostly for blending with cotton, to suit the tropical conditions. Even in the field of textile exports, the role of synthetic fibres may increase further. This situation has to be kept in view while assessing the cotton requirements of the country in the coming years. In addition to the use of synthetics, the incorporation ot jute and allied fibres including sunhemp, ramie, Agave, banana, pineapple pulp, etc. may have to be considered appropriately, if not for production of textiles and garments, at least for the manufacture of rough cloth for some specific needs in the futuristic scenario, so as to develop a wide range of use pattern for the natural fibres and bring about value addition. A collaborative programme arrangement amongst the ICAR fibre-based Institutes will be of considerable utility in this regard.

Plant Protection

Discover Novel Genes For Insect Resistance
The recent advances made in transgenic research over the past decade and the advent of insect resistant transgenic (genetically modified) crops, have opened up exiting possibilities, new areas of research and new avenues in eco-sustainable pest management. However, thus far all the genes deployed in GM research, without exception, have been discovered abroad and were products that were identified for their high suitability for the local relevance and application. The same products were then released for use in other countries. Over the past few years, open market economy and the associated IPR changes have facilitated a possibility for overseas inventors to apply patents in India. In such a changed scenario, indigenous discoveries assume enormous importance and significance for the country. Also, indigenously developed products would be more suited to meet national challenges and local needs. Thus in the context of GATT and WTO guidelines, product discovery assumes great significance for India. There is an imminent need to discover/invent/develop novel products for sustainable use in pest management, exploiting the rich biodiversity available in India. An exploratory search for insecticidal plant and microbial species should be carried out. A few recent examples deal with the use of allatotropins, allatostatins, proctolin etc that have a significant effect on several lepidopteran species when consumed. Peptide phage display technology will be used to identify inhibitors for key target sites in insects. The

potential of such peptides and neuropeptides for bollworm control has not yet been explored anywhere. The search for the insecticidal proteins should include plant sources (leaves, seeds, roots etc.), microbial organisms (Bacillus, Xenorhabdus, Photorhabditis etc.) and neurohormones from insect species (*Helicoverpa*, *Pectinophora* and *Earias*).

Milestones

a) Database on Indian indigenous toxin resources and generate physical library
b) Short-listing of candidate material and preliminary insect bioassays
c) Obtain native *B. thuringiensis* strains and isolate new microbial toxin strains
d) Biochemical partitioning of promising material and bioassays
e) Use of peptide phage display to identify metabolic inhibitors
f) Development of clones for the synthesis of peptide hormones
g) Identification of carrier proteins and combined bioassays on target insects
h) Short-listing of promising carrier proteins and toxin proteins/peptides
i) Purification of candidate proteins and antiserum development
j) Use immuno techniques to identify clones from expression libraries
k) Isolate and/or synthesize genes and prepare gene constructs
l) Use transformation systems to examine efficacy of the constructs in pest control

Expected output

a) New microbial strains and insecticidal toxins from natural sources
b) Novel insecticidal toxins and genes
c) Novel systems comprising of carrier proteins and insect hormones
d) New genes and gene constructs for insect pest management
e) Indigenous patents

Cotton fiber improvement using silk genes from silkworm, *bombyx mori* and spider *araneus* sps.

Cotton fibre quality using recombinant DNA technology has been improved using the PHB genes from bacteria (John and Keller, 1996). Hormonal manipulations of developing cotton fibres through genetic engineering were successful as an experimental procedure but it did not result in significant improvement of fibre strength. Antisensce RNA technology using antisensce mRNA specific to E6, H6 and FbL2 A genes were linked to the 35S, E6 or FbL2A promoters and introduced into Deltapine cotton. Fibre traits such as strength, length and micronaire of various transformants were measured and the results suggested that these proteins are required at very low levels for normal fibre development to occur. Sucrose phosphate synthase gene, the enzyme that was reported to improve fibre quality especially under stress, was isolated from spinach and was introduced into cotton (Haigler et.al. 2000). The resultant cotton transgenics pushed the fibre quality to the premium range even when grown under stressful cool night conditions. Prokaryotic genes have also been used to improve fibre quality.

Synthesis of synthetic genes governing the expression of fibroin (H- Fib, L- Fib, P25), sericin (Ser1 and Ser 2) and seroin in the silk worm *Bombyx mori.* would be initiated. Spider silk known as spindrons and their gene sequences are available too. Full-length gene sequences are available (NCBI accession numbers AB112020, AH 000965, AB112021, AB007831, AB193317, BMOSER I96 etc). Synthetic genes will be designed based on these sequences and synthesized from commercial sources. Development of an expression system of fibroin, sericin and seroin genes of Bombyx and spindroins of spiders. Designing constructs using these genes in consonance with fibre specific promoters. Fibre specific genes of cotton- E6, Fb-B6, Fb- B8, FbL2A and H6 have been manipulated to reduce or eliminate their expression through antisensce technology. Their promoters have been characterized and have been used for transgene expression (John, 1996). Based on the transcriptional ctivity of the FbL2A gene promoter fused to reporter genes in transgenic plants, gene expression of FbL 2A increases rapidly to peak levels around 35 days post anthesis coincident with maximum deposition of cellulose. Transformation of cotton using constructs carrying silk genes either through particle bombardment or through *Agrobacterium* mediated transformation. Selection of transformants using appropriate marker systems and evaluation of cotton fibre quality. Transgene integration and its confirmation using PCR, Southern blot and ELISA methods. These are standard protocols in any transgene production.

Milestones

a) Designing and synthesis of silk genes from silkworm and spider
b) Expression of silk genes from silkworm & spider in *E. coli* systems
c) Development of constructs with silk genes suitable for plant transformation
d) *Agrobacterium* or particle gun bombardment transformation of cotton
e) Confirmation of gene integration through PCR, ELISA and Southern Blot
f) Analysis and analysis of fibre quality.

