भाकृअनुप
ICAR

Annual Report 2010-11

CICR

CENTRAL INSTITUTE FOR COTTON RESEARCH
केन्द्रीय कपास अनुसंधान संस्थान, नागपुर

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वार्षिक प्रतिवेदन 2010-11

CENTRAL INSTITUTE FOR COTTON RESEARCH, NAGPUR

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Preface

What does it take to enable India become world leader in cotton? With the abundant natural resources, talent and will to succeed, with some good efforts in research and development, India should be able to reach its pinnacle soon. The area at 111.6 lakh hectares in 2010 is an all time record and highest ever for any country in history. It is more than one third of the current global area. Cotton prices have been at an all time high, reaching more than Rs 6000 per quintal during March 2011. Expectations have increased and the area is likely to reach 120 lakh hectares in 2011. This year Brazil has produced a record 119 lakh bales from 10 lakh hectares. India has been able to produce 312 lakh bales from 103 lakh hectares. Among the six major cotton growing countries, Brazil (2027 kg/ha) holds highest productivity level followed by China (1311 kg/ha), USA (945 kg/ha), Uzbekistan (859 kg/ha), Pakistan (684 kg/ha) and India (478 kg/ha). The global cotton production increased significantly over the past 5 years. During 2010 a total of 25,185,000 metric tonnes (148 M bales, 170 kg/bale) were produced. The area under Bt cotton hybrids in India reached about 90% and thus the proportion of long staple cotton increased to more than 78% which was about 38% prior to 2002. India's cotton is having a perceptible impact on the global import-export scenario. India became a leading global exporter of raw cotton with exports ranging from 0.6 to 1.5 M tonnes raw cotton each year from 2005 onwards, while concomitantly, imports declined from 0.43 M tonnes to 0.09 tonnes. This year exports touched 1.1 M tons. The yields appear to have stagnated at an average of 500 kg/ha over the last 6 years starting from 2004, irrespective of the increase in area under Bt cotton hybrids. With challenges increasing constantly, CICR is in the process of reorienting its research programmes to address the emerging challenges and this report provides an overview of the research and development activities undertaken during 2010-11.

An early maturing, medium staple variety, CNHO-12, containing high oil content was notified for the irrigated areas of central cotton zone. *G. arboreum* variety CISA 614 (CICR-2) was also notified for its cultivation in entire north zone. Six genetic stocks with novel and unique traits were registered with NBPGR. Four gene constructs AC_2, βC_1, CP and βV_4 were employed in Agrobacterium mediated transformation for CLCuV resistance using RNAi approach. Bt Adapt II, a stochastic two gene resistance prediction model was developed and validated for devising resistance management strategies for Bt cotton. A new RNA virus belonging to Luteovirideae was identified on cotton for the first time in India. Intra specific variation in the cotton leaf hopper *Amrasca devastans* based on mtDNA studies was reported for the first time. IRM strategies developed by the institute were implemented in 19 districts, covering 236 villages reaching out to 13990 cotton farmers cultivating cotton over 25476 ha. New research projects on high density planting systems for maximizing cotton productivity and basic studies on leaf reddening were initiated. An innovative programme on the isolation and identification of seed specific promoters and gossypol synthesis gene for silencing through RNAi interference was initiated. On rainfed Vertisols and vertic Inceptisols, spacings of 45×15 cm and 45×10 cm were found optimum for short, compact genotypes of *G. hirsutum* and *G. arboreum* respectively. To address the problem of labour shortage for manual weeding, a stale seed bed techniques using a mixture of pendimethalin 1.0 kg a.i./ha and glyphosate 1.0 kg/ha, one week after pre-sowing irrigation was standardized for weed management under winter irrigated tracts of South Zone.

The research achievements presented herein reflect the fruits of the untiring efforts by the entire staff of the institute. The technical support and generous financial assistance from the Indian Council of Agricultural Research and other funding agencies-DBT, DST etc., provides the necessary impetus to accelerate the R&D output. I am highly grateful to Dr. S. Ayyappan, Secretary, DARE and Director General, Dr. Swapan Kumar Dutta, Deputy Director General (Crop Sciences), Dr. K.C. Jain (former ADG, CC) and Dr. N. Gopalakrishnan, Assistant Director General (CC), ICAR, New Delhi for the guidance and support provided and also for encouraging new research initiatives. The invaluable contribution of Dr M. V. Venugopalan, Head, PME Unit, Dr Mahendra Singh Yadav and members of the editorial board are gratefully acknowledged.

K.R. Kranthi
Director

Contents

2. Executive Summary

2.1 Crop Improvement

Nagpur

- The total cotton germplasm holding at CICR is 10375 accessions that include all four cultivated species i.e., *Gossypium hirsutum* (7523), *G. barbadense* (287), *G. arboreum* (1907) and *G. herbaceum* (565), 26 wild species, 15 races and 32 interspecific derivatives and 20 perennials.
- Twenty three exotic accessions (*G. hirsutum* – 18 and *G. arboreum* – 5) were procured from Pakistan under Reciprocal Germplasm Exchange Agreement.
- Twenty-three morphological variants of *G. arboreum* race cernuum having high boll weight (5 g to 7 g), high GOT (42% to 48%), short medium staple (16 mm to 19 mm) and coarse fiber were collected from Tribal region of West Garo Hills, Meghalaya.
- Six genetic stocks with novel and unique traits (*G. hirsutum* - 4, *G. arboreum* - 2) were identified and registered with NBPGR, New Delhi.
- Eighty-six genotypes suited to High Density Planting System were identified from the global germplasm selected on the basis of short internodes, compact fruiting branching habit, early maturing and bolls retentivity.
- Fifteen *G. aridum* based CMS, 137 *G. harknessii* based CMS, 57 restorer, 20 GMS line were maintained by crossing to its fertile counterpart (B-line) by selfing and sibmating.
- Sixty-four genotypes of *G. hirsutum* are in various generations of backcross under conversion of elite genotypes using approved BN-Bt event by conventional method.
- A new variety CNHO 12 (Saraswati) developed at CICR, Nagpur released in 2009 for the irrigated condition of Central zone was notified in the Gazette of India.
- CNA 1003 (ROJA) (*G. arboreum*) has been identified for cultivation in rainfed situation of South Zone by Central Variety Identification Committee during AICCIP Workshop held at CCSHAU, Hisar on April 6-8, 2011.
- CNA 1007 that ranked first in lint yield (608 kg/ha) and third in seed cotton yield was retained for 2nd year in Br.24 (a/b) trial in South Zone. CNA 1008 has been promoted to Br.24(a/b) in Central and South Zone during the crop season 2011-12.
- Four *G. arboreum* entries namely CNA 397, CNA 398, CCA 1014 and CCA 1015 were sponsored for Initial Evaluation Trial Br. 22 (a/b) of AICCIP for crop season 2011-12.
- Six new advance selections of *G. hirsutum* namely, CNH 14, CNH 44, CNH 50, CNH 1107, CSH 121 and CSH 1111 were sponsored for IET Br. 02(a/b) and 3 selections namely, CNHO 12, CNH 1108 and CNH 1109 were also sponsored for compact plant type trial Br. 06(a/b).
- Seven events of T_5 generation (*G. hirsutum* variety LRK 516), 3 events of T_2 generation (Anjali Ac Bt having Bt *cry1Ac*) and 2 of T_1 generation (Anjali FBt- having Bt *cry1F*) were taken to event selection trial.
- New transformation events were generated with *G. hirsutum* cultivars Suraj and LRA 5166 using *cry1Ac* and *cry1F* genes.
- Molecular characterization and insect bioassay were conducted on RG 8 Bt plants.
- Transgenic plants of the three genotypes H 777, HS 6 and F 846 with Sense and Antisense coat protein and Antisense replicase protein were grown in the contained trial of RCGM for event selection.
- Four gene constructs AC2, CP, βC1 and βV4 were used in Agrobacterium mediated transformation for CLCuV resistance by RNA i approach. The plants containing AC2-sense primer were confirmed by PCR for the presence of gene.
- Four drought tolerant events of *DREB 1 A* and *BcZF1* genes were grown in the confined greenhouse RCGM trial.
- Detailed morphological characterization was performed in the germplasm lines belonging to eleven working groups. The variation in gossypol gland density in leaves hold promise to consider gossypol gland density as a special character in DUS testing.
- Quality seeds of cotton, soybean, redgram and Bengal gram were produced under Mega Seed Project.

Coimbatore

- Two superior cultures were tested in Initial Evaluation Trial of AICCIP under irrigated condition viz., CCH 820 (Long Staple Culture) and CCH 10-1 (Medium Staple Culture).
- Culture CCH 2623 tested in the Coordinated Varietal Trial under irrigated conditions recorded a mean seed cotton yield of 1515 kg/ha and 1910 kg/ha in south and central zone, respectively and it was superior to check Surabhi (1277 kg/ha) and LRA 5166 (1489 kg/ha). This culture has been retained in Coordinated Varietal Trial for one more year of testing in both zones.
- Ninety-two NDGB lines and 14 USAGB lines of *G. barbadense* germplasm were maintained and variability was studied during 2010-11 crop season.
- Twenty-two exotic *G. barbadense*, accessions were field evaluated during 2009-10 and 2010-11. Accessions EC-617836 (631 kg/ha), EC-617837 (629 kg/ha) and EC-617840 (614 kg/ha) gave higher seed cotton yield than the control Suvin (371 kg/ha).
- Nine interspecific hybrids viz.; CCHB-2, CCHB-6, CCHB-7, CCHB-8, CCHB-11, CCHB-13, CCHB-20, CCHB-21 and CCHB-22 (SCY ranges from 2632 to 2799 kg/ha) showed significantly higher seed cotton yield over the check hybrids RCHB-708 Bt (2113 kg/ha) and DCH-32 (1927 kg/ha). Hybrids CCHB-22 and CCHB-11 recorded more than 30% yield compared to check RCHB-708 Bt.
- Distinctiveness, Uniformity and Stability testing was taken up in two trials comprising 23 and 19 candidate varieties of tetraploid cotton and one candidate alongwith two reference varieties of diploid cotton.

- In total, 87 application forms comprising of new and extant cotton varieties were submitted to PPV&FRA through NBPGR for registration under PPV&FR Act, 2001.
- Electrophoretic analysis of cotton seed proteins was compared using Tris Soluble Proteins, Salt Soluble Globulins and Methanol precipitated fraction separated by SDS-PAGE. Electrophoretic estimation using Salt Soluble Globulins was found better than other two methods.

Sirsa

- Three hundred and thirty germplasm lines (working collection) were evaluated and their DUS characters were recorded. Superior accession for boll weight : MEADE 9030 D(3.8), UPA (62) 31-65(3.8), CSH 911 (3.7); for yield/plant : CNH 151(153 g), 9-1487(150 g), DELTAPINE C 5(150 g); for boll number : DELTAPINE C 5(56), CNH151(51), 359754(45); for seed index : WC 12 NL(11.6), S 344(11.6), COKER 100 STAPLE(11.5); for GOT RED 5-7(40.3), MLL(40), AURBURN OKRA 213 – OBP – SPB 1978(39.4); for Lint Index: B 61 – 2038(7), L-147(7), BJR JK-97-16-4 (7) were identified.
- *G. arboreum* Variety CISA 614 (CICR-2) has been notified by Ministry of Agriculture for its cultivation in entire north zone.
- Based on 3 years performance, intra-*hirsutum* GMS hybrid CSHG 1862 was promoted for agronomy trial in North zone and it has been identified during the AICCIP Workshop held at CCSHAU Hisar from 6-8 April, 2011. CSHG 1862 showed superiority for seed cotton yield by 11.5%, tolerance to CLCuD and better fibre quality spinning at 50's count.
- The GMS hybrid CISAA 14 recorded seed cotton yield of 2773 kg/ha against zonal check 2617 kg/ha, ranked 4th and was retained in Br.25(a) zonal trial for further testing. It possesses 38.0% GOT, 2.5% span length of 22.9 mm and strength of 17.7 g/tex.
- *G. hirsutum* entry CSH-3129 (SCY 22.8 q/ha) ranked 4th in position and was promoted to Br04 (a) trial.
- *G. hirsutum* entry CSH-3158, with average seed cotton yield of 26.15 q/ha ranked 6th and has been promoted to Br03(a) trial.
- Intra-*hirsutum* hybrid CSHH 3008 was promoted from Br 05(a)-1 National trial to Zonal trial Br05(a)CHT.
- Following eight entries (*G. arboreum*-2, *G. hirsutum*-2, GMS based *G. arboreum* hybrids-2, GMS based *G. hirsutum* hybrid-1, Intra *hirsutum* hybrid-1) were sponsored in AICCIP trials namely *G. arboreum*-CISA 7R, CISA 105; *G. hirsutum*-CSH 2810, CSH 3114;GMS based G. arboreum and *G. hirsutum* hybrids- CISA A17, CISA A18, CSHG 3118 and Intra *hirsutum* hybrid CSHH 4007.
- Forty-seven *G. hirsutum* cultures were evaluated and the CLCuD resistant cultures CSH 2934 with highest GOT (35.0%) and CSH 2936 with highest seed cotton yield of 2723 kg/ha were identified.
- Breeder seed of female and male parent of Hy. CSHH 198, CSHH 243, CSHH 238, CICR 2, and *desi* cotton varieties CISA 310 and CISA 614 was produced.

2.2 Crop Production

Nagpur

- On rainfed Vertisols, the genotype PKV 081 was found most suitable for high density planting system (HDPS) (166000 plants/ha) based on yield (1921 kg/ha), morphological features, earliness, tolerance to sucking pests and boll weight. In *G. arboreum* on the basis of yield, CINA 404 (2174 kg/ha) performed best under HDPS (222000 plants/ha). However other high yielding genotypes viz., JK-5 (1842 kg/ha) and AKA-07 (1815 kg/ha) were dwarf and more compact than CINA-404. Across the genotypes a spacing of 45 x 13.5 cm (166000 plants/ha) was optimum for short compact types. Similarly a spacing of 45 x 10 cm (222000 plants/ha) was optimum for short compact plant types of *G. arboreum*.
- In both *G. hirsutum* and *G. arboreum* application of 25% extra fertilizer dose is essential to sustain higher yield under HDPS. Application of Maleic hydrazide (@ 500 ppm at 45 DAS (days after sowing) and Mepiquat chloride (@ 60 ppm at 45 DAS) showed promise to further enhance the yield under HDPS.
- The physical nipping of plants reduced the plant height in Bt hybrids and foliar application of maleic hydrazide also brought about the same effect by effectively inhibiting the meristem growth in both main stem and sympodial branches.
- Bt cotton intercropped with Roselle produced higher cotton equivalent yields, nutrient use efficiency, C:B ratio and net returns than sole Bt cotton on rainfed Vertisols.
- Controlling weeds by harrowing once before sowing or Roundup 2.5 l ha^{-1} + pendimethalin 1.0 kg a.i. ha^{-1} alongwith three inter-cultures and two hand weeding was effective for weed control in rainfed cotton on Vertisols.
- Stance was effective in reducing the plant height by reducing the internodal distance in Bt hybrids. Defoliant Dropp effected 90-100 % defoliation after 15 days of spray and it was superior to Ethrel exhibiting 73- 90% defoliation.
- Receding moisture and high light intensity induced reddening of leaves. Foliar application of nutrients, hormones and fungicide could not control leaf reddening, but the intensity of reddening varied. Plants sprayed with monocrotophos showed no reddening all through the season. With foliar application of Methomyl, the whole plant turned red within 24-48 hours after application.
- Improved cotton production technologies were demonstrated in the villages, Nandura and Loni (District Yavatmal) in 66 acres by 33 farmers under NAIP (cotton value chain) project. Higher seed cotton yield (2350 kg/ha) was recorded in closer spacing (75 x 60 cm) followed by INM practices (2165 kg/ha) as compared to farmers' practice (1190 kg/ha). Technology on protective irrigations with 90 x 60 cm spacing produced higher yield (2400 kg/ha).
- Under mechanization of cotton cultivation, a small sized manually operated cotton planter was developed for planting cotton seed and an adjustable cultivator was designed and developed for intercultural operation for narrow spaced cotton crop and a fertilizer applicator has been modified for equal distribution of fertilizer from both

tubes. Field efficiency manually operated small hand picker varied from 56 % to 100 % of the manual.

- Knowledge assessment and adoption of cotton intercropping practices revealed that around one third respondents (34%) in the districts of Akola and Khandwa were placed under full knowledge group while one forth respondents (26%) had fully adopted various components of intercropping.
- The sociological problems faced by the cotton farmers were family responsibilities, family conflicts, increasing alcoholism/ drug abuse. The overall percentage of sociological factors for agrarian distress among the farmers was noted to be 68.81 per cent (71.59% in Yavatmal and 66.15% in Jalgaon). Among economical factors, the majority of the respondents expressed that, the rising cost of cultivation, yield uncertainties, labour problem, inadequate irrigation facilities and increasing dependency on others in farming leads to distress among them.
- In Yavatmal district, highest achieved cotton yield among the sample was 2750 kg/ha whereas average yield was 1730 kg/ha. Yield gap was estimated to be 1020 kg/ha. In Jalgoan district, yield gap was estimated to be 1302 kg/ha. Important constraints which are contributing to this yield gap were ranked based on the loss associated with them. Incidence of sucking pests, weeds problem and leaf reddening, delayed sowing due to late onset of monsoon and water logging were the main constraints.