Expected output

a) Silk gene isolation
b) Enhancing fibre qualities (strength and fineness)
c) Indigenous patents

Farmer Usable Diagnostic Kits For Transgenic Purity

Genetically modified crops have emerged as important components of modern eco-friendly high yielding agriculture. Thus far a total number of 20 transgenic crop plants incorporating 42 genes with 97 transgenic events were developed by 28 commercial companies including public funded institutions and have been released for commercial cultivation in 21 countries. Since, the first introduction in 1996, the area under transgenic crops increased to 90 m hectares by 2005. In India, eleven crops (cotton, corn, brinjal, cabbage, cauliflower, ground nut, mustard, okra, pigeonpea, rice and tomato) have been genetically transformed for enhanced resistance to insects and viruses and are in various stages of testing. Six Cry (crystal) genes (c*ry1Aa, cry1Ab, cry1Ac, cry1F, cry1B, cry2Ab*) and *vip-3A* gene from *Bacillus thuringiensis* were used for insect resistance in nine crops. It is important to develop simple cost effective methods to assist farmers in the detection of transgenic purity of the product before they use the seed for sowing. Apart from assisting farmers, the GMO detection kits will help regulators and quarantine personnel to detect and track down the spread of approved, unapproved and unintentionally released GMOs in the environment. A database will be developed to enlist all genes, markers, promoters, traits and crops that have been released for commercial cultivation in India and elsewhere in the world. The database will also include genes, markers, promoters, traits and crops that are under active consideration in transgenic research and are likely to be released soon for commercial cultivation. Generic markers and the most commonly used trait conferring genes and promoters will be shortlisted to be used for detection methods. New methods will be attempted to design lateral flow strips that can detect DNA from plant samples 'on-the-spot' without having to isolate DNA or carry out PCR and electrophoresis. Transgene encoding proteins will be produced and purified either from over-expressing clones or will be obtained from commercial sources. The proteins will be used as antigens to produce specific antiserum, which will be used to develop ELISA, lateral flow strips (dip-sticks) and dot-blot methods. A common lateral flow strip will be designed to enable the detection of any of the most commonly cultivated GMOs, to be used at port of entry for quarantine purposes.

Milestones

a) Database (Indian and global) on markers, promoters & genes
b) Short-listing of candidate molecules for detection kits
c) Primer designing, PCR testing and validation
d) Development of new DNA based lateral flow strip
e) Purification of candidate antigen proteins
f) Immunization & antiserum development
g) Development of ELISA, Dip-sticks & Dot-blot kits
h) Establishing detection limits, accuracy & repeatability
i) Multilocation validation of the kits
j) Commercialization and making the kits available for use
k) Training to farmers, stake holders and technology dissemination

Expected output

a) Twenty five Dip-stick express kits for all major transgene products
b) Twenty five ELISA kits for all major transgene products
c) Twenty five PCR kits for all major transgene products

Farmer Usable Diagnostic Kits For Biopesticide Purity

Biopesticide purity is one of the greatest concerns in IPM. Thus far standard methods for biopesticide analysis are unavailable. It would be extremely useful to develop farmer usable kits to enable biopesticide purity detection. The format for immuno-Kits has already been developed by CICR, Nagpur and can be used to to develop similar kits that facilitate an on-the-spot assessment and detection of biopesticide purity within 10 minutes.

Milestones

a) Short-listing of biopesticide candidate molecules for detection kits
b) Purification of antigen proteins from bacterial, fungal and viral pesticides
c) Immunization & antiserum development
d) Development of ELISA, Dip-sticks & Dot-blot kits
e) Establishing detection limits, accuracy & repeatability
f) Multilocation validation of the kits
g) Commercialization and making the kits available for use
h) Training to farmers, stake holders and technology dissemination

Expected output

a) Dip-stick express kits for all major biopesticides
b) Farmer empowerment to test biopesticide quality for on the spot test
c) Establishment of simple infrastructure for biopesticide quality testing

Commercialization Of Diagnostic Kits For Resistance Detection And Testing Of Pesticide Purity

At least ten kits have been developed by CICR, Nagpur to enable resistance detection and testing of pesticide purity. The kits will be commercialized and made available to end-users.

Milestones

a) Field and laboratory testing of kits for resistance detection
b) Quality testing from market formulations to test insecticide quality
c) Establishing detection limits, accuracy & repeatability
d) Multilocation validation of the kits
e) Commercialization and making the kits available for use
f) Training to farmers, stake holders and technology dissemination

Expected output

a) Dip-stick express & ELISA kits to detect insecticide resistance
b) Dip-stick express & ELISA kits to check quality for major pesticides
c) Farmer empowerment to test pesticide quality for on the spot test
d) Establishment of simple infrastructure for resistance detection
e) Establishment of simple infrastructure for pesticide quality testing

Farmer Usable Disease Detection Kits

Milestones

a) Short-listing of important diseases where diagnostics are required
b) Cloning of surface protein antigens from the pathogens
c) Purification of antigen proteins from recombinant clones
d) Immunization & antiserum development
e) Development of ELISA, Dip-sticks & Dot-blot kits
f) Establishing detection limits, accuracy & repeatability
g) Multilocation validation of the kits
h) Commercialization and making the kits available for use
i) Training to farmers, stake holders and technology dissemination

Expected output

a) Dip-stick express & ELISA kits to detect diseases for on the spot test
b) Indigenous patents

Resistance Risk Assessment Through Ecological And Genetic Modeling

Over the past decade several simulation models have been proposed to predict the adaptability of pests to insecticides and transgenic crops. Some of the key factors influencing adaptability were identified as Bt-toxin expression in plants, sensitivity of the pest, initial frequency of resistance allele and inheritance of resistance. The model output was solely considered for development of resistance management strategies. Such studies have been done so far only at CICR, Nagpur and will be strengthened.

Insect Diversity In Cotton Ecosystems: Molecular Mapping

Cotton ecosystems have been ravaged by pesticide onslaught over the past five decades. There are very few studies to document the biodiversity and genetic variability of predators, parasitoids, parasites, entomopathogens etc. that were available in the Indian ecosystems, and are remaining currently in our cropping systems. Such studies assist in exploiting the variability in biodiversity of the entomophagous fauna for advantage. Mitochondrial DNA sequencing has opened up new avenues for bioversity mapping for posterity and utility.

Gene Pyramiding For Comprehensive Resistance To Pests And Diseases

CICR has a rich germplasm that has been partly characterized but not exploited properly. A well focused approach can ensure that appropriate germplasm lines can be identified and consolidated so as to enable the development of comprehensive resistant varieties that can help resource poor farmers. Such efforts can be enormously useful in reducing the input costs.

Molecular markers shall be isolated for resistant traits and pooled together in a pyramid through marker assisted breeding programmes.

Explore Insects As Novel Plant Transformation Vectors

Several species of insects are known to act as vectors in transferring virus and bacterial diseases to plants. In most cases insects such as whiteflies and aphids are known to deliver viruses into plant cells without any changes in the pathogen DNA. Such systems can be explored to examine for the full potential of development of novel methods of plant transformation.

Insect Enzymes For Bioremediation Of Insecticides

The cotton bollworm *Helicoverpa armigera* has displayed an enormous propensity for resistance development to insecticides. It was found to be endowed with a remarkable array of enzymes that could detoxify a wide range of xenobiotics including the target insecticides to which the species showed resistance. Such enzymes can be used for bioremediation purposes to detoxify insecticides especially through enzyme-immobilized resins for water purification.