Coimbatore

- Cotton plants responded to foliar application of nutrients better under irrigated condition than under moisture stress. Nutrient consortia of DAP 1% + KCl 0.5% + $MgSO_4$ 0.5% + $FeSO_4$ 0.25% + $ZnSO_4$ 0.25% + other micronutrients increased yield significantly both under irrigated and moisture stress condition.
- Genotypes viz., LRA 5166, Anjali and H777 more tolerant to heat stress than Bt cotton (RCH 2, RCH 20, Bunny, MRC 6918, Mallika and Thulasi. Among the Bt cotton hybrids MRC 6918 and Mallika were more sensitive to heat stress.
- 125% RDF with foliar spraying of DAP 1.5% + K 0.5% + Mg SO_4 0.5% + boron as solubor 0.15% recorded the higher seed cotton yield (3653 kg/ha), net return and B/C ratio under Bt cotton + coriander system compared to sole Bt cotton in winter irrigated tract.
- Stale seed bed technique (SSBT) using a mixture of pendimethalin 1.0 kg + glyphosate 1.0 kg one week after irrigation (one week before sowing) recorded the highest weed control efficiency of 86.6% on 35- 45 DAS and on par seed cotton yield with HW thrice under SSBT.
- The pre emergence application of pendimethalin followed by one hand weeding at 35 - 40 DAS and post emergence application of either phenoxy-p-ethyl 100 g or quizalofop-ethyl 50 g on 60 DAS recorded better control of weeds and on par seed cotton yield with hand weeding thrice (20, 40 and 60 DAS).
- On an average, Bt cotton growers of Karnataka are incurring an expenditure of Rs. 37582.62 per ha towards cultivation. Human labour is the major cost item accounting for 50.01 per cent of working expenses. Fertilizers and manures occupy second and third place accounting for 16.19 per cent and 11.09 per cent respectively of working cost. On an average cotton farmers are producing 1800 to 2200 kg of seed cotton per ha. B:C ratio was worked out to be 1.39. An increase of 26 per cent in net returns was observed in Bt cotton cultivation when compared with non Bt cotton.
- In the post WTO period between 1995-96 to 2010-11, the area, production and yield had grown at 0.85, 7.35 and 6.45 % respectively. During the post WTO period, the quantity of imports almost remained stagnant at 13 lakh tonnes and gradually reduced during post Bt era from 22 lakh bales of 170 kgs each to 5 lakh bales. The export increased from 17 lakh bales during 1999-00 to almost 83 lakh bales of 170 kgs each during 2009-10.
- From the Marlow Chain analysis, it is evident that China has been the only stable importer of Indian cotton, as reflected by the high probability of retention that increased from 0.04 during the pre-reforms period to 0.62 during the post-WTO pre Bt period to 0.71 during post Bt era. Italy and Thailand have depicted low probability retention of 0.67 and 0.54, respectively.
- The yield gap ranged from 600 to 716 kg/ha in Coimbatore and Perambalur districts of Tamil Nadu. Weed infestation, non-availability/ shortage of hired labour and inadequate irrigation facilities are major constraints affecting cotton production.
- Assessment of the livelihood changes perceived by the growers in different production systems were analysed using Sustainable Livelihood Analysis. The biotech cotton production system had created significant changes in the livelihood of cotton growers.
- With the use of "Multi Criteria Decision Analysis" and GIS tools attempt has been made to develop Decision Support System for selection of suitable genotype for the specific agro climatic conditions.

Sirsa

- The net income of Rs. 65190 with MRC 7017 and Rs. 65340 with Bioseed 6488 was higher in sole cotton followed by paired row with 3 rows of mungbean with Rs. 61100 with MRC 7017 and Rs. 61350 with Bioseed 6488.

2.3 Crop Protection

Nagpur

- Field dynamics of mealybug *Phenacoccus solenopsis* in 3 cotton cropping systems of India have been studied. Field dynamics of mealybug *Paracoccus marginatus* and *Creontiades biseratense* has been studied in cotton + pulses –maize cotton cropping systems while population dynamics of *Campylomma livida* was studied in cotton + pigeon pea –fallow cropping system of India.
- Sampling techniques for *C. livida* indicated that top one – third portion of plants harboured highest number of mirids and a sample size of 15 plants per acre was found to be optimum to assess mirid population.
- Growth parameters of *P. solenopsis* were studied at constant temperatures of 20 °C and 35 °C at Nagpur.
- Biology of leaf hopper *Amarasca devastans* was studied.

Nymhal period of instar I, II, III and IV was in the range of 2-4 1-5, 1-3 and 1-4 days with average period of 2.58, 2.14, 2.03 and 1.84 days respectively. The total nymphal period was 8.59 days which was less than the adult period of 13.37 days. The total life cycle of male and female was 21.38 and 23.19 days respectively.

- Population dynamics for mirid *Campylomma livida* was studied at 6 different locations. The highest population was recorded during 37th SW (6.16 per plant) in cotton intercropped with citrus followed by cotton adjacent to water canal. The mean population during the season was maximum in unprotected field (1.61 per plant) and minimum (1.08 per plant) in cotton surrounded by soybean and sorghum.
- Record of 166 host plants of *P. solenopsis* has been made during season and off season across India.
- The Ahmadabad native Bt strain was effective against *H. armigera,* efficacy was on par with the standard strains HD1 and Btk. It belongs to the *cry2A* class.
- Native Bt strains isolated from the saline soils of Barrackpore and from Pasighat of the North east were found effective against *Spodoptera*. Some of these Bt strains belong to *cry2A* class while some belong to the *cry9* class. Atleast two strains carry *cry2A* and *cry9* genes together.
- Leaf hoppers on cotton in North India are genetically different from populations of South and Central India. Evidence is provided based on the CO1 sequences of 258 single insect samples.
- Comparing sequences of COI, COII and NADH1 regions using MEGA 4 it was observed that transversion was predominant in the COI region while transitions occurred in the NADH1 and COII regions.
- Twenty-four haplotypes based on the CO1 sequences were identified in the leaf hopper.
- Neonicotinoid resistance is high in Central and South Indian cotton leaf hopper populations as compared to populations of North India. Resistance ratios to imdacloprid and thiomethoxam was highest in Haveri (6,200 fold and to thiomethoxam 56.5 fold).
- Interspecific variation in the toxicity of *cry2Ab* was observed with *Spodoptera. S. exigua* is several folds more susceptible to the toxin as compared to *S. litura*.
- The variability in toxicity of *cry1Ac* to *H. armigera* was 58 fold across the country.
- dsRNA for three genes, Protein 40, Aminopepetidase and pectate lyase reduced reniform nematode penetration by 37-46%. Of these two genes, protein 40 and Aminopeptidase have also been found to reduce penetration of root-knot nematode indicating that the two genes, Protein 40 and Aminipeptidase have potential for their use in RNAi mediated management of phytonematodes.
- Bt Adapt II a stochastic two gene resistance prediction model was developed and validated.
- Lectin detected in ELISA kit developed for CEA and AMTL. CEA banana lectin and AMTL in combination showed neither addictive nor synergistic effects on aphids, jassids and white flies, indicating the probability of relatively common spectrum of related reception for these lectins.
- IRM strategies implemented in 19 districts, covering 236 villages reaching out to 13,990 cotton farmers cultivating cotton over an area of 25,476 ha.
- Biochemical and molecular characterization required for CIB registration was carried out for four bacterial isolates (NG, D6, G1 and G5) belonging to *Photorhabdus, Xenorhabdus spp*. symbiotically associated with entomopathogenic nematodes and which have been found effective against insect pest including mealybug.
- Insecticidal toxin genes Tcc2, TcdA, TcdB, TcdAb and TcdA2 with amplicon size ranging between 750-1000bp were amplified from bacterial symbiont of entomopathogenic nematodes using primer pairs designed. The sequences had similarity with *Photorhabdus* toxins having oral and intrahaemocoleic toxicity.
- Positive correlation (r=0.901) was observed between incidence and severity of BLB in PKV081.
- Though substantial amount of genetic diversity exists in CLCuV strains of North India, there is no relation between genetic diversity and geographical distribution as observed using beta DNA sequences.
- A new RNA virus member of Luteovirideae was identified occurring on cotton by RT-PCR for the first time in India.
- 16SrRNA sequences of 6 bacterial biocontrol agents showed that three belonged to *Pseudomonas aeruginosa*, two to *Bacillus subtilis* and one to *Ochrobactrum anthropii.*
- A record of 9 species of parasitoid and 8 species of predator was made. Among the parasitoids, *A. bambawalei* (Hymenoptera: Encyrtidae) parasitised mealybug *P. solenopsis* between 5 to 100 % in the three cotton growing zones of India.
- Genotypes tolerant to sucking pests including leaf hopper, leaf reddening with high yielding potential were identified as Ankur Jai BG II, Ankur – 3042 BG II, Atal BG II, Express Fusion Bt (NCEH – 14 Bt) and VICH – 303 Bt (BG II).
- Validation of IPM versus recommended package of practices was carried using 6 Bt genotypes. IPM interventions were beneficial over RPP in all treatments, except sole Express fusion Bt.
- Cotton pest surveillance was carried out in 29 districts of Maharashtra and advisory was issued as and when required, based on the pest situation.

Coimbatore

- Seasonal dynamics of mealybug and mirid bug revealed 32.1 – 40.7% and 18.2 – 27.7% mean infestation respectively on cotton in five project villages of Tirupur district.
- Out of twenty eight Bt cotton hybrids (27 BG II & 1 BG), three BG II Bt hybrids viz., MRC 7583 BG II, Akka BG and Ankur 5642 BG II were found tolerant to leaf hopper with hopper injury grade of 1.0 and significantly higher yield of 1645, 1611 & 1435 kg/ha as compared to check hybrid DCH 32 which recorded 1088 kg / ha.
- Three entries *viz*., SP 911 BG II, SP1037 BG II and Ankur 1976 were tolerant to mealybug with 0.2 to 0.4 grade level of

infestation and recorded significantly higher yield of 2013, 1662 and 1546 kg/ha as against 1704 kg/ha in MRC 7351(Check Hybrid).

- Six *hirsutum* genotypes *viz*., CCH 809, CCH815, LRA 5166, CCH 819, CCH 820 and CCH 825 were found tolerant to leaf hopper and recorded less than 1.0 grade injury as against 2.37 injury grade in ICGH 630. Six entries *viz*., ICGH 341, 370, 410, 474, 480 and 630 were identified as tolerant to bollworms and recorded yield ranging from 71 to 111 g/plant. Twenty three entries *viz*., CCB 20, CCB 23, CCB 24, CCB 25, CCB 26, CCB 27, CCB 28, CCB 29, CCB 31, CCB 32, CCB 33, CCB 34, Suvin (C), CCB – 1-1, CCB 5, CCB 11, PIMA 121, SUDON 436, ICB 125, GSB 39, CCB 17, CCB 18 and ICGH 370 were found free from leaf roller as against standard varieties LRA 5166, MCU5VT and Suraj which recorded 57.5, 60.0 and 67.5% infestation, respectively.
- Imidacloprid, Acephate 75SP (750 g), Acetamiprid, and Acephate 95% SG (562.5 g) were effective against leaf hopper with a reduction of 53.2, 51.0, 37.2 and 35.0%, respectively and increased seed cotton yield significantly by 11.6 to 25.0%, over control.
- Mirid bug *Creontiades biseratense* occurred from October second fortnight to January first fortnight, under cotton with pulses cropping system. Significantly minimum and maximum population of nymphs and adults were recorded during last week and second week of November and January respectively. Occurrence and its correlation to abiotic factor has been worked out.
- Status of sucking pests *viz*., aphid, leafhopper, thrips and whiteflies population were below threshold level and averaged 3.93, 1.16, 0.73 and 0.32 and 1.23, 0.73, 0.50 and 0.24 /3 leaves in IRM and Non IRM fields respectively at Tirupur District, Tamilnadu.
- Number of surviving larvae *P. gossypiella* on NBt hybrids were significantly higher as compared to the larvae in Bt hybrids, within three BG, BG II and NBt hybrids of RCH, MRC and Bunny genotypes.
- Cotton seed based artificial diet has been standardized for rearing pink bollworm *P. gossypiella*.
- Establishment of parasitoid *A. papayae* on mealybug *P. marginatus* in cotton was recorded at CICR, RS, Coimbatore. High intensity of parasitisation and adult emergence were recorded on twigs alone and twigs with leaves, respectively as compared to leaves alone.
- Pheromone trap catches of *P. gossypiella* was recorded from December to February 2011. Average adult catch per trap per night was maximum during the last week of January (165.75/trap) and the larval population recovered from the bolls in that particular field was maximum during this period only in two non Bt hybrids of RCH 2 NBT (19.75/5 bolls) and Bunny NBT (16.75/5 bolls).
- Bioassays conducted with *cry1Ac* (0.1,1 and 10 ppm concentrations) on F_1 population of field collected Pink bollworm *P. gossypiella* from Dharward, Coimbatore and Nandyal, indicated LD_{50} and LD_{90} values 0.060 and 0.092, 0.058 and 0.089, 0.069 and 0.105 respectively.
- During 2010-2011, the IRM strategies were successfully implemented in 15 villages of Gudimangalam Block at Tirupur district under the project TMC MM II IRM. A total number of 188 farmers from 15 villages with an area of 143 ha were covered. Implementation of IRM strategies in the project villages resulted in the reduction of number of sprays from 7 to 4 and the plant protection cost from Rs.7248/ha to 4483/ha besides an increase in yield from 3230 to 3340 kg/ha between Non IRM and IRM farmers.
- The Per cent Incidence (PI) and Severity Index (SI) of *P. marginatus* ranges from 02 to 80 and 1.00 to 2.07 respectively. Higher SI and PI recorded during the month of January and February.
- Cotton field adjacent to weedy road recorded with highest mean PI (48.08) and SI (2.06) followed by sole cotton (PI-41.15 and SI -1.07) and field surrounded by fallow land with weeds (PI-41.54 and SI-1.13).
- Growth parameters of cotton mealybug *viz*., *P. marginatus* and *P. solenopsis* at 20°C and 25°C indicated rate of increase is high at 25°C compared to 20°C. While comparing all the growth parameters of *P. solenopsis* and *P. marginatus*, growth is favoured at 25°C than 20°C and *P. marginatus* more susceptible to temperature changes than *P. solenopsis*.
- Chitin added medium shows higher activity of pathogenesis related enzymes than other sources. Among the entamo-pathogens, *M. anioplea* shows high enzymes activities followed by *B. bassiana* and *V. lecanii*. Saccharose containing medium gave high biomass production irrespective of the entomopathogen.
- Foliar application of *B. bassiana* gives maximum endophytic colonization percentage of 32 at 10^8 concentrations.
- *Fusarium solani* and *Fusarium oxysporum* are predominant endophytes. *B. bassiana* readily forms an endophytic relationship in Bt and Non Bt cotton and causes no plant pathological symptoms.
- Two bacterial antagonists *viz*., *Psuedomonas flourescens* and *Bacillus subtilis* were isolated from nematode suppressive soils. Both bacteria significantly reduced the hatching and survival of reniform nematode.
- Evidence was provided for nematicidal property of *Anonas comosus*, *Chromolena odorata* and *Mimosa invisa* against reniform nematode.
- Bacterial cells alone and cell free extracts of bacterial symbiont (*Xenorhabdus stockiae*) of a native entomopathogenic nematode, *Steinernema siamkayai* was tested against *H. armigera*, *S. litura*, *Sylepta derogata* and *P. marginatus* under in vitro condition. Both bacterial cells and extracts were pathogenic to test insects.
- A maximum of 70% viability and virulence of spores was recorded when a native isolate of *Lecanicillium lecanii* was multiplied on SDAY medium and formulated in talc. Oil in water emulsion based formulation of *L. lecanii* stored at 9 $\pm$ 1°C recorded 78.33 % viability at the end of six months of storage.

Sirsa

- The resurgence (8.29%) in whitefly population due to fipronil was recorded after 10 weekly spray applications but in case of individual spray round, the 2nd spray resulted into maximum resurgence (77.31% after one day and 47.89%

after seven day of spray application) in whitefly population.

- Among various insecticides and biopesticides tested, imidacloprid (53.63%) resulted in maximum reduction of jassid population and neem oil + nirma powder resulted in maximum (52.95%) reduction of whitefly population. Maximum thrips population was reduced by biopesticide, Pest guard L 50EC (45.37%). The biopesticides and entomopathogens were found safer to generalist predators.
- Peak infestation due to mealybug in cotton–wheat system was highest during the June –July and October-November, 2010. Weed species, *Kanghi buti*, *Xanthium* and *Congress grass* were found to be the major starter host for the onset of infestation on cotton season. From 20 Ground truth data collection locations of different blocks, mean average mealy bug seasonal incidence (%)-15.37, severity index-0.91 and parasitization due to *A. bambawalie* (%)-11.20 was recorded.
- Infestation and observations on Pink bollworm larval recovery were recorded from four locations of North Zone (Faridkot, Sriganganagar, Sirsa and Hisar through examinations of 150 green bolls thrice at 140, 160 and 175 DAS from Bt and non Bt cotton. The PBW larval recovery from non Bt cotton ranged between 6 to 120 from the bolls collected at different intervals and % recovery was 6.67 to 80%, whereas no larval recovery was recorded.
- Reduction in insecticide spray from 20.73-39.5% in twenty IRM villages and yield increase of around 270 kg/ha leading to net increase in income of 14000/- per ha was observed in Sirsa and Hisar districts.
- On the basis of 3 sprays applied in chemical control of sucking pests through foliar application at 75, 90 and 105 days after sowing the maximum reduction (58.08%) in jassid population was recorded in case of imidacloprid 200 SL; in whitefly population (51.40%) was recorded in acephate 75% SP @ 750 g a.i./ha and in thrips (51.18%) was observed in case of fipronil under AICCIP.
- The entomopathogen *F. pallidoroseum* did not show any adverse effect on beneficials.
- *Spinacea*, *Chenopodium*, *Solanum nigrum*, *Lantana camara* and *Convolvulus arvensis* were identified as new weed hosts as they tested positive for CLCuV with Coat protein primer.
- Seed cotton yield reduction with 60%PDI varied from 27.45% (NECH-6) to 43.52% (Bioseed-6488) and with severity grade 4, it varied from 35.59% (RCH-134) to55.0% (Bioseed-6488), due to CLCuV.

3. Introduction

3.1 : Brief History

Nagpur

Indian Central Cotton Committee used to sponsor cotton research schemes on an adhoc basis till the work of the committee was taken over by the ICAR in 1966. All India Coordinated Cotton Improvement Project (AICCIP) initiated by the Council in the year 1967 with headquarters at Coimbatore gave new fillip and direction in terms of multidisciplinary and multi-centre approaches with the active involvement of State Agricultural Universities. The 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 low level of productivity since major cotton growing area is under rainfed conditions, a need for expanding the research efforts in the spheres of basic and fundamental research was felt, the Central Institute for Cotton Research was established at Nagpur by the ICAR, in 1976. The two regional stations of IARI at Sirsa (Haryana) and Coimbatore (Tamil Nadu) were transferred to CICR to cater to the needs of cotton farming in north and south India, respectively.

The main mission of CICR is to increase the production, productivity and profitability of cotton cultivation in different agro-ecological cotton growing zones through the development of relevant, feasible, economically viable and ecologically sound production and protection technologies including the development of improved varieties and hybrids and promoting basic and strategic research.

3.2 : Mandate

- **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 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**

3.3 : Major Research Achievements

The institute has developed several genetically modified genotypes of *Gossypium hirsutum* and *Gossypium arboreum* (*desi*) varieties incorporating *cry1Ac*, *cry1F*, *cry1Aa3* genes for insect resistance, chitinase genes and viral coat protein genes for disease resistance and *dreb* and *Zn-finger* genes for drought resistance. These varieties are being subjected to biosafety testing and are expected to be made available to farmers within the next 4-5 years, after approval of the GEAC. The institute is known all over the world for its pioneering work on molecular pathology especially on the geographical diversity of bacterial blight pathogens and also for the complete range of DNA based detection kits of all cotton pathogens. The institute has pioneered the development of immunological ELISA (Enzume linked immunosorbent assay) detection kits and DNA based PCR tests to detect genetically modified (GM) crops that express any of the Bt genes such as *cry1Ac*, *cry2Ab*, *cry1F*, *cry1C* and also with generic markers for NPT-II and UID-A.

In a new exciting development, two new genetically modified events have been developed by the institute for resistance to the cotton leaf curl virus resistance. A novel class I *chitinase* gene confirming fungal disease resistance was amplified, cloned from *G. hirsutum* (LRA 5166) and transformed into grey mildew susceptible *G. arboreum* cultivars PA 255, PA 402 and RG 8. The events were found to be promising and are being intensively tested for resistance. Lectin genes CFA from *Colacasia esculenta* and AMTC from *Amorphophallus poeniphalus* were effective against aphids and whitefly and in combination with banana lectin form a potent source of gene for the developmental of sucking pest resistant GM cotton.

From the conventional varietal improvement programme, two high yielding *G. arboreum* varieties *viz*., CISA 310 and CISA 614 were released and notified for cultivation in the North zone. In addition, an early maturing, high oil yielding compact *G. hirsutum* variety CNHO 12 was released and notified for the Central zone.

The institute has the world's second largest germplasm collection and 26 wild species which are being used in 'introgression breeding' to develop varieties resistant to insect pests, diseases and abiotic stress. Several other innovative aspects of useful research include the discovery of apomixis, cleistogamy, temperature sensitive male sterility and five-loculed genotypes.

The institute has obtained several national and international patents in South Africa, China and Uzbekistan. The Bt-detection kits have been patented and commercialized. The kits have become extremely popular with farmers, extension workers and seed testing agencies, as evidenced by the fact that kits worth more than Rs. 422 lakhs have been purchased thus far. The Bt-detection kits enabled regulation, streamlining and ensuring Bt-cotton seed quality for farmers in the country. All seed testing laboratories in the country have been using the kits. The bollworm resistance management strategies using the resistance detection kits were implemented in 26-32 cotton growing districts in the country over 10 years with financial support from the ICAR and the Ministry of Agriculture, Government of India. The research and technology innovation thus resulted in reducing the usage of insecticides by more than 60-80% without any reduction in yields. The project which

has been funded by the Ministry of Agriculture has about 100,000 farmers as direct beneficiaries and was implemented in 1650 villages covering nearly 200,000 hectares in 30 districts of 10 cotton growing states since 2002. The direct benefits from the project implementation are estimated to be more than Rs. 160 crores on account of insecticide reduction and enhanced yields. Last year, the IRM strategies were disseminated in 330 villages of 11 districts in North zone, 172 villages in 11 districts of Central zone 150 villages of 10 districts in South zone and 10 villages of South 24 Pargana, district of East zone reaching out to 38,472 cotton farmers.

Artificial diets for aphids, jassids and white flies were developed. For eco-friendly (organic) pest management, Mealy Kill was found effective against mealy bugs and synthetic analogues of methyl jasmonate, ocimene and limonene were effective against jassids, aphids and mealy bugs. A talc based formulation of entomopathogen *Lecanicillium leccani* was developed which was effective against mealy bugs (*Phenococcus solenopsis* and *Paracoccus marginatus*). Insecticide resistance in jassids was quantified in a networking mode for the first time. Jassids were found to exhibit 5450 fold and 2500 fold resistance to imidacloprid and thiamethaxam as compared to 57 fold resistance to conventional chemicals such as monocrotophos.

Agronomy of NHH 44 Bt on rainfed Vertisols of Central zone was standardized and 90 x 30 cm spacing was found optimum. Supplementing the recommended NPK with Zn (10 kg/ha) and B (3 kg/ha) was found necessary to sustain rainfed cotton yield on shallow (less than 50 cm) black soils. A prototype of a 2-row fertilizer applicator as an attachment to the bullock drawn blade harrow was developed. Agrotechniques to boost the productivity of ELS cotton – fertigation (90:19:37 kg N:P:K) in 6 splits, alternate day drip irrigation at 0.8 Etc, soil moisture conservation through bio-degradable mulches were standardized.

The institute has developed many implements and devices and has filed patent applications for 'solar powered knap sack sprayer' and 'bullock drawn planter' that have been developed and commercialized. The CICR has also developed and validated a cotton crop simulation model for yield gap analysis and regional production forecast. The socio-economists of the institute have carried out detailed studies on the agrarian crisis in Vidharbha and other cotton growing regions of the country and have suggested programmes research approaches that can offer solutions to the crisis. CICR has initiated special research programmes under the 'Technology Mission' project to face the emerging challenges and pave the way towards yield enhancement.

The Institute contributed immensely towards yield enhancement through its research findings that helped in developing remedial measures for the management of mealybugs, leaf reddening, and wilt problems which have recently become a menace, especially reducing yields of Bt-cotton.

3.4 : Staff Position (as on 31st March, 2011)

Name of the Post	Sanctioned Cadre Strength				Post Filled Up			
	NGP	CBE	Sirsa	Total	NGP	CBE	Sirsa	Total
Director (RMP)	1	-	-	**1**	1	-	-	**1**
P.C. (Cotton) & Head	-	1	-	**1**	-	1	-	**1**
Scientific	50	22	7	**79**	32	17	6	**55**
Technical	50	20	7	**77**	46	12	6	**64**
Administrative	34	9	5	**48**	27	6	5	**38**
Supporting	59	30	10	**99**	45	18	10	**73**
Krishi Vigyan Kendra								
Training Organizer	1	-	-	**1**	1	-	-	**1**
Technical	11	-	-	**11**	8	-	-	**8**
Administrative	2	-	-	**2**	2	-	-	**2**
Supporting	2	-	-	**2**	1	-	-	**1**

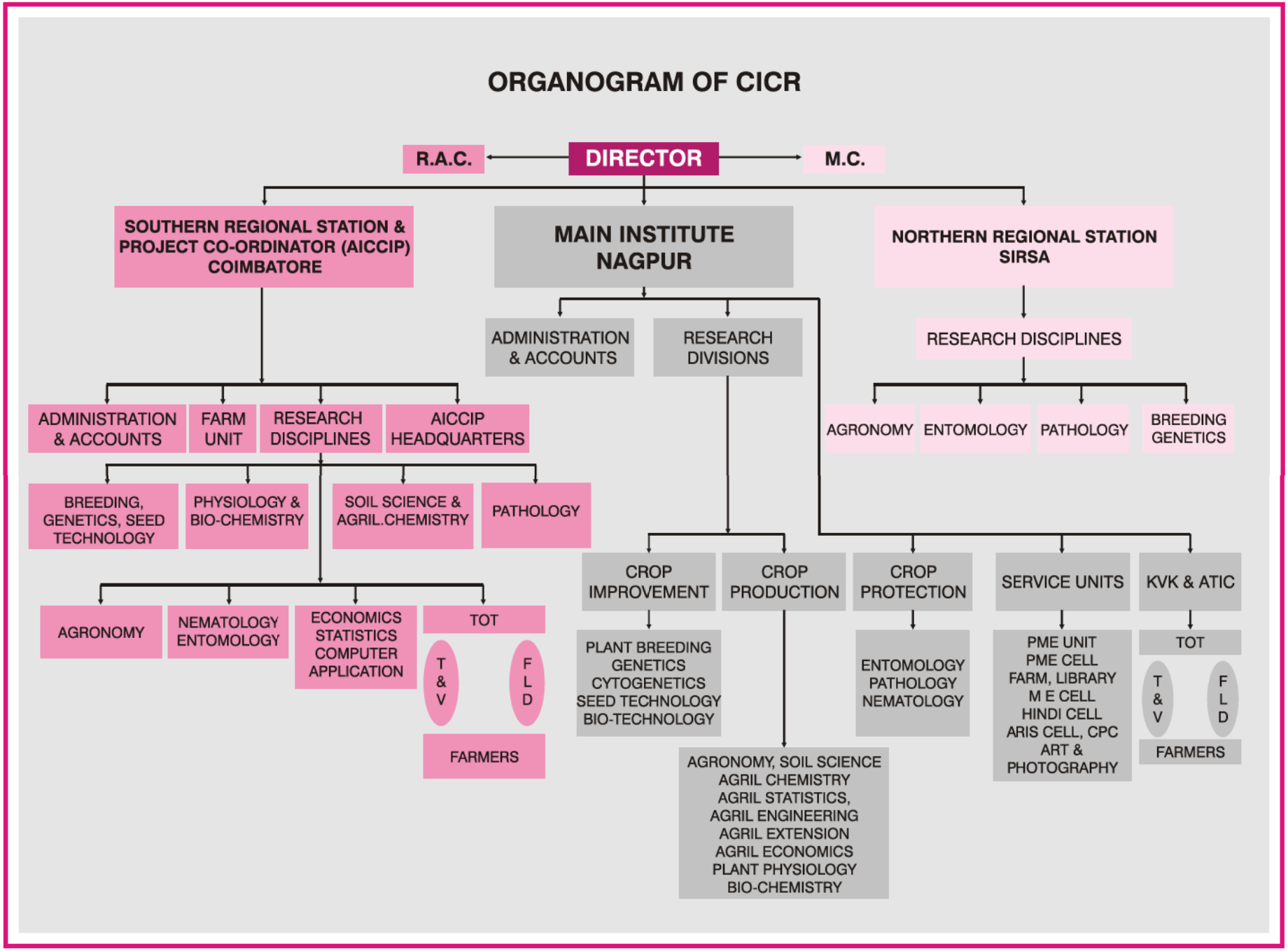
NGP – Nagpur; CBE - Coimbatore

3.5 : Financial Statement

The budget grant and actual expenditure for the year 2010-11 are furnished below:

(Rs. in Lakhs)

S. No.	Scheme	Sanctioned	Expenditure
1	Plan	300.00	299.95
2	Non-Plan	1806.47	1806.22
PLAN SCHEME			
3	National Seed Project (Crop)	5.60	1.31
4	Krishi Vigyan Kendra	117.75	115.03
5	AICRPS Remtt.	857.00	857.00
6	PC Cell (AICCIP)	43.00	42.99
7	TMC MM-I	430.30	430.30
8	TMC MM-I CICR	219.70	219.69
9	MSP	25.05	23.15
10	ITMU Project	70.50	6.40
	Total Plan Scheme	**1768.90**	**1695.88**
NAIP PLAN SCHEME			
11	NAIP Value chian	28.79	27.96
12	NAIP DSS	16.08	13.36
13	NAIP Geosis	4.75	4.29
14	NAIP L & CB	4.60	4.59
15	NAIP ASRB	14.60	11.23
	Total NAIP	**68.82**	**61.43**
DEPOSIT SCHEMES FUNDED BY OUTSIDE AGENCIES			
16	Transgenic Crop	35.21	16.87
17	Bt.Cellous	0.04	0.00
18	MMFRQDBT	0.57	0.00
19	Fast Track	2.78	2.23
20	RNAi DBT	5.20	3.78
21	Gene Stacking	6.40	5.83
22	DUS Scheme, Ngp	5.00	3.58
23	DUS Scheme, Cbe	7.50	4.18
24	Dupont Scheme	3.34	0.00
25	J.K. Toxin	6.74	0.12
26	NMITLI	31.67	20.66
27	DBT Marker	6.05	3.82
28	Indo AUS DBT	12.54	5.70
29	Genetic Eng.(AKI)	5.76	5.58
30	Maint. Of Breeder Seed Scheme.	0.03	0.00
31	TMC Scheme MM-II	77.01	73.55
32	Mahyco I	9.18	2.32
33	Mahyco Bollgard II	13.87	3.81
34	FLD Scheme	0.45	0.42
35	Training	6.67	3.88
36	Testing fee	150.29	81.48
37	FLD KVK	1.11	1.09
38	Bt. Kit	112.14	0.03
39	DUS Mahyco RKD	2.65	1.02
40	SPM	3.24	3.24
41	CROPSAP	2.60	2.43
42	EBAM Project	30.50	10.74
43	EPN (BT Cloning)	21.38	21.21
44	DUS Testing (VS)	1.78	0.23
45	DUS Testing CBE	2.38	0.35
46	I & ISS Project	6.35	5.87
47	DNA Bar Code	10.00	4.03
48	GEAC Project	18.51	18.48
49	Cotton Picking	29.89	7.55
50	DBT Insect RNAi	23.59	9.09
51	BRL-II	10.00	7.19
52	GA ARIS	9.68	5.15
	Total	**672.08**	**335.52**


ORGANOGRAM OF CICR
DIRECTOR
R.A.C.
M.C.
SOUTHERN REGIONAL STATION & PROJECT CO-ORDINATOR (AICCIP) COIMBATORE
MAIN INSTITUTE NAGPUR
NORTHERN REGIONAL STATION SIRSA
ADMINISTRATION & ACCOUNTS
FARM UNIT
RESEARCH DISCIPLINES
AICCIP HEADQUARTERS
BREEDING, GENETICS, SEED TECHNOLOGY
PHYSIOLOGY & BIO-CHEMISTRY
SOIL SCIENCE & AGRIL.CHEMISTRY
PATHOLOGY
AGRONOMY
NEMATOLOGY ENTOMOLOGY
ECONOMICS STATISTICS COMPUTER APPLICATION
TOT
T & V
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CROP IMPROVEMENT
CROP PRODUCTION
CROP PROTECTION
SERVICE UNITS
KVK & ATIC
PLANT BREEDING GENETICS CYTOGENETICS SEED TECHNOLOGY BIO-TECHNOLOGY
AGRONOMY, SOIL SCIENCE AGRIL CHEMISTRY AGRIL STATISTICS, AGRIL ENGINEERING AGRIL EXTENSION AGRIL ECONOMICS PLANT PHYSIOLOGY BIO-CHEMISTRY
ENTOMOLOGY PATHOLOGY NEMATOLOGY
PME UNIT PME CELL FARM, LIBRARY M E CELL HINDI CELL ARIS CELL, CPC ART & PHOTOGRAPHY
TOT
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AGRONOMY
ENTOMOLOGY
PATHOLOGY
BREEDING GENETICS

4. Research Achievements

4.1: Cotton Genetic Resources

Nagpur

Biodiversity, characterization, conservation and utilization of cultivated and wild species

Central Institute for Cotton Research (CICR) has a mandate of collection and maintenance of global cotton germplasm. The total cotton germplasm holding is 10375 accessions that include all four cultivated species i.e., *Gossypium hirsutum* (7523), *G. barbadense* (287), *G. arboreum* (1907) and *G. herbaceum* (565), 26 wild species, 15 races and 32 interspecific derivatives and 20 perennials.

Twenty three exotic accessions (*G. hirsutum*–18 and *G.arboreum*–5) were procured from Pakistan under Reciprocal Germplasm Exchange Agreement. Twenty three morphological variants of *Gossypium arboreum race–cernuum* were collected from Tribal region of West Garo Hills, Meghalaya. The variants possess high boll weight (5 g to 7 g), high GOT (42% to 48%), short medium staple (16 mm to 19 mm) and coarse fiber. Three perennials of *G. arboreum* were also collected from Phulwari, West Garo Hills tribal region of Meghalaya.

Seed of 800 accessions of *G. arboreum* were sent to NBPGR, New Delhi for long term storage and conservation. Another set of 560 accessions of G. hirsutum were kept in medium term storage at CICR, Nagpur.

Six genetic stocks with novel & unique traits (*G. hirsutum*-4 *G. arboreum*-2) were identified and registered with NBPGR, New Delhi (Table 1).

Table 1 : The genetic stocks registered with NBPGR during 2010-11.