Food Sprays To Augment Biocontrol Agents

Entomophagous insect populations operate as density dependent populations. New technologies such as transgenic crops and new selective insecticides do not favour the build up of pest populations, which would otherwise serve as food source for predators and parasitoids. Food sprays have been effectively used in several countries and are covered by IPR (patents) and therefore not available for use. There is an immense need to augment the parsite and predator populations by the use of extraneous source of food sprays.

Identify new low cost biological technologies and optimize exisiting inputs for pest management in rainfed cotton.

Research on pest/ predator/ parasite ecosystems will enable identification of critical factors that favour the beneficial fauna. Such factors must be suitably exploited for use in low input rainfed systems of crop protection. Several botanicals and indigenous pest control systems can be tested for their compatibility with the small scale cotton production systems.

Strengthen biological control through reducing the cost of bioagent production and enhancing formulation technologies.

Biocontrol systems rely mostly on live production systems, which can be limiting in terms of production costs. There is an imminent need to

i. Develop simple and low cost production technologies
ii. Formulation technology for biopesticides has not been separately developed and relies on the ingredients that are used with conventional pesticides. Such research can find effective solutions that can assist in enhancing the efficacy of bioagents.

Develop crop protection support technologies for organic cotton.

Organic cotton production is extremely challenging from the pest management point of view. It is necessary to identify appropriate technologies such as pest resistant varieties and organically derived pest control systems to support the organic endeavour in the country.

Development of farmer friendly intervention thresholds for pest management.

The conventional economic thresholds were developed earlier based on the damage potential and the relative cost of pest control. Over the past decade new technologies such as bollworm resistant transgenic cotton and several eco-friendly pesticides have radically changed the scenario of pest management. The relative efficacy and cost of conventional and new pest management systems are different and therefore the earlier methods have become irrelevant.

iii. It is necessary to devise simple methods of scouting to assist farmers intervene with appropriate methods of pest control.
iv. Intervention thresholds are not available for biocontrol agents.

Identify suitable transgenics for specific regions to optimize trait value.

Transgenic crop technology is here to stay. The technology offers a tremendous scope to enhance productivity with low input costs in pest management. If properly optimized, transgenics can prove to be extremely useful to the resource poor farmers of rainfed regions of Maharashtra and other parts of the country.

Immunological insecticide residue detection for organic cotton.

Insceticide residues can be detected most reliably through immunological approaches such as ELISA and dip-sticks. Such methods will be developed for organic cotton certification.

Creation of repository of cotton insect pests and their natural enemies:
In view of the changing biological diversity and evolution of biotypes there is need to map insect pests as well as natural enemies. Institute should possess a national repository of all metamorphic stages of predators and parasitoids along with their host insects of cotton.

Standardization of techniques of evaluating host plant resistance including development of molecular markers :
Methodologies adopted for identification of resistance sources should be uniform with high degree of reliability and reproducibility across locations. With the availability of biotechnological tools and sources of resistance currently, there is possibility to develop molecular markers for sucking pest resistance.

Understanding The Dynamic Interactions of Plant-Pest And Natural Enemies
While elucidation of ditrophic interactions of plant and pests aid in revising economic thresholds, tritrophic interactions would improve the strategy of IPM.

Studies On Pink Bollworm To Develop Strategies For Control Of The Pest
The emergence of pink bollworm as a threat to cotton production in the last few years in all cotton growing parts of the country warrants investigations on the biology , ecology and development of management strategies.

Pesticide residue analysis of cotton fibre and oil:
Under the changing economic and environmental regimes and to address the human health, safety, and well being under Integrated Pest Management and organic farming there is need for establishment of Pesticide residue analysis laboratory for quality control of cotton fibre and oil.

Forewarning insect pests:
Changing climate and pest scenarios over localities need to be continually kept under observation vis-à-vis changing cropping pattern for a successful forewarning. Creation of national networks for online information on the insect pest situations and continuous data set generation for quality forecasts should the future line of work.

Development Of Mini-Electronic Gadgets & Software To Detect Pest And Natural Enemy Densities Integrate Data And Recommend Appropriate Remedial Measures

A. Electronic sensors to detect specific pests and intensity of infestation
B. Electronic sensors to detect predator and parasite populations

Insect behavior is guided by semiochemicals (pheromones) called allomones and kairomones. These chemicals have been identified for many species. Subsequently many such chemicals were synthesized in the laboratory for several economically important species and used under field conditions either to monitor their presence or to create mating confusion. Insects have receptors to recognize allomones, kairomones and many other chemicals present in nature. If such receptors can be developed artificially to detect the chemical signals, the detected signals can be converted digitally, amplified and thereafter alert for the presence of the concerned organism. Therefore it should be possible to prepare small electronic gadgets which can be used to detect specific pests and intensity of infestation, predator and parasite population densities, integrate the entire data and also make on the spot recommendations to initiate appropriate remedial measures.

The pest scouting gadgets can be handy, accurate and will reduce the drudgery that farmers face in pest scouting and calculation of economic thresholds.

Electronic Sensors To Detect Intensity Of Pest Damage

Plants emit chemical signals under stress. Signal transduction pathways in cotton are interspersed with many chemical signals including ethylene, jasmonic acid and several related volatiles. If such chemicals can be detected through sensors and if the intensity can be quantified through small electronic gadgets, it would become convenient to make an immediate damage assessment. Thus, based on the intensity of damage, appropriate remedial measures can be initiated. The crop damage assessment gadgets can help in alerting farmers on the overall health of the crop. The gadgets would prompt for an immediate need for crop inspection.

Production Of Biopesticides In Cell Lines And Clones

Production of HaNPV, SNPV and several viruses can be done in cell lines so as to enhance the production capacities.

Cloning Of Super-Virulent Strains of Natural Enemies

Cloning natural enemies for higher pest control potential (enhanced searching efficiency; thylatoky/ enhanced predation etc.)

Development of computer aided expert system for identification of nematodes-plant parasitic and entomopathogenic nematodes up to species level.

Identification of nematodes is based on morphometeric characters and is time consuming. Development of computer aided expert system will aid in quick identification of nematodes by nematologists as well as by non nematologists and will aid in mapping of estimated about an estimated five thousand species of nematodes still in unchartered territory.

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Discovery and identification of marker/ kit for rapid checking virulence for quality control of entomopathogenic nematode formulation used for cotton lepidopetran insect contol.