Name	Species and race	Registration No.	Unique and Novel Traits
SLL - 33	*G.hirsutum race -latifolium*	INGR 10060	Single leaf lobe
YPLL - 29	*G.hirsutum race - latifolium*	INGR 10061	Yellow pigmented leaf lobe
CSLL - 59	*G.hirsutum race - latifolium*	INGR 10062	Cup shaped leaf lobe
ABGMS (CSHN)	*G.hirsutum race - latifolium*	INGR 10058	Genetic male sterility
CISA - 2	*G.arboreum race - bengalense*	INGR 10057	Sterile mutant
CINA 333	*G.arboreum race - bengalense*	INGR 10059	High seed cotton yield potential with shoot claw of petal

Evaluation of germplasm

Five hundred and fifty germplasm accessions of *G.hirsutum* including exotics were evaluated under high density planting system at 30 cm x 20 cm spacing. Eighty-six genotypes were identified and selected on the basis of short internodes, compact fruiting branching habit, early maturity and bolls retentivity. Twenty nine single plant selections and seven segregating progenies were evaluated for seed cotton yield, boll weight, GOT and fiber traits.

Exotic accessions of *G.barbadense* were identified for seed cotton yield EC – 617836 (1024.07 kg/ha) and EC – 617837 (1020.14 kg/ha), ginning outturn EC 617841 (32.3 %), EC – 617844 (31.0 %), staple length EC 617843 (35.5 mm), EC 617854 (34.8 mm), EC 617837 (34.1 mm), EC 617838 (33.4 mm) , and fiber strength EC 617841 (32.3 g/tex), EC 617844 (31.0 g/tex), EC 617840 (30.3 g/tex).

Cluster boll bearing accessions

Sixteen accessions of *G. hirsutum* were evaluated for morpho-economic characters and fibre properties. The promising accessions were identified for boll weight CB 214 (5.6 g), CB 204 (4.9 g), CB 206 (4.7 g); for GOT CB 214 (39.3%), CB 216 (37.3%), for staple length CB 215 (26.9 mm) and for fibre strength CB 210 (20.5 g/tex) and CB 215 (20.6 g/tex).

Assessment of gossypol content

Gossypol content of 69 germplasm lines of *G. arboreum* working collection belonging to different character groups such as GOT, MHL, Marker, boll weight, early maturing groups was determined and percent gossypol content was found to be in the range 0.25-0.97%.

Molecular characterization of cotton germplasm

Characterization of core accessions

Molecular characterisation of 94 core accessions using 55 primers (22 SSR, 14 SRAP, 8 TRAP and 11 RAPD) was carried out, of which 48 primers (20 SSR, 13 SRAP, 5 TRAP and 10 RAPD) were polymorphic. Fifty-five primers amplified a total of 277 fragments of which 158 were polymorphic which corresponds to 57.03 per cent polymorphism across 94 accessions. Polymorphism detected by SSR, SRAP, TRAP and RAPD was 26.98, 49.45, 56.75 and 87.20 per cent, respectively. The size of amplified fragments ranged from 300 bp to 3 kb, 170 bp to 3kb, 120 bp to 920 bp and 150 to 400 bp while the similarity coefficient (SC) values ranged from 0.83 to 1, 0.71 to 0.98, 0.56 to 0.94, and 0.31 to 0.94 for RAPD, SRAP, TRAP and SSR, respectively. The combined marker analysis revealed an overall SC ranged from 0.70 to 0.94 with an average of 0.82. The dendrogram analysis using RAPD + SRAP + TRAP + SSR similarity matrix data revealed eight major clusters and three accessions as outgroup members (Cat-3773, Cat-1911, Cat-3056). The lowest SC of 0.70 was found between Cat-299 with Cat-3773, Cat-3846 and Cat-3904 while the highest SC of 0.94 was between Cat-692 and Cat-1034. Distinct genotypes from among the different clusters were identified that can be used in breeding programmes.

Characterisation of working germplasm

Molecular characterization and genetic diversity analysis of 24 working germplasm of *G. hirsutum* (Early group – 10, Bacterial blight resistant group – 8 and Jassid & bollworm resistant group – 6) using PCR based RAPD, ISSR and Microsatellite (SSR) markers was carried out.

Eleven polymorphic RAPD primers produced a total of 98 amplification products of which 54 were polymorphic (54.88%) with 4.9 average number of polymorphic amplicons per primer. The UPGMA clustering of twenty-four working germplasm lines revealed a major cluster consisting of 23 germplasm lines while one line I-81 as distinct outgroup having similarity coefficient of 0.89. The main cluster was grouped into two clusters A and B with similarity coefficient of 0.912. Cluster B consisted of only one germplasm line BAR 1218 from Bacterial blight resistant group. The cluster A was sub-divided into sub-clusters A1 and A2 having similarity coefficient of 0.913. The sub-cluster A1 has twenty germplasm of different character groups whereas sub-cluster A2 has two germplasm KW-61-276 and UPA-57-17, both resistant to Bacterial blight.

Genetic diversity analysis by ISSR markers

Fifteen polymorphic ISSR primers produced 149 amplification products of which 91 were polymorphic (61.94%) with 6.06 average number of polymorphic amplicons per primer.The UPGMA clustering pattern revealed a major cluster consisting a total of 23 germplasm while PEE DEE 0111 A from USA emerged as outgroup and distinct with similarity coefficient of 0.89. Twenty-three lines were grouped into two clusters, cluster A & cluster B having similarity coefficient of 0.901. The cluster B consisted of only one accession, CO2 from Coimbatore, resistant to Bacterial blight. The cluster A was subdivided into sub-clusters A1 and A2 having similarity coefficient of 0.909. The sub-cluster A1 had twenty germplasm whereas sub-cluster A2 had two germplasm lines COKER 413 and KEMP from USA sharing similarity coefficient of 0.921.

Genetic diversity analysis by microsatellite markers

Fifteen polymorphic microsatellite primers produced a total of 75 amplicons of which 61 were polymorphic (85.26%) with 4.26 average number of polymorphic amplicon per microsatellite marker. The UPGMA analysis revealed a major cluster consisting of 23 germplasm while CNH-154 emerged out to be most distinct having similarity coefficient of 0.73. Twenty-three germplasm could be grouped into two clusters, cluster A & B having similarity coefficient of 0.74. The cluster B consisted of two germplasm, CNH-123 and DCI 122 having similarity coefficient of 0.808. The cluster A was further subdivided into two sub-clusters A1 and A2 having similarity coefficient of 0.793. The sub-cluster A1 has eighteen germplasm of different groups whereas sub-cluster A2 has three germplasm i.e. BAR-1218, KW-61-276 and KEMP resistant to Bacterial Blight sharing similarity coefficient ranged from 0.840 to 0.900.

Principle coordinate analysis

Principle Coordinate Analysis (PCA) generated from RAPD, ISSR and microsatellite data of twenty-four cotton working germplasm showed that all the germplasm were relatively spread out on all the three axes. The first, second and third axes explained 15.01 %, 12.70 %, 9.92 % variation for RAPD, 14.75 %, 11.25 %, 9.95 % for ISSR and 22.31 %, 16.49 %, 11.60 % for microsatellite markers, respectively.

Characterization of total working collection using DNA markers

In National Cotton Gene Bank of Cotton at CICR, Nagpur presently a total of 388 working germplasm collection of G. hirsutum is maintained that has been divided into various groups depending upon their specific characters viz. yield group (YG), mean halo length group (MHL), boll weight group (BW), oil content group (OIL), naked seeded group (NS), ginning outturn group (GOT), salt group (SG), marker group (MAR), fibre and strength group (FSG), variety group (VAR), okra group (OK), bacterial blight resistant group (BBR), jassid and bollworm resistant group (JBWR), boll worm resistant group (BWR) and early group (EG). Character groupwise genetic diversity analysis was carried out using PCR based STMS Markers.

Twenty eight STMS primers were employed that produced a total of 139 amplicons of which 113 amplicons were polymorphic, resulting in 80.65 per cent polymorphism and 4.03 average number of polymorphic bands per primer. The number of DNA amplified fragment per primer ranges from 3 (JESPR 208) to 8 (BNL 2709) and the average amplicons size between 100 to 1000bp.

Unique amplicons/markers

Unique amplicons were identified for few of the genotypes namely MWR-2 (BNL 1694_{170}, BNL 1694_{190}), BURI-0-394-Y (JESPR 215_{100}, JESPR 360_{100}) and IC-356312 (MUCS-422_{380}).

STMS cluster analysis

The data obtained by STMS markers were analyzed by NTSYS-pc software Version 2.02. The UPGMA clustering pattern of 388 working germplasm showed two major clusters, Cluster A and B. Cluster A consisted of 379 and cluster B consisted of 9 germplasm. OKRA-LEAF from total 388 working germplasm emerged out to be the most distinct. The similarity coefficient by STMS markers were in the range of 0.74-0.92. Principal Coordinate analysis (PCA) based on genetic similarity matrices were used to visualize the genetic relationships of *G. hirsutum* working accessions.

Groupwise analysis and dendrograms obtained by STMS markers

Group I : Yield Group - Out of 30 working accessions, GRS-60-6-IL-3-G and UPA 57-17 showed 92 % similarity whereas EC-110788 emerged out as distinct and diverse germplasm. The similarity coefficients among STMS markers were in the range of 0.67-0.92.

Group II : Mean Halo Length Group – Out of 10 working germplasm, EL-958 (MHL-690) and G-21-17-619-3-MS showed 92 % similarity. The similarity coefficients were in the range of 0.57-0.92.

Group III : Boll Weight Group - Out of 33 working germplasm, ACALA-8-1 x10-SP and DUNN-56-C-A from USA showed 96% similarity. The similarity coefficients were in the range of 0.73-0.96.

Group IV : Oil Content Group - Out of 13 working germplasm, M-4 and MACHA showed 89% similarity whereas 21 from Siruguppa emerged out as diverse germplasm. The similarity coefficient of STMS markers were in the range of 0.73-0.89.

Group V : Naked Seeded Group - Out of 11 germplasm, AC-520 and Acala-1517-D-64 showed 91% similarity whereas AC-83 and ACALA x HOPE-76-15-5 emerged as most diverse. The similarity coefficient were in the range of 0.76-0.91.

Group VI : Ginning Outturn Group - Out of 21 germplasm, HA-46-124 and 86-Al-1 showed 96% similarity while 7203-14-104 and STAM-42 from USA were most diverse. The similarity coefficients of STMS markers were in the range of 0.75-0.96.

Group VII : SALT Group – Of the 6 germplasm, J-34 and MAHALAXMI showed maximum 85% similarity. The similarity coefficients of STMS markers were in the range of 0.77-0.85.

Group VIII : Marker Group – Of the 66 working germplasm, SA-16 and SA-747 from USA showed 98% highest similarity. The similarity coefficients of STMS markers were in the range of 0.66-0.98.

Group IX : Fibre Strength Group - Out of 16 germplasm, DELTAPINE-45 and DELTAPINE (CJ) from USA showed 91% similarity whereas P-56-6 & MWR-2 emerged as outgroup and diverse among other germplasm. The similarity coefficients of STMS markers were in the range of 0.75-0.91.

Group X : Variety Group – Out of 56 germplasm, J-34 and SS-265 showed 96% highest similarity. The similarity coefficient of STMS markers were in the range of 0.65-0.96.

Group XI : Okra Group - Out of 18 germplasm, AROZONA-SUPER-OKRA-CC-MLL-DH-OKRA & SUPER-OKRA-CC-MLL-DH showed 96% similarity. The similarity coefficients of STMS markers were in the range of 0.72-0.96.

Group XII : Bacterial Blight Resistant Group – Out of 18 germplasm, UPA(62)31 & 101-102-B from Uganda & USSR showed 95% similarity. The similarity coefficients of STMS markers were in the range of 0.72-0.95.

Group XIII : Jassid and Bollworm Resistant Group - Out of 58 working germplasm lines from Coimbatore, Akola, Malwa and Surat showed 96% highest similarity whereas JK-344 & 36-YY-GJHS-53 from Surat and Dharwad emerged out group in cluster as most diverse among other germplasm. The similarity coefficients of STMS markers were in the range of 0.62-0.96.

Group XIV : Boll Worm Resistant Group - Out of 5 germplasm, NDLH-1745 and BW-28 showed 87% highest similarity whereas P-846 from Punjab emerged out as most diverse. The similarity coefficients of STMS markers were in the range of 0.80-0.87.

Group XV : Early Group – Out of 27 germplasm, EC-141679-84 and DCI-108 from USA and Nagpur showed 92% similarity whereas 320-F-CC from Jalandhar emerged out as most diverse. The similarity coefficients of STMS markers were in the range of 0.74-0.92.

Coimbatore

Maintenance and evaluation of *G. barbadense* germplasm

Ninety-two NDGB lines and 14 USAGB lines of *G. barbadense* germplasm were maintained and variability was accessed during 2010-11 crop season. Twenty-two exotic *G. barbadense* accessions were also field evaluated during 2009-10 and 2010-11. EC-617836, EC-617837 and EC-617840 gave higher seed cotton yield than the control Suvin. 2.5% span length of all the EC lines was less than Suvin except the line EC-617843 (36 mm) which was at par with Suvin (36.5 mm). The highest bundle strength was noticed in the accessions EC-617844 and EC-617840. The ginning percentage of EC-617836 (30%) EC-617840 (30.3%) and EC-617844 (31%) was higher than the check Suvin (27.0%). EC-617864 exhibited exceptionally high micronaire of 5.8 against the control Suvin (3.5 μ/inch).EC-617838 and EC-617855 were identified as early maturing germplasm lines, requiring 191 days for uniform bursting while other lines and control matured in 225 days. Accessions EC-617841 and EC-617864 exhibited bigger boll size while EC-617843 with fibre length (35.5 mm), bundle strength (29 g/tex) and micronaire of 3.6 holds promise for commercial exploitation.

Sirsa

Collection, conservation and maintenance of genetic resources

Three hundred and thirty three (333) new germplasm working collection grouped based on superior traits were evaluated for yield contributing parameters, fibre properties, morphological parameters, reaction to pest and diseases etc. These lines were also characterized for 34 DUS parameters. The range for various parameters i.e. for seed cotton yield/ plant 15-153 gm, boll weight 1.3-3.8 g, boll number 5-56, ginning outturn 27-40.3%, seed index 5-11.6 g, lint index 2.2-7, number of monopodia 0-5, number of sympodia 2-14 and for plant height 34-200 cm was observed. The superior accession i.e. for boll weight (g) MEADE 9030 D(3.8), UPA (62) 31-65(3.8), CSH 911 (3.7); yield/plant (g) CNH 151(153), 9-1487(150), DELTAPINE C5 (150); height (cm) LAM Guntur (200), 356587 (170), S4727 (155); number of monopodia GISV -86/58(5), WC 12 NL(4), GALAMA(4); number of sympodia CNH154(14), 356587(13), LAM Guntur (12); boll number DELTAPINE C5 (56), CNH151 (51), 359754 (45); seed index WC 12 NL (11.6), S 344 (11.6), COKER 100 STAPLE(11.5); ginning outturn (%) RED 5-7(40.3), MLL(40), AURBURN OKRA 213 – OBP – SPB 1978 (39.4); lint index B 61 – 2038 (7), L-147 (7), BJR JK-97-16-4 (7) were identified. The germplasm lines were supplied to the breeders of the North Zone by organizing germplasm day.

4.2 : Hybrid Cotton

Nagpur

Maintenance of parental lines (male steriles and restorers)

Fifteen *G. aridum* based CMS, 137 *G. harknessii* based CMS, 57 restorer and 20 GMS lines were maintained by crossing to its fertile counterpart (B-line) by selfing and sibmating. The M2 generation of AK 32 CMS (*G. aridum*), Rajat CMS (*G. harknessii*) and G 67 GMS lines were raised. Individual sterile plants in 356 single plant progenies were identified and maintained through crossing. Eight restorer lines (four each of *G. hirsutum* and *G. barbadense*) received from Israel were evaluated during the crop season. All the *G. hirsutum* restorer lines were susceptible to sucking pest and showed severe leaf reddening with very low boll setting and boll drying.

Comparison of conventional and male sterility based hybrids

CMS and conventional hybrids of the same background were tested for their comparative performance. The CMS hybrid PKV Hy3 recorded higher yield (1358.49 kg/ha) than its conventional counterpart PKV Hy2 (1166.63 kg/ha). The other two CMS hybrids viz., PKV Hy4 and PKV Hy5 recorded poor yield than the conventional hybrids.

TGMS system

To determine the suitable stable window period for getting complete sterility, sowing of TGMS line 1-1 was taken up at three different times viz. on 22nd May 2010, 30th June 2010 and 10th February 2011. The crop season in May and June produced flowers which had 10 – 30% pollen fertility mainly due to sudden fall in sunshine hours and cloudy weather and decline in mean minimum temperature. It was observed that the pollen grains were completely round and fully stained in fertile flowers, partially stained, slightly deformed in partially fertile flowers and were completely deformed in fully sterile flowers within the same TGMS line. The February sown plants showed complete male sterility morphologically and through pollen staining. Six hybrids developed through TGMS were sown along with released and popular hybrid, AKDH-7 and popular varieties PA 402 and PA-255 to evaluate their performance. The yield of hybrids was very low due to heavy

rainfall during the crop season.

EGMS System

Eight EGMS lines namely EGMS 145, EGMS 132, EGMS 108, EGMS 18, EGMS 35, EGMS 36, 08093-10R and EGMS 3822266 were maintained at CICR, Nagpur. These lines were sown for recording observations on pollen sterility during summer months i.e. April-June, 2011.

Coimbatore

Nine F_1 hybrids viz; CCHB-2 (2632 kg/ha), CCHB-6 (2776 kg/ha), CCHB-7 (2647 kg/ha), CCHB-8 (2756 kg/ha), CCHB-11 (2649 kg/ha), CCHB-13 (2751 kg/ha), CCHB-20 (2770 kg/ha),CCHB-21(2645 kg/ha) and CCHB-22 (2799 kg/ha) on par with respect to seed cotton yield and significantly superior over the check hybrids RCHB-708 Bt (2113 kg/ha) and DCH-32 (1927 kg/ha) have been identified. All the best performing hybrids showed better lint index (5.1-5.3) than the check hybrids (4.0). The yield increase of 32.4 % has been recorded in CCHB-22 followed by CCHB-6 (31.4%), CCHB-20 (31%), CCHB-8 (30.4%) and CCHB-13 (30%). The best yielding hybrids CCHB-6, CCHB-8, CCHB-12 and CCHB-13 possessed higher ginning percentage of 36 as compared to the check hybrids DCH-32 (29%) and RCHB-708 Bt (28%).

In another trial, CCHB-33 was identified as the best hybrid with 29.47% increase over RCHB-708 Bt and 33% over DCH 32. A trial was laid out with eight best selections made from various advanced trials conducted during the last five years with RCHB-708Bt and DCH-32 as checks. Out of eight advanced hybrids, CCHB-110 with an average yield of 2801 kg/ha (33%) ranked first over the best check RCHB-708 Bt (Table-2). The hybrids CCHB-110 and CCHB-48 possess highest ginning percentage of 35 as compared to checks RCH 308 Bt (30%) and DCH 32 (32%).

Table 2: Performance of advanced interspecific ELS hybrids

Sr. No.	Hybrids	S C Y (kg/ha)	% increase in yield over RCHB-708	SI	LI	GOT (%)
1	CCHB-56	2615*	24	8.9	4.6	34
2	CCHB-48	2684**	27	9.2	5.1	35
3	CCHB-110	2801**	33	9.5	5.2	35
4	CCHB-215	2612*	24	9.3	4.7	34
5	CCHB-5339	2509	19	8.7	4.3	33
6	CCHB-51074	2236	6	9.5	4.2	31
7	CCHB-2628	2669*	27	9.8	4.0	29
8	CCHB-2630	2544*	21	9.4	4.6	33
	RCHB-708 (c)	2108	-	9.2	4.0	30
	DCH-32 (c)	2005	-	8.9	4.1	32
	S Ed	148.7	-	-		
	CD @ 5%	312.5	-	-		
	CV%	7.30	-	-		

** Highly significant, * Significant

Interspecific ELS hybrids

A new set of crosses were made with seven potential female parents of *G. hirsutum* and five male parents of *G. barbadense*. Thirty-five cross combinations were made in Line x tester mating design.

Sirsa

Diploid hybrid cotton

Identification of parents and general combiners

Thirty GMS hybrids along with parents (CISA 6, CISA-6-214, GBaV 105, JLA 505, JLA 1600, LD 733, PA 532, RG 548, RG 550, Sarvotam 1, DS 5, CISA 2 & GAK 413A) were tested in randomized block design in three replications. Parents CISA 6, JLA 505, PA 532, Sarvottam 1, GAK 413 A were found good general combiner for seed cotton yield, CISA-6-214, JLA 1600, RG 550, GAK 413A for GOT (%), CISA 6, JLA 1600 for boll weight, JLA 505 for 2.5% span length, JLA 505, JLA 1600, LD 733 for fineness and JLA 505, PA 532, RG 548, Sarvottam 1, DS 5 for strength. Based on the significant heterosis and specific combining ability, specific crosses were identified for various traits.

Maintenance and heterosis breeding

Three *arboreum* GMS lines GAK 413A, DS 5 and CISA 2 were maintained through sibmating. Different cross combinations were developed for sponsoring GMS based hybrid in AICCIP trial. Large amount of hybrid seed was produced for CISAA 17 and CISAA 18. Nine GMS lines (CISAG 4, CISAG 7, CISAG 8, CISAG 13, CISAG 14, CISAG 17, CISAG 20, CISAG 27 and CISAG 28) were maintained through sibmating.

In North Zone, the GMS based hybrids CISAA 17 and CISAA 18 gave higher seed cotton of 2072 kg/ha and 2645 kg/ha respectively than the zonal check CICR 2 (2033 kg/ha) (Table 3). Both the hybrids were better with respect to fiber length and strength as compared to check hybrid. The hybrid CISAA 18 has been promoted for large scale testing in North Zone. In Central Zone, CISAA 17 and CISAA 18 gave higher seed cotton of 1859 kg/ha and 1957 kg/ha and ranked 6th and 2nd respectively and both have been promoted in Central Zone. In South Zone, CISAA 17 recorded seed cotton yield of 1385 kg/ha and ranked 4th and it has been promoted for large scale testing. GOT of both the hybrids was consistently high (38 and above) in all the three zones.

Table 3 : Performance of *G. arboreum* hybrid CISAA 17 and 18 (GMS based) in Br-25(a) AICCIP Trial

Entry/ Character	Seed Cotton Yield (kg/ha)	Rank	GOT (%)	2.5% Span Length	Bundle Strength
North Zone					
CISAA-17	2072	7	38.0	24.6	19.2
CISAA-18	2645	2	37.9	23.3	18.5
Zonal Check (CICR 2)	2033	8	39.8	20.3	16.8
Central Zone					
CISAA-17	1859	6	39.1	23.4	19.3
CISAA-18	1957	2	38.2	21.9	18.2
Local Check	1673	9	36.5	26.2	21.1
South Zone					
CISAA-17	1385	4	39.9	24.1	19.4
Local Check	1047	9	34.7	23.9	17.7

Tetraploid Cotton

Maintenance of CMS lines

Eleven CMS lines representing parents of promising hybrids viz. LRA 5166, Jhorar, RB 281, LH 1134, Pusa 31, HS 6, K 34007, F505, F1183, CSH 25 M, and SH 2379 were maintained through sibmating. The restorer lines namely CIR-8, CIR-12,

CIR-23, CIR-26, CIR-32, CIR-38, CIR-47, CIR 70, CIR 97P1, CIR 97P3, CIR 119P1, CIR 119P3, CIR 526P1, CIR 526P3, CIR 926P2, CIR 926 P3, CIR 1169P1 and CIR 1169 P2 were maintained through selfing.

Evaluation of GMS hybrids

Forty-four (44) GMS hybrids along with their parents were tested in Randomized Block Design in three replications. The male parents S -123, Ratna, BN and female parents GMS-20, GMS-21 were found to be good general combiner for seed cotton yield while S-123, LH 900, GMS-17, GMS-21 for ginning percentage. The cross combinations GMS-21x M-45, GMS-21 x LH 900, GMS-21 x CISV-1were high yielding hybrids with significant SCA effect.

Performance of GMS based hybrid CSHG 1862

The GMS based hybrid CSHG 1862 recorded more than 12 percent seed cotton yield over the zonal check hybrid CSHH 198 in three years of testing. An agronomy trial was conducted in North Zone during 2010-11. The different row spacing were statistically at par at Faridkot and Sirsa, whereas 67.5 x 75 and 67.5 x 60 cm spacing gave highest seed cotton yield at Bathinda and Sriganganagar, respectively. Among the fertilizer levels, 100% RDF seems to be better at Sriganganagar and Bathinda, whereas 75% RDF & 125 % RDF was optimum at Sirsa and Faridkot. The detailed performance of the GMS hybrid CSHG 1862 in agronomy trial is given in Table-4.

Table 4 : Effect of different row spacing and fertilizer levels on performance of *G. hirsutum* GMS based hybrid (CSHG 1862) in North Zone

Treatments	Faridkot			Bathinda			Sirsa			Sriganganagar		
	SCY (kg/ha)	BN	BW (g)	SCY (kg/ha)	BN	BW (g)	SCY (kg/ha)	A. BN	BW (g)	SCY (kg/ha)	BN	BW (g)
Row spacing (cm)												
67.5 X 60	1656	39	4.05	1875	31.5	-	1662	23	3.27	2544	83	3.39
67.5 X 75	1278	43	4.13	1955	33.0	-	-	-	-	2540	84	3.49
67.5 X 90	-	-	-	1660	29.7	-	-	-	-	2377	85	3.64
100 X 45	-	-	-	-			1514	26	3.54	-	-	-
100 X 60	-	-	-	-		-	1423	25	3.60	-	-	-
CD at 5%	-	-	-	230	NS	-	NS	NS	NS	NS	NS	NS
Fertilizer levels (kg/ha)												
75% RDF	1349	36	3.87	1750	29.1	-	1638	25	3.28	2233	82	3.32
100% RDF	1484	43	3.99	1977	34.7	-	1540	24	3.53	2520	84	3.58
125% RDF	1568	45	4.42	1772	30.6	-	1423	23	3.63	2708	86	3.61
CD at 5%	-	-	-	175	2.37	-	NS	NS	NS	274	2.3	0.24

Performance of intra-hirsutum hybrid CSHH 3008 in Br 05 (a)

An intra-*hirsutum* hybrid CSHH 3008 recorded mean seed cotton yield of 2184 kg/ha with 32.7 percent ginning outturn and ranked at 4th position as compared to zonal check CSHH 198 (Table-5). The hybrid also recorded higher 2.5 % span length (29.1 mm) and bundle strength (23.8 g/tex). The hybrid has been promoted for 2nd year of testing in North zone.

Table 5 : Performance intra-*hirsutum* hybrid CSHH 3008 in Br 05 (a) CHT trial

Name of the hybrid	Seed Cotton Yield (kg/ha)	Lint Yield (kg/ha)	Boll Weight (g)	GOT (%)	2.5% Span Length (mm)	Mic. value	Tenacity (g/tex)
CSHH 3008	2184(4)	716	4.6	32.7	29.1	4.9	23.8
Local Checks	2105(5)	702	4.6	33.3	27.3	4.8	22.7
CSHH 198 (ZC)	1929(8)	636	4.3	33.1	27.6	5.1	23.0
CD	321.2	-	-	-	-	-	-
CV (%)	10.2	-	-	-	-	-	-

4.3 : Genetic Improvement

Nagpur

A. *G. arboreum* (diploid cotton)

Three trials, *viz*. Common, Zonal and Introgression trial, were conducted in three replications involving two arboreum checks *viz*., AKA 8401 and PA-255 and a *hirsutum* check LRK-516 in all three trials. LD-1010 recorded the highest seed cotton yield (2156 kg/ha) and GOT of 39.4% in common trial and was superior to all the three checks followed by CISA-6-214 (1719 kg/ha). PA-720 recorded a superior staple length of 29.1 mm with a fibre strength of 19.0 g/tex. In the introgressed trial PAIG-39 exhibited staple length of 28.5 mm, strength of 22 g/tex and a micronnaire of 4.8 followed by PAIG-12 with staple length of 28.8 mm, fibre strength of 21.7 g/tex and micronnaire of 4.9. PAIG-62 recorded maximum yield of 666 kg/ha in the introgressed material trial of *G. arboreum*.

***G. arboreum* variety CNA 1003 (ROJA) identified**

G. arboreum culture, CNA 1003 (ROJA) with medium fibre properties performed extremely well in south zone for three consecutive years and emerged as top ranking entry. The entry underwent agronomical trial in South Zone and the seed cotton yield of 1463 kg/ha was obtained at Dharwad. It gives better yield at spacing of 60x30 cm and 75 x 30 cm and showed higher yield at higher doses of fertilizers (Table 6). CNA 1003 (ROJA) was identified for rainfed situations of South Zone by Central Variety Identification Committee during AICCIP workshop at CCSHAU, Hisar on April 6-8, 2011.

Table 6 : Agronomic performance of CNA 1003 at Dharwad in South Zone

Treatments	Seed Cotton Yield (kg/ha)	No. of Bolls /Plant	Boll Weight (g)	No. of Bolls/ Plant	Yield /Plant (g)
CNA 1003	1463	19.5	2.64	19.5	44.2
AKA 0110	1417	20.1	2.77	20.1	49.7
CD 5%	26.0	NS	NS	NS	NS
Spacing (cm)	CNA 1003	AKA 0110			
60 x 30	1464	1407			
75 x 20	1445	1487			
75 x 30	1480	1427			
CD 5%	NS				
Fertility levels NPK (kg/ha)	CNA 1003	AKA 0110			
40:25:25	1439	1389			
60:30:30	1442	1432			
80:40:40	1507	1500			
CD 5%	83				

Entries promoted

G. arboreum culture CNA 1007 has been evaluated in Zonal trial Br. 24(b) in South Zone. It ranked 3rd in seed cotton yield and first in lint yield (Table-7). CNA 1007 was retained for second year trial in South Zone.

Table 7: Lint yield of CNA 1007 in Zonal trial Br. 24(b) in South Zone

Genotype	Dharwad	Nandyal	Kovilpatti	Mean(SZ)	Rank	GOT
CNA1007	1064	288	472	608	1	39.1
ARBa08-49	927	370	425	574	3	35.8
DLSa-17 (SZ)	798	285	486	523	5	35.9

Three *G. arboreum* cultures CNA 1008, CNA 1009 and CNA 1010 were evaluated in IET of the AICCIP in 2010-11. *G. arboreum* culture CNA 1008 performed well in Central and South zone and ranked at 6th and 5th position, respectively for seed cotton yield. CNA 1008 has been promoted to Br.24(a/b) in Central and South Zone for the crop season 2011-12.

Entries sponsored for AICCIP trials

Four *G. arboreum* entries namely CNA 397, CNA 398, CCA 1014 and CCA 1015 were sponsored for Initial Evaluation Trial Br. 22 (a/b) of AICCIP for crop season 2011-12.

Promotion in non-traditional areas

During 2010-11 crop season, 46 kg seed of *G. arboreum* (AKA-5, AKA 7, AKA-8, CINA- 385 , PA (402) and *G. hirsutum* (PKV-O81, LRK-516, NH-615 and Suraj) were distributed to 26 farmers through NGO, CARD, Anjangaon Surji for plantings in Melghat area of Vidarbha. Only three farmers grew *G. arboreum* AKA-5 in their fields. One of the farmer based at foothills of Melghat region with supportive irrigation harvested 2000 kg/ha on medium type of soil. Some farmers have been adopting arboreums, despite the spread of Bt cotton in Melghat region.

Sirsa

Notification of variety CISA 614 for commercial cultivation in North Zone

The variety CISA 614 was tested in 32 locations in the North Zone (Punjab, Haryana and Rajasthan) during 2004-2007 and

recorded an overall mean seed cotton yield of 2204 kg/ha as against 1834 kg/ha of HD 123 (zonal check) and 1990 kg/ha of local check. The increase in seed cotton yield of the new variety CISA 614 over the common (Zonal check) check was of the order 20.17 per cent. In agronomy trial the variety CISA 614 recorded the highest seed cotton yield of 3792 kg/ha at 67.5 x 30cm spacing. CISA 614 recorded slightly superior fibre characteristics in comparison to zonal, local checks and qualifying varieties. It was identified by Variety Identification Committee (AICCIP) held at ANGRAU, Hyderabad 6-8 April, 2009 and notified vide Gazette of India No.608 dated April 1, 2010.

Registration new genetic male sterile line CISA 2

CISA-2 – a spontaneous sterile mutant of *G. arboreum* having yellow flower with red petal and green plant has been registered with unique germplasm by the plant Germplasm registration Committee of the ICAR vide Registration No. INGR10057 and National Identity No. IC 0538548. The new GMS line has open flowers which facilitates easy crossing whereas the earlier reported lines have closed flowers that do not allow for easy crossing.

Evaluation of promising varieties

Under station trial, 8 genotypes were evaluated, none of the genotypes could out yield the check CISA 614 (2997 kg/ha). However the genotype CISA-6-256 (2465 kg/ha) gave numerically higher yield than the local check LD 694 (2329 kg/ha).The entries with better yield are CISA-6-256 (2465 kg/ha), followed by CISA-6-214 (2130 kg/ha), CISA -6-209 (2106 kg/ha), CISA-6-295 (1784 kg/ha) & CISA-6-350 (1578 kg/ha). The highest GOT (41.5%) was recorded by CISA-6-350 and highest boll weight by CISA-6-123 (3.4 gm). Forty four single plants were selected based on their yield performance.

Seven genotypes were evaluated in RBD and identified CISA 8 (3203 kg/ha), CISA 294 (3150 kg/ha) and CISA 405 (3098 kg/ha) as high yielder than the checks (CISA 310, LD 733, HD 123). CISA 405 was sponsored in Br22a/b trial of AICCIP.

Development of mapping population for fibre length and strength

A mapping population is being developed by effecting crosses between parents with distinct 2.5% span length and strength (g/tex). In Cross I, 251 F_4 plants of cross HD 123 x Arbha 35 were evaluated and seed cotton yield ranged from 20 g to 295 g/plant, GOT (%) from 21.8 to 52.2% and mean halo length from 12 to 26.6 mm. In Cross II, 297 F_4 plants of cross RG 8 x

Arbha 35 were evaluated. The seed cotton yield ranged from 21.5 to 242.2 g/plant, GOT from 24.4 to 52.4% and mean halo length from 13 to 28.0 mm.

Mapping population for GOT

The F_2 populations consisting of 185 plants from a cross involving parents with High x Low GOT [SA-977(HG) x SA-112(LG)] was obtained.

Development of heterotic genepool

Twenty one multiple crosses were made for development of heterotic genepool. Sirsa cultures: CISA-101p-2, CISA-101p-3, CISA-101p7, CISA11p10, CISA101P3, CISA111p1, CISA111p2, CISA112p5, CISA130, CISA104 and single plant selections were crossed with VNWA-1 a culture from Nagpur.