Virulence is the basic criterion for quality control of entomopathogenic nematode formulation used for cotton lepidopetran insect contol. Discovery and identification of marker/ kit system for rapid checking virulence for help in quality control of entomopathogenic nematode formulation.

Use of nematodes as indicators of cotton soil health.

Sustainability of cotton cultivation is affected by biotic and abiotic processes operating at both above as well as below ground. Nematodes are one of the most ecologically diverse animal s occupying nearly all ecological niches. Thus nematodes can be placed in at least five trophic groups and these groups can be identified easily based on morphological features associated with the mode of feeding. This coupled with their relative abundance, stability of population temporally with no wild fluctuation , standard sampling procedures make strong case for nematodes to be used as indicators of soil health.

Factor quantification that influence phase change in bacterial symbiont of entomopathogenic nematodes.

EPN owe their efficacy to a large extent on associated bacterial symbiont- *Xenorhabdus* or *Photorhabdus spp*. Under certain conditions, there is spontaneous conversion of primary phase to secondary phase bacteria. This phenomenon is of much importance in mass production protocols as conversion of primary to secondary phase can suddenly plummet nematode culture. Role of abiotic factors in influencing phase change has been studied. The genetic studies on such behavioral pattern need to be understood and efforts have been initiated in this direction.

Genomics of toxin production and regulation in epn-bacterial system.

New designer epn – bacterial symbiont systems with better virulence, host finding and tolerance to environment.

Designing of farmer friendly production system for mass production of epn-bacterial bioagent.

Nematode Vaccinaton To Boost Plant Immunity

Mophological Biochemical And Genetic Basis Of Host Plant Resistance To Nematodes

Development of cotton varieties possessing combined resistance to diseases.

Cotton with inherent resistance to key pathogens will be developed to employ the same in IPM package.

A. Genetic approach

- **Screening of genotypes for pest resistance for breeding program.**
- **Development of markers and maker assisted selection of resistant plants**

The genotypes with good agronomic traits will be evaluated against diseases that are endemic in nature. Molecular Markers for resistance to diseases will be identified. These will be utilized for marker assisted screening and breeding for disease resistance.

- **breeding for disease resistance**

- The lines with good attributes will be utilized in the breeding programme for multi adversity resistance (MAR).
- MAR lines will be utilized for transformation with transgenes cloned for disease resistance.

B. Biotechnological approaches

1. Cloning useful genes for engineering resistance to disease

Useful genes encoding products that are toxic to pathogens of cotton will be cloned from various sources viz., plants, microbial antagonists, parasites, etc. of cotton pathogens.

a. **Candidate genes toxic to plant pathogens:**
   - Genes encoding endochitinase from effective strains of *Trichoderma* and *Serratia* spp., chitinases and glucanases from cotton, phloroglucinol from *Pseudomonas fluorescens* strains, defensins from plants.
   - Plant transformation with some of these useful genes will be carried out to impart disease tolerance. These genes can also be incorporated into plants already possessing inherent tolerance to bollworms, sucking pests and diseases to further strengthen the defense potential.

b. **Cloning of broad spectrum disease resistance genes**

- **Microarray analysis** of various genes expressed in pest and disease tolerant cotton will be developed and used for identification of key transcriptomes responsible for resistance.

- **Construction of CDNA and genomic library of cotton genome** cDNA library of defence related ESTs will be developed for the differentially expressed mRNAs. That in turn will be cloned using genomic library of cotton developed in BAC and YACc

- **Bacterial blight** Isogenic lines of cotton have been developed and resistance gene analogs have been cloned. Broad spectrum disease resistance genes will be cloned and used in molecular breeding and gene pyramiding

- **Grey mildew** Differential display strategy will be adopted to identify gene products in grey mildew immune cotton lines that are induced as a result of pathogen challenge. The genes will be identified and used as candidates for cloning in hirsutum cotton and also for pyramiding in MAR cotton

- **Development of CLCuV resistant transgenic cotton** PDR strategy using dsRNAi mediated resistance against cotton leaf curl virus is being attempted to develop CLCuV resistant transgenic cotton. The same technique will be employed to develop resistance against tobacco streak virus on cotton

- **Development of disease resistant transgenic cotton** Novel genes like *NPRI*, the first gene of SAR pathway successfully imparted resistance against a number of diseases by induction of secondary defence system in plant. Similarly Xa21, a broad spectrum *R* gene from rice with multiracial resistance against *X. oryzae*, is a candidate for *Xanthomonas* resistance in crop plants. The genes are already available with us. The same as well as their homolgs from different crops will be employed for development of disease resistant transgenic cotton with approval of ICAR.

C. Development Of Molecular Diagnostic Tools

- **Molecular characterization of major pathogens.** Various genes governing critical phenotypes and those involved in cotton-pathogen interaction and signal transduction of disease resistance will be cloned and sequenced. The sequences will be utilized to develop molecular diagnostic tools as well as in developing strategies to develop disease resistant plants.

- **Kits for pathogen detection** Diagnostic tools already developed for detection of pests and pathogens of cotton will be commercialized as ready-to-use kits. Kits will also be developed for detection of all cotton pathogens (Immunodiagnostic kit for detection of CLCuV is in progress).
    - These tools will be employed to detect the presence of pathogens in soil and environment, differentiation of race / biotypes and in epidemiological investigations.
    - Real-time PCR assays for each pest and pathogen using specific PCR primers will be developed to quantitate the populations and determine ETL. Based on ETL levels disease management interventions will be made.

- **Diagnostic kits for transgene identification** Immunodiagnostic kits will be developed for detection of various transgenes (including Bt gene and other novel genes) That are being / will be cloned in cotton.

Development of an expert system for disease management.

Epidemiology And Development Of Forecasting Models

- Regular surveys will be conducted to monitor outbreak of new diseases, pest resurgence or appearance of new strains of pathogens and pests. These will be correlated with environmental and edaphic factors recorded with the help of coordinating centres.
- Computer-aided prediction and forecasting models will be generated based on various observations.
- Qt-PCR assays and molecular diagnostic kits will be relied heavily in detecting the presence of pathogen in soils, plants, identification of pest species from insects and in forecasting the outbreak.

Biological Control

- Research on conservation biocontrol of pests will be strengthened. Effective strains of antagonistic pathogens (fungal, viral, and bacterial) and entomophagous nematodes will be employed in the field for pest and disease control.
- The active principles will be identified from the antagonist and genes governing production of these inhibitory metabolites (like chitinases, phloroglucinol etc.) will be cloned and used for expression of inherent resistance by genetic engineering.
- The biological control agents will be improved for greater efficiency.