Tetraploid cotton improvement

Nagpur

Drought tolerance

Drought tolerant efficiency (DTE) was used as a criteria for identification of genotypes based on their performance under rainfed and irrigated condition. Three crosses Pusa 56-4 x 30 I, Pusa 56-4 x 29I and Pusa 56-4 x 28 I recorded DTE of 76.86, 95.42 and 70.34 per cent, respectively. Pusa 56-4 x 30I and Pusa 56-4 x 29 I had shown high DTE for two consecutive years. Cross Pusa 56-4 x 29 I recorded highest yield of 506.34 under rainfed condition while Pusa 56-6 x 28 I recorded higher yield under irrigated condition. Eleven lines (DTS 155-09, DTS 100-09, DTS 104-09, DTS 39-09, DTS 62-09, DTS 108-09, DTS 67-09, DTS 44-09, 28I, 29 I and 30 I) were found to be tolerant based on chlorophyll value, membrane stability, reducing sugar, amino acid content and phenols. One culture (DTS 121) has been sponsored for testing in AICCIP national trial as CSH 121. Application for registration of culture CNH 30I tested under AICCIP trial and identified as drought tolerant (Seed cotton yield: 1515.08 kg/ha, boll weight of 3.5 – 4.0 g, 2.5 % span length of 24.5 mm, uniformity ratio of 49 per cent, micronaire of 3.8, fibre strength of 19.5 g/tex and ginning outturn of 35 per cent) has been submitted to NBPGR. Seeds from individual F_2 plants of three crosses Pusa 56-4 x 30I, 30I x Pusa 56-4 and Pusa 56-4 x 29I have separately been harvested to carry forward to F_3 and development of RILs for drought tolerance.

Biotic stress resistance

To develop genotypes and hybrids with tolerance / resistance to boll worm, efforts were made to transfer approved BN Bt event into elite cotton genotypes and parents of hybrids from different agro-climatic zones. The following genotypes are under conversion and are in different back cross generation:

BC generation	Genotypes (61)
BC4 (20)	NZ : F 1861, H1242, CSH 198 ?,CSH 198 ?, CSH 238 ?, CSH 238 ?, CZ : KH 138, Surat Dwarf SZ : CPD 731, CPD 758, SCS 9, LRA 5166,SCS 101, Surabhi, Abadhita, RAH 30, PSS 2, TCH 1002, CCH 5104, SCS 37
BC 3 (5)	NZ : RK 4145 SZ : DS 28, MS x 72-1358, CPD 787, L 761
BC 2 (12)	NZ : Pusa 56-1, Pusa 56-2, Pusa 56-4, Pusa 56-6, RS 810, RS 875, NH 452, CZ : Rajat, PKV 081, AK 32, AKH 8828, SZ : MCU 12
BC 1 (15)	NZ : H 1117, HHH 287(m), HD 324, HD 123, F 2236, F2036, F 2086, F 2188, LH 2076, F 2164 CZ : PH 93, NH 152, NH 615, PH 1009 SZ : NARSIMHA
BC 2 (4)	GMS LINE : LRA 5166, KH 2, B 59-1684, G 67
F_1 (9)	NH 452, DHY 286, Laxmi, CSHH 198 (M), CSHH 243 (F), CSHH 243(M), Khandwa 2, G Cot 16

Nine GMS based Bt hybrids were evaluated along with RCH 2 Bt, Bunny Bt and BN Bt. All the GMS Bt hybrids were superior to RCH 2 Bt hybrid (801.71 kg/ha). The heterosis over RCH 2 Bt ranged from 3.27 to 46.65 per cent. FP 14 x BN followed by FP 5 x BN and FP 17 x BN were some of the promising hybrids recording more than 20 per cent heterosis.

Jassid tolerance

Three hundred and ninety single plants were selected based on tolerance to jassid, higher number of bolls per plant, earliness, compact plant type and tolerance to jassid from crosses PKV Rajat × Acala 1517, AKH 081 × ND 63, Daet –S-SL × G Cot 16, NH 545 × ND 63. Crosses viz. H 1252 × LH 1948 and PKV Rajat × LH 1948 were identified for compact plant type. Seventeen F_5 progenies of these crosses were carried forward based on their consistent performance for plant type and tolerance to jassid. From 25 F_2 populations (interspecific Rai - derivatives crossed with cultivated genotypes), 90 single plants were selected based on earliness, tolerance to jassid and yield potential. Promising segregating material was identified from NISC 261 × P 56-4, NISC 261 × AKH 081, NISC 261 × PKV Rajat, NISC 63 × LRK 516, NISC 64 × Pusa 56-6, NISC 64 × EC 277959, NISC 65 × Pusa 56-6 crosses.

CISH-16, a *G. hirsutum* culture was found highly tolerant to sucking pests particularly Jassids and white fly based on one year field testing (2009-10) and and one year controlled condition evaluation (2010-11) under AICCIP trials at LAM, Guntur.

Genetic enhancement

Fourteen selections were evaluated using NH-615 as check variety in two replications. Three selections showing significantly higher seed cotton yield namely Sps-7-5 (1818 kg/ha), Sps-7-7 (1402 kg/ha) and Sps-7-1(1396 kg/ha) were identified. Selections with staple length of 30 mm namely, SPS-7-6, SPS-7-7, SPS-7-10 and SPS-7-13 were identified for further evaluation.

In 78 F_3 populations, few single plant selections with superior traits such as SPS 3–29 – an erect naked seeded type and SPS 3-42 - a very short staple fibre type (<13 mm approx) were identified. In F_6 Populations, SPS-6-2 (Pedigree- RS 875 x Rex) and SPS 6-10 (Pedigree – Deviraj x CAT 685) two compact plant progenies were phenotypically confirmed. SPS 7-12

(Pedigree – LRA-5166 x CIHS-97-9) was sucking pest free in 3 years testing. SPS 7-3 was found resistant to sucking pests, medium early and hairy in phenotypic expression. SPS IM- 4-16 was determinate, medium boll uniform bursting and free from sucking pests. JBWR-JK 54 which was highly tolerant to sucking pests, hairy and had determinate growth contributed this character.

Development of heterotic pool for superior medium staple

One hundred and forty single plant selections were made for yield potential and superior medium staple from crosses involving PKV Rajat × NH 545, LRK 516 × Acala 1517, PKV Rajat × Acala 1517 in one group and ACCLD 163 × H 1252, H 1252 × LH 1948, Surabhi × ACCLD 163, H 1252 × MCU 9 in other group. Twelve genotypes selected from working collection based on molecular diversity were crossed in a 12 × 12 diallel mating design. The selected parents include IC -356581, BAR 7-2-P-5 (IC -356819), Sima-1, BM COT (95 BIL), AV- 3670, Stonevile-213(EC 137805), BJR-JK-97-16-4(IC-359059), NH-545, CIPT-1080(A), IC-357218, LH- 2076, IC-358429, COTOM-9, NH 630 and IC 358280. Crossed seeds were collected from diallel crosses for further evaluation.

Notification of CNHO 12 (Saraswati)

A new variety CNHO 12 (Saraswati) developed by CICR, Nagpur, identified in 2009 for the irrigated, timely sown condition of Central zone was notified in the Gazette of India in the year 2010-11 vide Notification No. SO -733 (E), dt. 01.04.2010.

New entries sponsored under AICCIP

Six new advance selection of *G. hirsutum* namely, CNH 14, CNH 44, CNH 50, CNH 1107, CSH 121 and CSH 1111 were sponsored for Initial Evaluation Trials of AICCIP Br. 02(a/b). Three entries namely, CNHO 12, CNH 1108 and CNH 1109, were also sponsored for compact plant type trial Br. 06(a/b).

Population improvement

Random mating population in *G. arboreum* and *G. hirsutum*

After fifth cycle of random-mating through conventional crossing, the population is being constituted and maintained by bulk harvesting one busted boll from each plant. A composite population was constituted and grown on large size plots. Gain in economic yield was compared with the base population. Gain in seed cotton yield was realized to the extent of 57% in *G. arboreum* despite bad crop conditions during 2010-11. In *G. hirsutum*, the corresponding gain in seed cotton yield was 42%.

GMS based random mating population

A composite population has been constituted from the seeds obtained from out-crossed bolls and a large population (each in an area of 2000 sq.m.) was grown in 2010-11. At flowering, the individual plant in the population was checked for sterility/fertility at anthesis at an interval of a week and tagged all sterile plants. The segregation for fertile and sterile plant was monitored throughout the crop season. All the out-crossed bolls from the sterile plants in the population were bulk harvested and ginned to constitute a next cycle of GMS based random mating population. A 5th cycle of GMS based random mating has been completed in *G. arboreum* while 4th cycle has been completed in *G. hirsutum.*

Single plant selection

Based on manual testing of fibre length and strength 371 plant in *G. arboreum* and 87 plants in *G. hirsutum* composite random mating population were selected. About 201 single plant selections from GMS based plant progenies and 121 from conventional crossing based random mating plant progenies were re-selected for further evaluation that include plants with big boll size, better fibre quality and compact plant type. Selections are in the early segregating stage and need to be further evaluated in advance generations.

Coimbatore

Evaluation of advance selections

Two superior cultures viz., CCH 820 (Long Staple Culture) and CCH 10-1 (Medium Staple Culture) were sponsored for IET of AICCIP under irrigated conditions during 2010-11. Performance of both the cultures was not in top five and have not been promoted. Three other superior cultures viz., CCH 10-2, CCH 10-3 and CCH 807 were tested under rainfed situation in IET of AICCIP. Though the fibre quality of these cultures were superior to check varieties they could not be promoted as there was no yield advantage.

Culture CCH 2623 was tested in the Coordinated Varietal Trial under irrigated conditions in both central and South Zone. In Central Zone, CCH 2623 recorded a mean seed cotton yield of 1910 kg/ha and was superior to Zonal check LRA 5166 (1489 kg/ha). It recorded a mean ginning out turn of 34%. In South Zone, the culture CCH 2623 recorded a mean seed cotton yield of 1515 kg/ha and was superior to Zonal Check LRA 5166 (1277 kg/ha) and ranked at 5th position (Table 8). With a mean ginning out turn of 38% and lint yield 541 kg/ha, it ranked third among the entries. The culture has been retained in Coordinated Varietal Trial for one more year of testing in both Central and South Zones.

Table 8 : Performance of CCH 2623 for Seed Cotton Yield (kg/ha)in AICCIP Trials under irrigated conditions.

Culture	IET (2008-09)	PVT (2009-10)	CVT (2010-11)	Mean	% inc over ZC
Central Zone					
CCH 2623	1995 (1)	1932 (1)	1910 (9)	1945	43
Zonal Check	1226 (17)	1360 (8)	1489 (11)	1358	
Local Check	1610 (16)	1745 (6)	2022 (4)	1792	
South Zone					
CCH 2623	1911 (2)	1834 (2)	1515 (5)	1753	27
Zonal Check	1537 (31)	1338 (8)	1277 (11)	1384	
Local Check	1758 (10)	1289 (10)	1584 (3)	1543	

Figures in parenthesis indicate Ranking

Sirsa

Evaluation of CLCuV resistant cultures

Forty-seven *G. hirsutum* hybrids were evaluated for seed cotton yield, ginning outturn, fibre traits and resistance/susceptibility to CLCuV against the check variety RS 2013 and CLCuV susceptible variety RS 921. The highest seed cotton yield was recorded in the hybrid CSH 2936 (2723 kg/ha) followed by CSH 2938 (2603 kg/ha) as against the check variety RS 2013 (2135 kg/ha). Maximum ginning outturn of 35.7 per cent was recorded in the hybrids CSH 2816 and CSH 2916 as compared to local check varieties RS 2013 (31.8%) and RS 921(32.2%). The culture CSH 2939 recorded the highest 2.5 % span length (30.1 mm), whereas the highest bundle strength of 24.9 g/tex was observed in CSH 2939 and

Sirsa

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Forty-eight new germplasm lines were evaluated for compact plant type and zero monopodial branching. Seven genotypes (SA-1208, EC-2686-1, GC-110, GC-160, H-1265, KDGH-50-4 and VV-770) with less than average one monopodia/plant were identified and shall be used in breeding programme.

CSH-3158 ranked seventh in zonal trial (1986 kg/ha) against local check (1882 kg/ha) has been retained in Br03a trial. CSH-3129 ranked sixth (2038 kg/ha) against zonal check (1920 kg/ha) has also been retained for second year in Br04a. A new culture CSH-3088 was sponsored for Br02a trial.

4.4: Genetic Diversity through Introgression

Nagpur

Selfed seeds from interspecific F_1s involving wild species *G. longicalyx*, *G. armourianum* and *G. davidsonii* were obtained in order to develop F_2 population for specific fibre traits i.e. fibre fineness and fibre strength. Introgressed genotypes with compact plant type of *G. hirsutum* – NISC 43, 44, 45 and MSH-SDP-91 and *G. arboreum* – NISA 1 and NISA 2 were evaluated in the high density planting system.

4.5: State Multi-Varietal Trial (SMVT)

Nagpur

State multilocation varietal trials (SMVT) consisting of 12 genotypes of *G. hirsutum* and 17 of *G. arboreum* varieties were conducted at CICR, Nagpur. Due to continuous rain during the crop season, G. arboreum suffered more than the upland cotton varieties and yield was very poor. The seed cotton yield ranged from 203 to 763 kg/ha. The *G. hirsutum* culture AKH-2006-2 showed promise with highest yield of 608 kg/ha at Nagpur conditions.

4.6 : Molecular Breeding

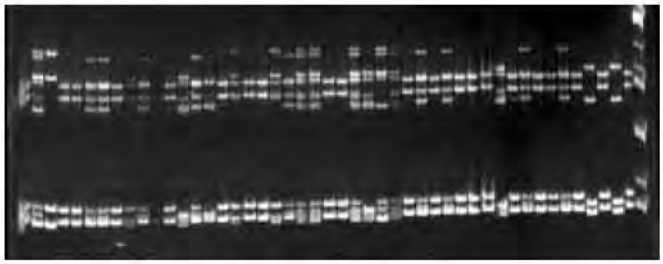


Fig. 1: Genotyping of F_2 mapping population ith SSR marker BNL 3261 in diploid cotton

Development of mapping populations (RIL's) for fibre quality traits in diploid and tetraploid cotton

In diploids, 193 F_6 plant progenies were raised. One random plant in each boll to row progeny was selfed and separately harvested which shall be carried forward to F_7 generation. In *G. hirsutum*, boll to row progenies (273) were grown, selfed bolls were obtained and the progenies will be carried forward to F_7 generation.

Development of mapping population for GOT

Two hundred genotypes consisting of 113 germplasm lines and 87 core accessions were evaluated for GOT for two consecutive years. GOT in these lines ranged from 18.18 to 52.94%. Only few genotypes showed consistency for GOT in both the years. Genetically diverse genotypes with high and low GOT have been identified to effect crosses and to develop mapping population.

Mapping bacterial blight resistant gene(s)

Four F_2 populations involving resistant and susceptible parents (Acala-44 x IM216, Ganganagar Ageti x IM216, Ganganagar Ageti x S295 and Ganganagar Ageti x 101-102B) were developed and extensively phenotyped for bacterial blight resistance. Individual F_2 plants were artificially inoculated with race 18 of *Xanthomonas axonopodis* pv. *malvacearum* by syringe infiltration method. Plants were observed for development of the disease. The segregation in F_2 was in 3:1 ratio, inheritance as monogenic trait, indicating single dominant gene for bacterial blight resistance.

For mapping bacterial blight resistant gene(s), two populations namely (Acala-44 x IM216 and Ganganagar Ageti x S295) have been chosen for detail genotyping. A total of 798 SSR markers were surveyed to screen polymorphism between bacterial blight susceptible and resistant parents that revealed 6 to 9% parental polymorphism. Highest polymorphism 9.15% (73 polymorphic SSR) was obtained (Fig.2&3) with the parents Ganganagar Ageti and S295. Bulk segregant analysis shall be carried out to tag the gene of interest.

Fig. 2 : Screening for parental polymorphism.
A- Acala-44, I- IM216, M- 100 bp Marker

Fig.3:Screening of SSR primers to survey parental polymorphism. GA- Ganganagar Ageti, S- S295, M- 100 bp Marker

4.7: Development of Transgenics

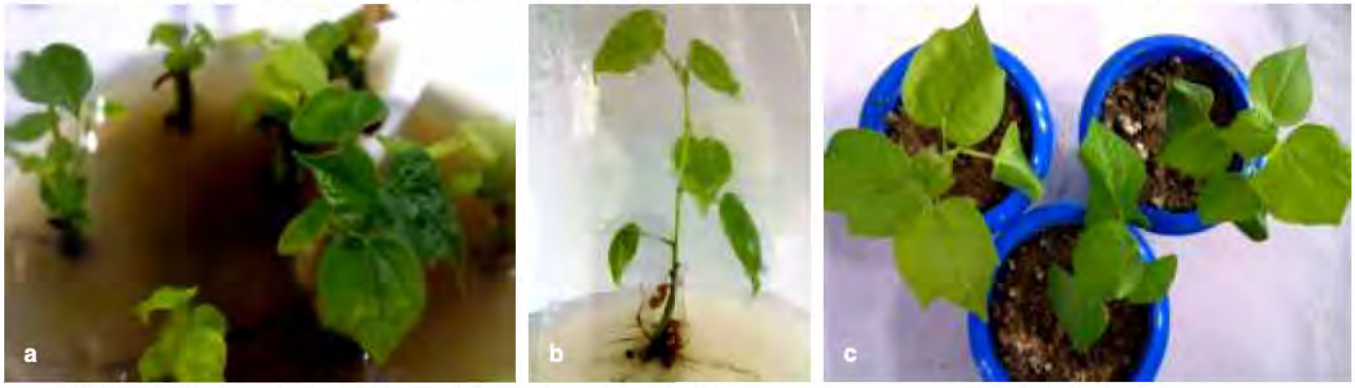
Nagpur

Bollworm resistant transgenic cotton in tetraploid and diploid cotton

Permission was obtained from RCGM/GEAC to conduct event selection trial of 7 T5 events of *G. hirsutum* variety LRK 516 (ILK Bt 77-1to 7), 3-events of T_2 generation (Anjali AcBt-1) having Bt cry1Ac and 2 T1 events of Anjali (FBT-1 & 2) having Bt *cry1F*. As per RCGM / GEAC guidelines, confined field trials were conducted and data were recorded at 40 and 90 days of plant growth. The protein expression ranged from 1.05 to 2.65 ppm at 40 days after sowing (DAS) and 1.04 to 3.50 ppm at 90 DAS. The occurrence of beneficial insects i.e. ladybird beetle, spider etc. and non-target insects especially sucking pests (jassids, thrips, aphids and whitefly) on Bt and non-Bt plants were recorded. Off season sowing of LRK 516 *cry1Ac* Bt (ILK-Bt-77) and Anjali FBt was undertaken for multiplication of seeds and to test Cry protein expression.