- Mass production protocols of biocontrol agents of pests and pathogens like *Trichogramma*, microbial agents viz, viruses (NPVs, GVs and CPVs), bacteria (Bacillus *thuringiensis, B cereus*), and fungal pathogens (*Beauveria bassiana, Metarrhizium anisopliae, verticillium lecanii, Nomuraea rileyii, Trichoderma rileyii, Gliocladium sp., Pseudomonas* spp.) will be standardized and commercialized. The optimum conditions for storage, efficiency and increasing shelf life of these biocontrol agents will be determined.
- Development of bio-sensor for monitoring rhizosphere/phylloplane colonizing population of pathogen and their interaction with other beneficial microbes.
- Identification, characterization and evaluation of native PGPR strains of cotton and their response in inducing SAR in plant.

Transfformation of effective antagonistic character of PGPR in fast multiplying native microorganism by novel methods.

PERSPECTIVE

By 2025 India's population would be around 1.3 billion. As a result the demand for cotton and other resources will increase. Its estimated that the cotton requirement for 2025 AD. Will be around 525 lakh bales.

- As mentioned, the population will go beyond 1.3 billion mark.
- Cotton requirement will be 525 lakh bales by 2025 AD.
- The share of cotton in textile will be 55-66%.
- Area under cotton will be in the range of 8-9 m ha.
- Area under irrigated cotton may increase to the level of 40-45%.
- The efficiency of inputs need to be increased to a higher level.
- Productivity of rainfed cotton needs to be enhanced.
- Resistance breeding for biotic and abiotic stresses will be given priority.
- Pests and disease problems will be changing with the change of cropping system. Pests will be developing resistance against pesticides. Newer races and biotypes will be appearing.
- Community or cooperative actions (contractual farming) in cotton cultivation including soil and water conservation, irrigation, pest control and mechanisation will be increasing in view of reduction of land holdings.
- Germplasm stock will increase.
- Greater efforts will be made to introduce hybrids in the North, improve '*desi*' cottons in the central and *barbadense* work in south India.
- Emphasis will be given to evolving day neutral, photo-insensitive, medium duration, semi compact varieties/hybrids with synchronous flowering emanable to machine picking.
- Application of biotechnology in solving some of the problems inherent to cotton will get impetus. Area under transgenic cotton will increase.
- Export potential for raw cotton as well as value added products will be enhanced thereby increasing our foreign exchange earnings.
- There will be modernization for ginning, pressing, spinning and textile industry.

Breeding for improved fibre qualities as per emerging needs will receive due attention.

- There will be competitive pricing, grading and better marketing for cotton at national and International level.
- Cultivation of organic (eco-friendly) cotton will receive more attention for getting increased foreign exchange.
- Farmers will be more knowledgeable about the improved cotton production technology due to improvement in Transfer of Technology approaches.
- Greater amount of linkages and coordination are envisaged at National and International evel.

PROGRAMMES

On the basis of lessons learnt and shortcomings in the earlier programmes, future programmes are planned on a time scale which are as follows

Time Frame

The action plan presented below on various aspects may be implemented as part of the research programme of the CICR, CIRCOT, AICCIP and under a Networking Pattern for selected items for which participating centres may be identified in due course. The research programmes envisaged till 2020 AD. Are shown in the form of PERT CHART on the time scale of 2005-2010, 2011-2015 and 2016-2020.

Research Programmes to be undertaken on a Time Scale

Research areas	2005-2010	2011-2015	2016-2020	2021-2025
NAGPUR				
CROP IMPROVEMENT				
Collection, conservation, evaluation and utilization of PGR of cultivated species of *Gossypium*	✓	✓	✓	✓
Utilization of wild species of *Gossypium* for introgression of useful economic traits for the improvement for cultivated cotton	✓	✓	✓	✓
Studies on genetic enhancement and population improvement in diploid and tetraploid cotton	✓	✓		✓
Genome mapping – making molecular linkage map of diploid and tetraploid cotton	✓	✓		✓
QTL mapping for economically important traits inclusive of fibre quality traits	✓	✓		✓
Development of long and extra-long staple cotton suitable for high speed and spinning rotobar jet varieties / hybrids	✓			✓
Development of extra-long *barbadense* variety superior to Suvin	✓			✓
Development of cotton varieties with resistance to biotic and abiotic stresses suited to organic farming	✓	✓		✓
Development of cytoplasmic male sterility based hybrids and diversification of cyto-source	✓	✓		✓
Gene pyramiding for multiple disease and pest resistance	✓	✓		✓
Cotton seed oil and quality improvement without affecting fibre yield and quality	✓	✓		✓
Development of cotton varieties amenable for machine harvesting	✓	✓		✓
Studies on genetics of seed dormancy	✓			✓
Studies on seed priming and pelleting for improving seed vigour	✓			✓
Development of long linted *G. arboretum* with high yield potential.	✓	✓		✓
Gene pyramiding of insect resistant genes especially the bollworm complex.	✓	✓	✓	✓
Development of Multi-Adversity Resistant (MAR) genotypes.	✓	✓	✓	✓
Pre-breeding / conversion of unadapted germplasm in all the four cultivated species into usable and value added varieties.	✓	✓	✓	✓
Improving fatty acid profile of cotton seed oil.	✓	✓		✓
Development of extra-long staple cotton.	✓	✓	✓	✓
Utilization of two-line and one-line method of hybrid seed production, fixation and exploitation of apomictic phenomenon for improving productivity and quality in cotton.	✓	✓		✓
Identification, characterization and conversion of photo-period sensitive germplasm accessions to make them suitable for north zone.	✓	✓	✓	✓
Improvement of fibre quality (length and strength) of north zone cultivars.	✓	✓	✓	✓
Seed Technology				✓
Rediscovering self defense mechanisms in cotton seed against seed microflora (physical, biochemical and molecular levels)	✓	✓	✓	✓
Development of farmers friendly diagnostic tools by dipstick		✓	✓	✓

method for seed viability (for dehydrogenase activity)				
Unravelling the scientific basis of indigenous technology know-hows on cotton seed quality enhancement	✓	✓	✓	✓
BIOTECHNOLOGY				
Targeted integration of economically important genes for cotton improvement				✓
Insect resistance genes available in public domain like Cry 1 Ac, Cry 1 Aa3, Cry I F, Cry I a5, Cry I Ac (Enc)	✓	✓	✓	✓
Disease resistance genes like PDR based approach for virus diseases, Xa21 and NPR1 homologs, chitinases, glucanases and other novel genes for broad spectrum resistance	✓	✓	✓	✓
For drought resistance DREB genes, dehydrin, osmotin genes	✓	✓	✓	✓
Fibre quality improvement genes like cellulose synthase	✓	✓	✓	✓
Oil quality improvement by targeted disruption of critical genes of fatty acid and metabolism		✓	✓	✓
Development of a repository of new gene construct for economically important traits	✓	✓	✓	✓
Screening of cotton germplasm for somatic embryogenesis	✓	✓	✓	✓
Selectable marker gene deletion in transgenics by recombination system	✓	✓	✓	✓
Organelles transformation				
Development of antibiotic marker free and environmentally safe chloroplast + transformation system in cotton	✓	✓	✓	✓
Structural Genomics / Molecular Breeding				
Molecular mapping of descrete traits on cotton map for biotic and abiotic stresses	✓	✓	✓	✓
Mapping quantitative trait loci (QTLs) for fibre quality characters in diploids and tetraploids and marker assisted selection (MAS)	✓	✓	✓	✓
Construction of molecular linkage map of diploid A genome and tetraploid AD genome	✓	✓	✓	✓
Molecular basis of tissue specific gene expression for delayed morphogenesis of gossypol glands	✓	✓	✓	✓
Molecular characterization of genes governing resistance against key diseases of cotton in NILs and other sources of resistance	✓	✓	✓	✓
Investigations on evolutionary basis of fibre in *Gossypium*	✓	✓		✓
Identification of molecular mapping of apomictic genes and exploitation of apomictin and TGMS phenomenon, for improving productivity and quality in cotton	✓			✓
Development of RILs and NILs for fine mapping of economically important traits in cotton	✓	✓	✓	✓
Molecular characterization of core collection / germplasm of upland and *desi* cotton	✓	✓	✓	✓
Development of molecular markers to identify economically important traits in cotton		✓	✓	✓
Development of molecular markers for identification of essentially derived varieties		✓	✓	✓
Functional Genomics				
Identification of transcripts governing tolerance to important pests, diseases and drought	✓	✓	✓	✓
Construction of cDNA library for ESTs expressed in response to	✓	✓	✓	✓

biotic and abiotic stresses				
Construction of genomic DNA library in BAC and YAC for cloning genes of economic importance	✓	✓	✓	✓
Microarray, development and analysis for mapping genes specifically expressed during biotic and abiotic stresses and fibre development		✓	✓	✓
Molecular basis of cotton seed invigoration	✓	✓		✓
Characterisation, isolation and transfer of fibre quality genes in cotton	✓	✓	✓	✓
Geminiviruses based gene silencing vectors as a reverse genetics tool for identification of gene function	✓	✓	✓	✓
Bioinformatics				
Development of database for cotton germplasm accessions	✓	✓	✓	✓
Cataloguing of accessions based on morphological, phenotypic and genetic characterisatics	✓	✓	✓	✓
Development of data base of cotton DNA markers and gene sequences useful in comparative and functional genomics of cotton	✓	✓	✓	✓
CROP PRODUCTION				
Production technologies to address the major issues of lower cost of production and sustainability				✓
Developing innovative and sustainable cropping systems	✓	✓	✓	✓
Development of region specific technologies towards precision farming		✓	✓	✓
Developing land management strategies for improving for C sequestration and improving soil health.		✓	✓	✓
Precise micro irrigation systems (water use efficiency and productivity)	✓	✓		✓
Precision tillage systems (efficient weed management)	✓	✓		✓
Developing integrated nutrient supply system	✓	✓		✓
Developing novel fertilizer products and diagnostic aids	✓	✓		✓
Development of organic cotton farming system (Seed to seed)	✓	✓		✓
Mechanisation of farm operations – Development of ergonomically efficient implements and tools				✓
Indigenous mechanical picker	✓	✓	✓	✓
Planter	✓			✓
Automated planting machines		✓	✓	✓
Stalk puller	✓	✓		✓
Precision Pesticide delivery systems	✓	✓		✓
Use of remote sensing techniques for acreage and crop condition assessment and its integration with GIS (weather and soil) for evolving on-line advisory service for optimized crop management.	✓	✓	✓	✓
Completely automated system of monitoring forecasting and decision		✓	✓	✓
Evaluation of growth and development and physiological efficiency of germplasm accessions and cultivars.	✓	✓	✓	✓
Development of cotton simulation model for yield predictor.	✓	✓		✓
Plant response to environmental cues		✓	✓	✓
Abiotic stress tolerance through phenotyping, MAS and		✓	✓	✓

transgenic approach				
Improving physiological efficiency by conversion of C3 to C4 pathway		✓	✓	✓
Mechanisms of development of fibre quality		✓	✓	✓
Understanding biochemical mechanisms of HSPs		✓	✓	✓
Proteomic studies		✓	✓	✓
Estimation of total factor productivity in cotton.	✓			✓
Structural changes in production system and alienation of cotton growers	✓			✓
International cotton trade, environmental scanning and market intelligence	✓	✓	✓	✓
New institutional arrangements for transfer of cotton production technology	✓	✓	✓	✓
Technology assessment and refinement	✓	✓	✓	✓
Plant Protection				✓
Discover novel genes for insect resistance Cotton fiber improvement using silk genes from silkworm, *bombyx mori* and spider *araneus* sps.	✓	✓	✓	✓
Farmer usable diagnostic kits for transgenic purity	✓	✓	✓	
Farmer usable diagnostic kits for biopesticide purity	✓	✓	✓	
Commercialization of diagnostic kits for resistance detection and testing of pesticide purity	✓	✓	✓	
Farmer usable disease detection kits	✓	✓	✓	
Resistance risk assessment through ecological and genetic modeling	✓	✓	✓	✓
Insect diversity in cotton ecosystems: molecular mapping	✓	✓	✓	
Gene pyramiding for comprehensive resistance to pests and diseases	✓	✓	✓	✓
Explore insects as novel plant transformation vectors	✓	✓		
Insect enzymes for bioremediation of insecticides	✓	✓		
Food sprays to augment biocontrol agents	✓	✓		
Identify new low cost biological technologies and optimize exisiting inputs for pest management in rainfed cotton.	✓	✓		
Strengthen biological control through reducing the cost of bioagent production and enhancing formulation technologies.	✓	✓	✓	
Develop crop protection support technologies for organic cotton.	✓	✓		
Development of farmer friendly intervention thresholds for pest management.	✓	✓		
Identify suitable transgenics for specific regions to optimize trait value.	✓	✓	✓	✓
Immunological insecticide residue detection for organic cotton.	✓	✓	✓	
Creation of repository of cotton insect pests and their natural enemies:	✓	✓	✓	
Standardization of techniques of evaluating host plant resistance including development of molecular markers :	✓	✓		
Understanding the dynamic interactions of plant-pest and natural enemies	✓	✓		
Studies on pink bollworm to develop strategies for control of the pest	✓			
Pesticide residue analysis of cotton fibre and oil:	✓	✓	✓	