New transformed events

New transformation events were generated using *G. hirsutum* cultivars *viz*., Suraj and LRA 5166 with *cry1Ac* gene and *cry1F* genes. Total 3864 embryonic explants were subjected to Agrobacterium mediated transformation and 33 primary putative transformants were selected in the kanamycin medium. Six independent transformants of LRA 5166 carrying Bt *cry1Ac* and 8 transformants with Bt *cry1F* showed transgene integration by gene specific PCR amplification.

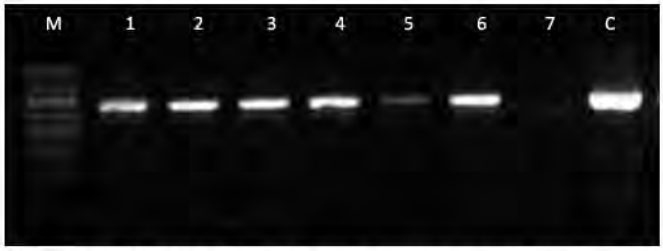


a) LRA 5166 plants under selection media b) Rooted complete plant c) Established plants

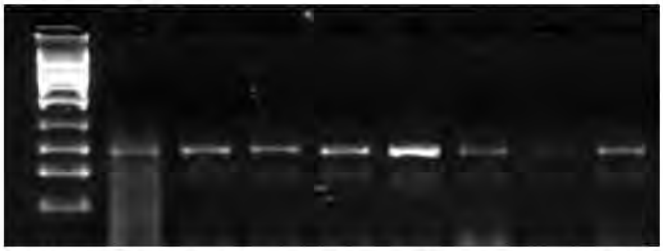
G. hirsutum variety *viz*. LRA 5166 was also transformed with *crylAa3*, *crylIa5* and *cry IF*. A total of 70 putative transformants with *crylF* construct, 35 with *crylIa5*, 35 with *crylAa3* were obtained.

Pollen tube pathway transformation

A new method of gene transfer was standardized to overcome genotype dependent somatic embryogenesis in cotton. *G. hirsutum* variety Suraj was subjected to pollen tube pathway transformation using Bt *cry1Ac* and *cry1F* genes. Total of 1340 flowers were effected for transformation, out of which 96 bolls were set and harvested. Transformed plants were confirmed for gene integration using gene specific primers for PCR amplification (Fig.4).



M: Marker, C: control,1-7: putative transformants carrying Bt *cry1Ac* gene

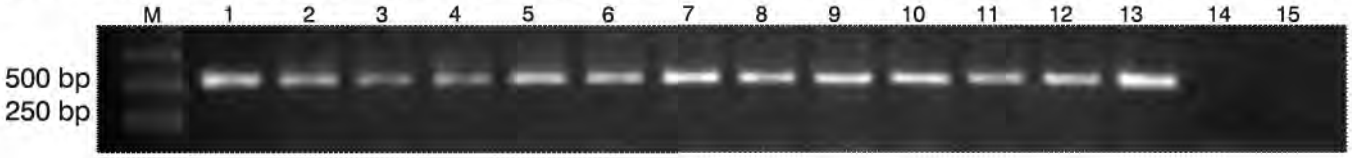


M: Marker, C: control, 1-7: putative transformants carrying Bt *cry1F* gene

Fig. 4 : Transformed plants through pollen tube pathway

Molecular Characterization of transgenic events

Four events of RG 8, six events of PA 255 and four events of PA 402 of *G. arboreum* containing *crylAc*, *crylAa3* and *crylF* genes were raised in contained facility. One hundred sixty three plants of Bt RG8 (*crylAc*) were subjected to PCR amplification using gene specific primers of which 38 plants were found to be positive. In PA 255 Bt, 25 plants were PCR tested of which 7 plants were PCR positive (Fig.5). The PCR positive plants of Bt RG 8 and Bt PA 255 were selfed and individual bolls were harvested separately for further evaluation and multiplication.

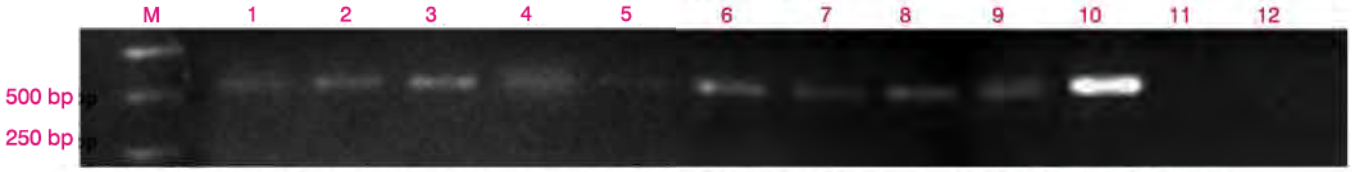


M, 1 Kb Ladder, 1-12, +ve transgenic plants, 13, Bunny Bt +ve sample, 14, Non-transgenic RG8 sample, 15-PCR –ve.

Fig. 5 : PCR amplification of *crylAc* in Bt RG 8-16 progenies

Bt expression in Bt RG8 and Bt PA 255

Leaf samples from PCR positive Bt RG 8 and Bt PA 255 were collected and subjected to ELISA test. The Bt protein expression was estimated in the range of 3.05 to 4.3 ppm in Bt RG 8-515 progenies. In Bt RG8-16 progenies, protein expression was estimated in the range of 3.05 to 5.6 ppm. These PCR positive plants hold promise for further advancement (Table 9). The Bt protein expression of Bt RG8-109 was recorded in the range of 3.0 to 4.6 ppm, however, none of the plant was PCR positive. In Bt PA255 progenies containing crylAc gene, protein expression was observed in the range of 2.0 to 3.0 ppm. Seven plants were found PCR positive (Fig. 6).



M, 1 Kb Ladder, 1-9, +ve transgenic plants, 10, Bunny Bt +ve sample, 11, Non-transgenic RG 8 sample, 12-PCR –ve.

Fig. 6 : PCR amplification of *crylAc* in Bt PA 255

Insect Bioassay

Bioassay studies were conducted in 35 Bt RG 8 plants. Insects were allowed to feed for three days continuously with Bunny Bt as a positive control and non Bt RG 8 as negative control. Progenies of plants no. 515 appeared to be resistant as evident from less feeding by insect.

Table-9 : Protein expression in different events

Genotype	Gene	Range of Bt protein (ppm)
RG8-515	*crylAc*	3.05-4.3
RG8-16	*crylAc*	3.07-5.6
RG8-109	*crylAc*	3.0-4.6
PA 255	*crylAc*	2.0-3.0

Bt RG8-515 **Bunny Bt (+ve control)** **-ve control (non Bt RG 8)**

Insect bioassay of Bt and non-Bt RG 8.

Transformation with Chitinase

Transformation was carried in *G. arboreum* cv PA 255 by *Agrobacterium* containing chitinase gene. In all, 142 T_1 progenies from selfed bolls were raised. Twenty-three of the 47 T_1 plants obtained from plant no.1 (T_0) were PCR positive while 17 of the 45 plants obtained from plant No.2 (T_0) were PCR positive (Fig. 7). Few of the plants tested for Southern analysis showed single gene insertion (Fig. 8). Assay of Chitinase activity carried out in Bt and non-Bt plants showed significant difference for Chitinase activity (Fig. 9).

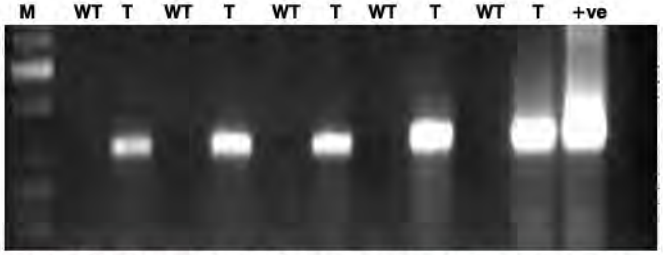


Fig. 7 : PCR confirmation of chitinase gene in putative transformants

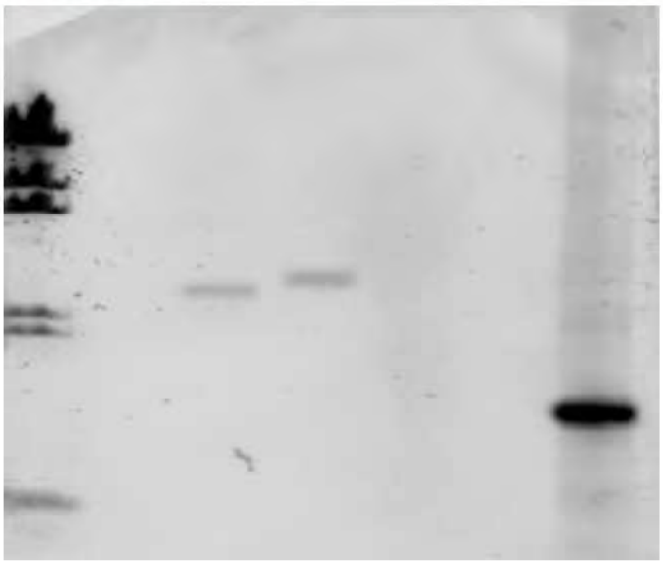


Fig. 8 : Southern analysis of chitinase gene in putative transformants

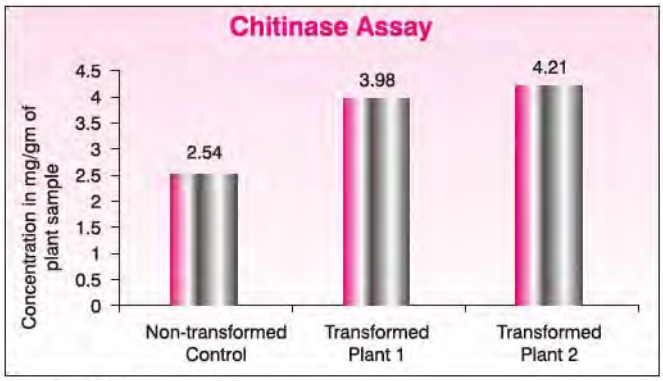


Fig. 9 : Chitinase activity assay

Evaluation of resistance of chitinase transgenic *G. arboreum* PA 255 against *R. areola*

New *in-planta* transformation technique

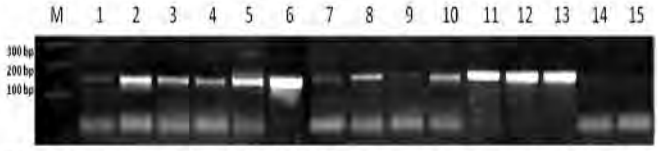
One hundred twenty five new events by new *in-planta* transformation technique were established containing *cry1Ac*, leaf curl virus and chitinase gene. Thirty-nine plants were tested PCR positive. Fifty three boll to row progenies containing *cry1Ac* and *cry1F* gene have been sown in the field during summer of 2011.

Transgenics for CLCuV resistance : Antisense approach

Transgenic plants of the three genotypes H 777, HS 6 and F 846 with Sense coat protein, Antisense coat protein and Antisense replicase protein genes were grown in the contained field trial of RCGM for event selection.Twenty-eight (28) transgenic events viz., HS6 (ARep)- 3, HS6 (ACP)- 4, HS6 (SCP)-3, H777(ARep)-2, H777(SCP)-2, F 846 (ARep)-5, F846(ACP)-4, F846(SCP)-5 were grown in the screening nursery and 62 plants were found to be free of disease till harvesting stage. The bolls from these plants were collected separately for further evaluation. The transgenic plants were reconfirmed for the presence of the gene by PCR and RT-PCR using gene specific primers.

RNA interference approach

Four gene constructs AC2, CP, βC1 and βV4 were used through *Agrobacterium* mediated transformation and the transformation frequency in different gene construct was found in the range of 7.4 to 11.7% (Table-10). The transformed plants were confirmed by PCR for the presence of gene (Fig.10).



M-100 bp ladder, 1-12 HS6-AC2-SA transgenic plant, 13- pBSK-AC2-SA plasmid +ve,14-HS6 non-transgenic –ve, 15- PCR –ve sample.

Fig. 10 : PCR Confirmation of putative transgenic HS6-AC2 plants by AC2-Sense primer.

Inverted repeat constructs	No. of explants co-cultivated	No. of explants selected in kanamycin	No. of reg-enerating shoots	Trans-formation frequency on kanamycin (%)
AC2	155	18	09	11.6
CP	390	29	25	7.4
bC1	120	10	09	8.3
bV4	224	25	13	11.7

Table 10 : Frequency of transformation of *Gossypium hirsutum* cv HS6

Genetic engineering for abiotic stress tolerance

Transgenics were developed in the elite genotypes LRA 5166 and LRK 516 with *DREB 1A* and PLEA1:*BcZF1* gene. The transgenics were confirmed for the presence of the gene by PCR using specific primers for *DREB 1A* and npt II. Sixteen transgenic plants of LRA 5166 (5 of *DREB 1A* and 3 of *BcZF1*) and LRK 516 (6 of *DREB 1A* and 2 of BcZF1) with *DREB 1A* and *BcZF1* were raised in pots along with one control plant of LRA5166 and LRK 516. The plants were grown under optimum growth conditions till flowering. Moisture was withheld at 75 days after sowing and plants were allowed to grow under receding moisture. The leaves of both non-transformed and transformed plant started drooping after seven days after stress induction. The transformed plants showed recovery during night and leaves were turgid in early part of the day. This helped the transformed plants to recover and grow normally.

Alternately, the leaf discs from non-stressed and both transformed and non-transformed plants were placed on PEG medium with varying degrees of stress (0, 0.4, 0.6, and 0.8 MPa). The biochemical changes induced due to stress was quantified at 0, 7 and 15 days after inoculation. The control plants showed an immediate burst in synthesis of reducing sugars, amino acids and proline, but declined by seven days, while the transformed plants showed a gradual increase in solute accumulation and was high even after 7 days. The non-transformed discs produced very high phenolics which leads to death of the tissues with stress.

RT-PCR study

The mRNA from transgenic plants were isolated and cDNA was synthesized using the transcriptor high fidelity cDNA synthesis Roche kit. The cDNA of the transgenic plants were used for amplification with npt II primer and *DREB 1A* gene specific primer. The amplified product was electrophoresed by agarose gel electrophoresis (Fig.11).

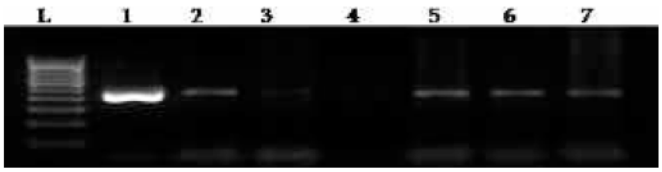


Fig.11 : Transformants with *DREB 1A* gene. L-100bp ladder, 1:P-plasmid, Lane 2-3 : Transgenic plants (LRA 5166) with DREB 1A gene. Lane 4:Non transformed plant, Lane 5-7: cDNA samples transgenic plants (LRK 516) with *DREB 1A* gene.

Isolation of seed specific promoter

Using known available sequences, primers were designed for Alpha globulin gene promoter (AGP) and PCR amplified from all four cultivated cotton species. The sequence analysis showed no variation in the amplified promoter sequence

across the species except for few bases. Genome Walker method (Clontech Palo Alto, CA, USA) was performed to obtain sequences of the promoter upstream of the published sequence. Genomic DNA was isolated from seed sample and genome walker library was constructed. Library was used for nested PCR using adopter and gene specific primers. The desired band (Fig,12) from the gel was eluted, cloned in to pGEM-T easy vector (Promega, Madison, WI, USA) and sequenced. Further, the unknown upstream sequence was PCR amplified using forward primer from the unknown sequence and reverse primer from the known sequence that resulted in expected fragment of (650bp) (Fig.13).

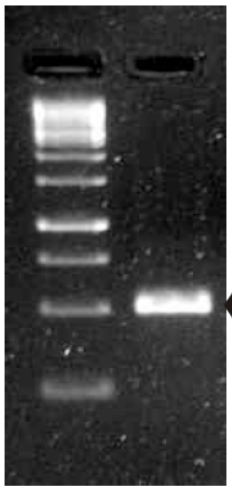


Fig.12 : Secondary PCR eluted product from Genome walking

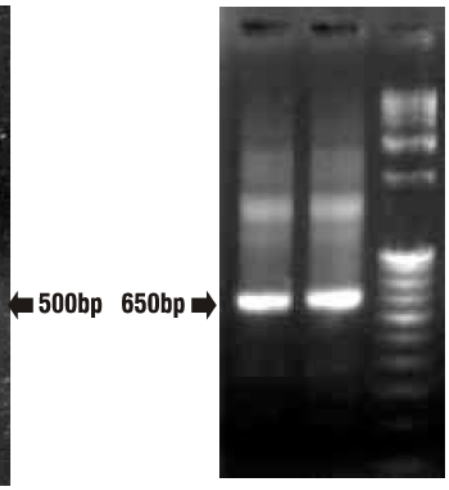


Fig.13 : PCR confirmation of unknown upstream sequence

Isolation of genes involved in gossypol biosynthesis

Primers were designed to amplify 375 bp conserved target sequences of δ *cadinene synthase* gene. The selected portion of the clone showed 78– 99 % homology to several other published sequences of δ *cadinene synthase* genes. Total RNA from matured embryo was reverse transcribed to obtain cDNA pool. δ *cadinene synthase* gene (375bp) was PCR amplified, sequenced and sequence was confirmed through homology search.