Forewarning insect pests:	✓	✓	✓	✓
Development of mini-electronic gadgets & software to detect pest and natural enemy densities integrate data and recommend appropriate remedial measures	✓	✓	✓	✓
Electronic sensors to detect intensity of pest damage	✓	✓	✓	✓
Production of biopesticides in cell lines and clones	✓	✓	✓	
Cloning of super-virulent strains of natural enemies	✓	✓	✓	✓
Development of computer aided expert system for identification of nematodes-plant parasitic and entomopathogenic nematodes up to species level.	✓	✓		
Discovery and identification of marker/ kit for rapid checking virulence for quality control of entomopathogenic nematode formulation used for cotton lepidopetran insect contol.	✓	✓	✓	
Use of nematodes as indicators of cotton soil health.	✓	✓		
Factor quantification that influence phase change in bacterial symbiont of entomopathogenic nematodes.	✓	✓	✓	
Genomics of toxin production and regulation in epn-bacterial system.	✓	✓	✓	✓
New designer epn – bacterial symbiont systems with better virulence, host finding and tolerance to environment.	✓	✓	✓	
Designing of farmer friendly production system for mass production of epn-bacterial bioagent.	✓	✓		
Nematode vaccination to boost plant immunity	✓	✓	✓	
Mophological biochemical and genetic basis of host plant resistance to nematodes	✓	✓	✓	
1. Development of disease resistant cotton **A. Genetic approach** Development of multi adversity resistance (MAR) cotton varieties possessing combined resistance to diseases	✓	✓	✓	✓
B Biotechnological approaches Development of markers and maker-assisted selection of disease resistant plants	✓	✓	✓	✓
Cloning useful genes for engineering resistance against disease	✓	✓	✓	✓
Microarray analysis and identification of key transcriptomes responsible for resistance	✓	✓	✓	✓
Construction of cDNA library of defence related ESTs and their cloning	✓	✓	✓	✓
Development of disease resistant transgenic cotton through targeted integration of known and novel genes	✓	✓	✓	✓
2. Development of molecular diagnostic tools	✓	✓	✓	✓
Molecular characterization of major pathogens	✓	✓	✓	
Development of ready-to-use diagnostic kits for detection of all cotton pathogens	✓	✓	✓	
Real-time PCR assays for each pest and pathogen using specific PCR primers will be developed to quantitate the populations and determine ETL	✓	✓	✓	
Development of Diagnostic kits for transgene identification	✓	✓	✓	✓
3. Epidemiology and development of forecasting models Computer-aided prediction and forecasting models will be generated based on various observations.	✓	✓	✓	✓
4. Biological control	✓	✓	✓	✓

Effective strains of antagonistic pathogens (fungal, viral, and bacterial) will be employed for disease control.				
The active principles governing production of inhibitory metabolites (like chitinases, phloroglucinol etc.) will be cloned and used for expression of inherent resistance by genetic engineering.	✓	✓	✓	✓
Improvement of biological control agents for greater efficiency	✓	✓	✓	
Identification, characterization and evaluation of native PGPR strains of cotton and their response in inducing SAR in plant	✓	✓	✓	
Development of bio-sensor for monitoring rhizosphere/phylloplane colonizing population of pathogen and their interaction with other beneficial microbes	✓	✓	✓	✓
Transformation of effective antagonistic character of PGPR in fast multiplying native microorganism by novel methods	✓	✓	✓	✓

RESEARCH AREAS IDENTIFIED IN THE LIGHT OF THE GUIDELINES OF THE DIRECTOR GENERAL, ICAR

SETTING OF REFERRAL LAB

Seed Testing Lab
Referral Lab for Seed Testing for seed purity and quality may be proposed after the enactment of the new Seed Act.

Referral laboratories/Diagnostic kits for nutrient management
It is proposed to develop a referral lab with all the requisite facilities for Organic cotton certification anticipating a surge in organic cotton production.

Besides, development diagnostic tools for assessing nutrient status are bound to help in effective and timely movement of major and secondary nutrient.

Future Challenges:
The pest management continues to be "pro-synthetic chemical oriented". With the introduction of Bt transgenic and insecticides of new chemistries there is a changing pest scenario, development of resistance to host plant defense chemicals, applied chemicals and genetically introduced toxins by pests would impede the routine pest management. Invention, identification and development of new genes/products of pest management and their patenting should be aimed at pesticide residue laboratory to facilitate monitoring of residue levels.

Forewarning the pests of outbreaks for better preparedness and their management, pest management decision making based on benefit analysis gain importance to strive for a balance of productive gains and pest management practices.

As CICR has been delegated with the responsibility of quarantine examination it is necessary to upgrade Net house and Glass house facilities for which a budgetary provision of Rs.5 lakhs could be made.

Following three labs are proposed:

Discovery lab

A library of plant and microbial material will be compiled based on existing literature and anecdotal references for the exploratory purposes. The genes will be evaluated for efficacy and bio-safety and then used for the development of transgenic crops.

Novel molecular methods such as peptide phage libraries to design/discover new pest control molecules, useable in transgenic crops and/or sprays. New compounds for pest management will be explored from biotic and abiotic sources for use as sprays. Diagnostic kits to detect spurious transgenic seed, spurious bio-pesticides and insecticides will be developed.

Pesticide Residue Research Laboratory

Molecular markers for disease resistance genes, their cloning and characterization, molecular diagnostic tools for pathogen detection, genetic diversity and establishment of phytogenetic relationship among different strains of pathogen should be developed.

DNA cloning lab is needed to clone, characterize and pyramid these genes for effective resistance against different pathogen.

Bio-control Lab :

The antagonist of pathogen exist in nature. In addition many of the antagonist can be genetically manipulated/modified for increased efficiency by modern molecular tools. The research needs to be earnestly intensified in this direction. The effective bio-control agents can be engineered by transforming/*Rhizosphere macroflora* with antagonistic/novel genes or by modifying the existing ones for grater affectivity.

International Collaborations

	AREA	**COUNTRY/LAB**
1.	Genetic engineering of fibre quality improvement (SBN)	CIRAD, France
2.	Molecular linkage mapping and MAS	PGML, UGA, USA
3.	Gene mapping	Texas A&M, USA
4.	Molecular mapping	University of Arkansas, USA
5.	Mechanisation of cotton cultivation	USA, Israel, Australia
6.	Low energy precision application (LEPA)	Cukurova University, Turkey
7.	Precision farming	USA, (Texas, A&M University, State University California)
8.	Nutrient modeling	Texax, A& M University/ USA University of Goetting Germany
9.	Soil quality assessment	Australia Justus Lipebig University, Griessen
10.	Phenology models for forecasts	Texas A&M University College Station, Texas
11.	Crop pest interactions	CSIRO, Australian Co-operative Research

		Centre, Narrabri, NSW, Australia.
12.	Pesticide residue analysis	Pesticide Residue analysis Laboratory, Chattous, Cambridgeshire
13.	Genome analysis EPN & bacteria complex	Ohio University, California University University of Ireland, U.K.

ROAD MAP FOR BASIC, ADAPTIVE AND ANTICIPATORY RESEARCH

A. BASIC RESEARCH

Crop Improvement

- Pre breeding and germplasm enhancement.
- Cotton Genomics
- Molecular breeding.
- Integrated gene management.

Crop Production

- Studies on nutrient dynamics in different cotton growing soils
- Soil water balance and modeling
- Determination of water use patterns and efficiency
- Basic studies on root growth and activity in relation to varying soil moisture and fertility
- Impact of microbial association on nutrient acquisition uptake and translocation.
- Integrated Plant Nutrient Management.

Crop Protection

- Taxonomy, biology and ecology of insect pests - repository of insects pests and natural enemies, dynamics and crop pest associations and ETLS.
- Monitoring and mechanism of insect resistance to insecticides.
- Identification of sources of resistance to insect pests and diseases.
- Development of molecular markers for host plant resistance to insect pests and diseases.
- Forecast insect pests and diseases using medium range weather forecasts.
- Strain and biotype variability in key pathogens and insect pests.
- Seed transmitted diseases their location, transmission, and quarantine and regulation.
- Role of nematodes in disease infections.
- Genetic improvement of entomopathogenic nematodes.

Plant Physiology and Biochemistry

- Screening germplasm lines for abiotic stress tolerance.
- Seed oil-quantitative and qualitative analysis-ranking the variability in seed oil-identification of lines with improved levels of unsaturated fatty acids.
- Development and validation of the yield model under varying agro-climatic conditions.

ANTICIPATORY RESEARCH

Crop Improvement
- Pre breeding and genetic enhancement.
- Molecular characterization of elite germplasm.

Crop Production
- Research on developing tillage systems to improve soil quality.
- Evolving appropriate crop contingency plans in a holistic and cropping system model to manage the impact of climate change.
- Enhancing nutrient and water use efficiency.
- Precision agriculture for cost competitiveness and quality improvement.

Crop Protection
- Development of alternative pest management technologies utilising biodiversity of plants and microbials.
- Development of pesticide residue monitoring and quality control systems.
- Establishment of quarantine centre for disease examination.
- Conservation and augmentation of bio-agents in cotton ecosystem.
- Developing multiple insect pest and disease resistant cultivars.
- Refinement of IPM packages for rainfed cotton.
- Validation of forecast models for insect pest and diseases.
- Diagnostic tools for detection of insect and pathogens.
- Diagnostic kits to detect spurious insecticide/ Bt cotton seed
- Diagnostic kits to detect insecticide resistance

Plant Physiology and Biochemistry
- Effect of global warming on biochemical and metabolic changes, growth, reproductive and yield responses.

ADAPTIVE RESEARCH

Crop Improvement
- Pre breeding and germplasm enhancement.
- Molecular characterization of elite genotypes
- Tailoring improved crop varieties and hybrids
- Quality seed production

Crop Production
- Validation and refinement of existing soil balance model.
- Identification and development of efficient cropping systems
- Development of integrated production technologies (including effective soil water, nutrient and weed management for different soils under varied agro-eco-regions)
- Development and refinement of technologies for organic cotton production.

Crop Protection

- Conservation and augmentation of bio-agents in cotton ecosystem.
- Developing multiple insect pest and disease resistant cultivars.
- Refinement of IPM packages for rainfed cotton.
- Validation of forecast models for insect pest and diseases.
- Diagnostic tools for detection of insect and pathogens.
- Diagnostic kits to detect spurious insecticide/ Bt cotton seed
- Diagnostic kits to detect insecticide resistance

Plant Physiology and Biochemistry

- Effect of plant growth regulators and nutrients on growth, yield and fibre.
- Study of physiological disorders.

COMMERCIALIZATION OF TECHNOLOGIES

- Varieties and hybrids as and when developed and released.
- Commercialization of mechanical planter (bullock drawn).
- Bt detection kits, insect quality and insecticide resistance detection kits. ICOTIPM - a CD.

RESOURCE GENERATION

- Male sterility conversion on demand by the private sector .
- Sale of seeds / germplasm including wild species (after approval of Council)
- Breeder seed production.
- Conducting National / International Training in Biotechnology and sale of detection kits.
- Resource generation is possible by way of testing new chemicals, molecules, plant growth regulators, nutrients, analyses of seed oil and gossypol estimation.
- Consultancies for mass production of bio-agents.

HUMAN RESOURCE DEVELOPMENT (HRD)

- The Hebrew University of Jerusalem, Israel fir gene identification (GB)
- Functional genomics, DAVIS, Florida, USA (JA)

FUTURE CHALLENGES

Crop Improvement

- Fibre quality - long staple and high fibre strength
- Resistance to abiotic stresses (drought, salinity, waterlogging)
- Resistance to abiotic stresses including CLCuV
- Breakdown of resistance (Bt, ClCuV etc.)

Crop Production

Higher CO_2 levels and enhanced temperatures are likely to boost biomass generation and yield, even though some other unknown derangements may set in.

- Enhanced nutrient mining (higher yield and biomass).
- Declining water availability necessitating improved water use efficiency

- Need for higher productivity and profitability along with energy efficiency in view of pressure on land and resources.
- Development and popularization of bullock and tractor drawn and affordable implements/equipments.
- Refining methodologies for crop condition and production assessment.

Crop Protection

- In view of the changing biological diversity and evaluation of biotypes there is need to map insect pests as well as natural enemies.
- Considering the need to conserve the natural bio-agents early in the crop season there is mandatory need to incorporate sucking pest tolerance in all growing cultivars.
- Elucidation of ditrophic interactions of plant and pests aid in revising economic thresholds, tritrophic interactions would improve the strategy of IPM.
- The emergence of pink bollworm as a threat to cotton production in the last few years in all cotton growing parts of the country warrant attention.
- Changing climate and pest scenarios over localities need to be continually kept under observation *vis-à-vis* changing cropping pattern for a successful forewarning.

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