RNAi vector construction

pBSK vector with intron sequence was used to construct Intron hairpin loop RNAi vector. The δ *cadinene synthase* gene sequence was analyzed and specific enzymes were employed to clone sense and antisense strands of δ *cadinene synthase* individually on either side of the intron sequence in plasmid pBSK-int creating inverted repeat construct. The gene was PCR amplified in both sense and antisense orientation and cloned in to the pBSK-int vector. Also, the target sequence from delta-cadinene hydroxylase was PCR amplified and sequenced.

Impact of Bt Cotton on poultry

Performance of White Leghorn layers under feeding of Bt and Non Bt cotton seed

Results of the experiment revealed that there was no significant difference in live body weight, egg weight, egg length and egg width between the layer which were fed with concentrate comprising Bt cotton seed cake, non Bt cotton seed cake and no cotton seed cake. Bt no. of eggs laid was significantly high in the group fed with concentrate comprising non Bt cotton seed cake. Similarly shell weight was also high in this group when compared with other groups. It was also found that crude protein content was comparatively high in Bt cotton seed cake than non Bt cotton seed cake.

4.8 : Seed Production and Seed Quality Improvement

Nagpur

Agro-techniques for enhancing productivity and seed quality

Four growth hormones (Primary messengers, growth retardant, secondary messenger and antioxidant) were tested on high yielding early maturing variety of *G. hirsutum*, NH 615. Foliar application of Salicylic acid @ 0.25% at flower initiation (58 DAS) and 15 days after flowering (73 DAS) gave significantly high seed yield over control. Spray of gibberillic acid @ 50 ppm at square initiation (40 DAS) and at flower initiation (58 DAS) as well as foliar application of secondary messenger at flower Initiation (58 DAS), 15 days after flowering (73 DAS) and 30 days after flowering (88 DAS) produced seeds with significantly higher seed index (7.86 g) compared to control (6.22 g). In another experiment conducted on late variety Narasimha, foliar application of primary messenger (Cytokinin) @25 ppm at square inititation (55 DAS) and at flower initiation (72 DAS) along with foliar application of nutrients (P, K,Mg) at 15 (87 DAS) and 30 days after flowering (102 DAS) and foliar application of secondary messenger ($CaCl_3$) @ 0.75% at square initiation (55 DAS), 10 days after flowering (82 DAS) and 20 days after flowering (92 DAS) gave significantly higher seed yield over control. Foliar application of secondary messenger application at flower initiation (72 DAS), 15 days after flowering (87 DAS) and 30 days after flowering (102 DAS) gave significantly higher seed index over control. In the third experiment, foliar spray of tricontanol @0.01% along with $CaCl_3$ @ 0.75% gave highest seed cotton yield as well as highest seed index compared to control.

DUS Characterization of working and core germplasm collection

A total of 352 germplasm lines belonging to eleven working groups as well as 530 lines of core collection have been characterized based on DUS traits. The working collection lines were observed for 27 DUS characters including seedling, flower, leaf and boll characters as well as on variation in number of leaf gossypol glands. Significant variation in gossypol glands density on leaves hold promise for consideration as a special character in DUS testing.

a) 142 glands/sq. cm. **b) Glands Absent** **c) 303 glands/Sq. cm**

Differences in Gossypol Gland Density

Testing & documentation of extant varieties, hybrids and their parents for DUS

Thirty-six candidate varieties/hybrids along with twenty-eight reference varieties including those of *G. hirsutum* and *G. arboreum* were raised. Complete thirty-seven total characters were recorded as per the DUS guidelines.

Coimbatore

Implementation of PVP legislation, 2001

DUS testing of tetraploid cotton genotypes were taken up in two trials comprising 23 and 19 candidate varieties. Similar trial was conducted for diploid cotton with one candidate and two reference varieties.

Registration of extant and new cotton varieties under PPV&FR Act, 2001 was initiated. In total, 87 application forms comprising of new and extant cotton varieties were submitted to PPV&FRA through NBPGR. Seeds of three varieties was deposited with national gene bank and the process of augmentation of seed for other 37 varieties from different cotton breeding stations is in progress.

Maintenance of reference collection assumes importance for the successful conduct of DUS test. One hundred and twenty two *G. hirsutum*, nine *G. barbadense*, three *G. arboreum* genotypes were sown during winter 2010 season. In all the varieties, off type plants were removed at flowering and selfed bolls were harvested. Harvested bolls were ginned and seeds were stored as reference varieties. A database on varieties released by State Varietal Release Committee, varieties in common knowledge, farmer's varieties, etc., was updated.

Establishment of genetic purity of hybrids using seed protein profile

Electrophoretic analysis of seed proteins was performed using Tris soluble proteins, salt soluble Globulins and Methanol precipitated fraction; separated by SDS-PAGE method for a hybrid CSHH-243 and its parents. Among the three methods, electrophoretic estimation using Salt Soluble Globulins gave promising results.

Seed Production

Nagpur

Table 11: Seed Production during 2010-11 under Mega Seed Project of ICAR

Crop	Stage	Production (in quintals)
Cotton -20 varieties *(G.hirsutum & G.arboreum)*	TFL	32.225
Soyabean cv. JS-335	CS	4.41
Red Gram-BSMR	TFL	15.49
Gram-Jali 9218	FS	13.51

Coimbatore

Breeder Seed Production

Table-12 : Breeder seeds produced and distributed during the year 2010-11.

Variety	Seed Production (kg)
LRA 5166	99
Supriya	9
MCU 5 VT	48
Surabhi	114
Suraj	42
Supriya	9

Sirsa

Table-13 : Maintenance of Nucleus and Breeder seeds

S.No	Variety	Quantity (kg)
1	CSHH 198 (F)	25
2	(M)	16
3	CSHH 243 (F)	15
4	(M)	10
5	CSHH 238 (F)	20
6	(M)	15
7	CICR 2 (F)	37
8	(M)	20
9	CISA 310	60
10	CISA 614	50

4.9: Nutrient Management

Nagpur

Studies on long term effect of fertilizer and INM on productivity, soil fertility and quality of cotton-soybean cropping system

The residual effect of continuous application of inorganic, organic and INM treatments was evaluated using sorghum crop. Higher grain yield was obtained where FYM alone or in combination with 75% inorganic fertilizer was applied. Higher values of organic carbon (0.61%), available nitrogen (114 kg/ha), phosphorus (9.2 kg/ha) and available zinc (0.61 ppm) were recorded in the organic manure treated plots as compared to pure inorganic fertilizer treatments.

Effect of different levels of fertilizers on yield Cry protein and gossypol content expression of Bt hybrids

Field experiment was laid out a split plot design in 3 replications with 3 Bt hybrids (Bunny Bt, RCH2 Bt and JKCH99 Bt) and their 3 non- Bt counterparts. Fertilizer (N,P,K) at 3 rates viz., 90:45:45, 120:60:60 and 150:75:75 were applied. Seed oil content was in the range 21 – 23%. Gossypol content varied in the range 0.43-0.64%. Total protein content (Lowry's method) was found to be 0.32-0.45 mg/g fresh weight of leaf. Bt hybrids, in general, contained more total protein than their non-Bt parts. Yield data showed no significant difference among different nitrogen doses, for Bunny Bt, Bunny N-Bt and RCH2 Bt hybrids. Oil content was found to be higher with 150:75:75 compared to the other two lower doses.

Coimbatore

Effect of nutrients and surfactant on metabolic activity and productivity of Bt cotton

Nutrient consortia of diammonium phosphate (1%) + potassium chloride (0.5%) + magnesium sulphate (0.5%) + ferrous sulphate (0.25%) + zinc sulphate (0.25%) + micronutrients was taken up for large scale field trial with and without surfactant (non ionic soap solution + 0.1% proponol) from 60 days after sowing at 15 days interval in Bunny Bt cotton. Irrespective of treatments, the photosynthetic rate, NR activity and chlorophyll content increased up to 90 days after sowing and declined by 120th day. The photosynthetic rate was 21.1 μ mol CO_2 m^{-2} s^{-1} at 90th day and declined to 17.4 μ mol CO_2 m^{-2} s^{-1}. Nutrients sprayed along with surfactant recorded significantly higher rate of photosynthetic rate at all stages of growth. Surfactant when used along with nutrient solution facilitated the opening of stomata significantly. For instance, at 90th day about 35% of the stomata remained opened after 30 minutes of nutrient spray while only 21-22 % of the stomata remained opened in control or plants that were sprayed without surfactant. Similar trend was observed at 60th and 120th day after sowing. Soon after foliar spray of nutrients, potassium absorption by the leaves was significantly more in plants where nutrients applied along with surfactant recording 46.0 ppm on 60th day compared to 41.5 ppm in nutrient spray without surfactant. Similar trend was observed at 90th and 120th day. Control plants which did not receive potassium through nutrient application recorded significantly lower amount of potassium in the leaves. For instance at 120th day, only 25 ppm of potassium was estimated in control plants (water spray) compared to 32- 40 ppm in plants that received nutrients spray.

About 27-29 bolls were harvested from nutrient spray treatments while only 24 bolls could be harvested from the control plants. The final yield was significantly more in plants that were sprayed with nutrient along with surfactant followed by nutrients without surfactant (Fig.14). The study revealed the importance of surfactant in nutrient absorption through foliage there by increasing the metabolic activity significantly which in turn could have enhanced the yield potential.

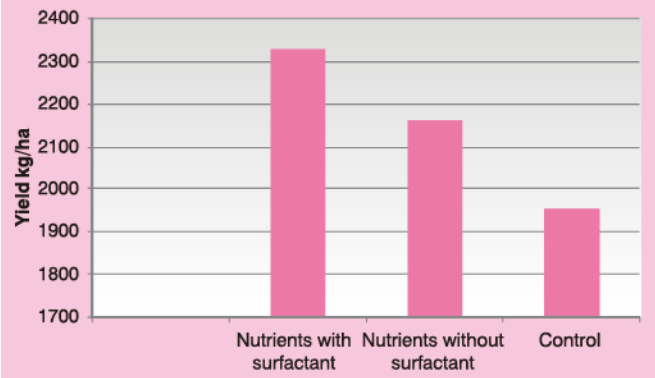


Fig. 14 : Effect of nutrients on productivity

Influence of surfactants on moisture absorption by cotton leaf surface

Moisture absorption by leaf surface was significantly more from the lower surface of the leaf 13.2% to 15.8% irrespective of the surfactants used. However, moisture absorption was further improved when both sides were immersed in solution to the tune of 19.7 % to 22.3%. Moisture absorption through upper surface of the leaf was significantly low 5.8% to 7.5%. All purpose spray adjuvant (APSA) and Triton-X surfactants facilitated moisture absorption process significantly. For instance, irrespective of the leaf surface, moisture absorption was 15.5% when APSA was added while Triton- X recorded 14.5% compared to 12.9 % in control (Water).

4.10 : Cropping Systems

Evaluation of Bt cotton based inter cropping systems

Nagpur

Eight cropping systems viz. Bt hybrid cotton (Bt) sole, Bt + pigeon pea, Bt + maize, Bt + soybean, Bt + castor, Bt + field bean, Bt + roselle, Bt + marigold were evaluated in main plots with four levels of fertilizers viz., F_1: 100 % RDF + Urea/ DAP 2%+1% $MgSO_4$ +10 kg ha^{-1} Borax spray, F_2: 100 % RDF + Soil application of $MgSO_4$ 25 kg and 10 kg ha^{-1} Borax, F_3: 125 % RDF + Urea/ DAP 2%+1% $MgSO_4$ and 10 kg ha^{-1} Borax, F_4: 125 % RDF + soil application of $MgSO_4$ 25 kg and 10 kg ha^{-1} Borax as sub plots plant densities 90 x 45 and 90 x 30 as sub sub plots in split plot design. Bt hybrid seed cotton yield, nutrient uptake and nutrient use efficiencies were not influenced by intercropping systems. Fertilizer application @ 125% RDF + soil application of $MgSO_4$ 25 kg and 10 kg ha^{-1}Borax and plant density 90 x 30 cm significantly improved nutrient uptake and also input use efficiency. All the intercrop yields except pigeon pea, soybean and castor were significantly higher than control but were not significantly altered by fertilizer doses or plant density of cotton. Bt cotton intercropped with roselle produced significantly higher cotton equivalent yields, nutrient use efficiency, C: B ratio and net returns Bt cotton biomass was highest with field bean intercropping due to positive legume effect.

Coimbatore

Weed management in multitier cropping system

Integrated weed management was evaluated under multitier cropping system. Hand weeding thrice at 15, 30 and 60 DAS gave the highest seed cotton yield (2110 kg/ha). The highest net return (Rs. 1,39,535/ha) was observed with pre emergence application of pendimethalin @ 0.75 kg a.i./ha followed by hand weeding at 30 DAS and application of pendimethalin @ 1.25 kg a.i./ha at 60 DAS lay by method for weed control. The least net return (Rs. 1,17,649/ha) was produced with weed control measures by adopting pendimethalin @ 0.75 kg a.i /ha as pre emergence followed by hand weeding at 30 DAS and post emergence application of targa super @ 50 g/ha at 60 DAS.

Incorporation (*in-situ*) of cereals on productivity of succeeding cotton

Incorporation of *in-situ* off season grown cereal crop before cotton significantly improved cotton growth and yield. Highest seed cotton yield (1762 kg/ha), total rainfall use efficiency (2.83 kg/ha-mm), partial factor productivity (14.7 kg/kg of nutrients) and economics of nutrient use efficiency (1.13 kg/Rs. invested on nutrients), gross return (Rs. 98,686/ha), net return (Rs. 70,588/ha) and benefit cost ratio (3.51) realized with *in-situ* incorporation of 45 days grown *ragi* by along with *Trichoderma viridi* followed by cotton crop. Cotton-fallow rotation produced the lowest seed cotton yield (1129 kg/ha), total rainfall use efficiency (1.8 kg/ha-mm), partial factor productivity (9.4 kg/kg of nutrients) and economics of nutrient use efficiency (0.72 kg/Rs invested on nutrients), gross return (Rs. 63,206 /ha) and net return (Rs. 44,176/ha).

Exploiting new geometry and nutrients management strategies for maximizing the productivity of Bt cotton based intercropping systems

In a novel method, short duration intercrops like coriander and radish were introduced on the other side of the ridge so that the cotton plant geometry is maintained exactly as that of pure crop of cotton. Bt cotton + coriander, Bt cotton + radish and sole cropping were studied under two geometry (90 x 60 cm as normal recommended geometry) and modified geometry of 120 x 45 cm so that the cotton plant population is same under both geometry and evaluated under four fertilizer treatments. The results indicated that the intercropping systems recorded on par seed cotton yield with sole cotton and among the intercropping systems, Bt cotton + coriander system recorded highest seed cotton equivalent yield (5062 kg/ha), followed by Bt cotton + radish system (4312 kg/ha) as against the lowest (3553 kg/ha) recorded under sole cotton. Bt cotton + radish system recorded the highest (1.43) land equivalent ratio followed by Bt cotton + radish system (1.21). Among the geometries, 120 x 45 cm recorded significantly higher seed cotton yield and seed cotton equivalent yield than 90 x 60 cm suggesting that wider row spacing is advantageous to Bt cotton than wider plant to plant spacing within the row. Among the fertilizer treatments, application of 125 % recommended NPK (RDF is 90:45:45) with foliar spraying of DAP 1.5%, K 0.5%, $MgSO_4$ 0.5% and Boron as solubor 0.15% (twice during flowering to boll development stages) recorded the highest seed cotton yield, seed cotton equivalent yield, net return and benefit cost ratio (Table 14).

Table 14 : Productivity and economics of Bt cotton based intercropping system

Treatment	SCY (kg/ha)	Intercrop yield (kg/ha)	Cotton equivalent yield (kg/ha)	Net return (Rs/ha)	Land equivalent ratio
Bt cotton + coriander	3447	8250	5062	2,23,670	1.43
Bt cotton + radish	3397	6370	43.12	1,85,680	1.21
Sole cotton	3553	6370	3553	1,47,720	-

Sirsa

Studies on soil plant narrations in intercropped *kharif* legumes with Bt cotton under irrigated condition

Experiment on cotton intercropped with mungbean variety SML 668 with different geometry was carried out with less spreading Bt hybrids viz. MRC 7017 and Bioseed 6488 to find out its suitability. The seed cotton yield in sole cotton 2173 kg/ha with MRC 7017 and 2178 kg/ha with Bioseed 6488 was significantly higher than the paired row system. In treatments with intercrop, 400 kg/ha yield of mungbean with MRC 7017 and 389 kg/ha with Bio-seed 6488 was observed with 3 rows of mungbean at 30 cm spacing were accommodated in 135 cm space available between the paired rows. The extra expenditure Rs. 3800 for seed cost of mungbean and hand weeding charges for cultivation for mungbean as intercrop also estimated and deducted from total income of the system. The net income Rs. 65190 with MRC 7017 and Rs 65340 with Bioseed 6488 was higher in sole cotton at spacing 65.5 x 75 cm followed by paired row with 3 row mungbean Rs. 61100 with MRC 7017 and Rs. 61350 with Bioseed 6488.

4.11: High Density Planting Systems (HDPS) for Maximizing Productivity

Nagpur

Development of high density planting systems (HDPS) for maximizing productivity of rainfed cotton

Separate experiments involving 5 genotypes of *G. hirsutum* across 5 plant geometries (accommodating 55000 to 166000 plants/ha) and 5 genotypes of G. arboreum across 5 plant geometries (accommodating 111000 to 222000 plants/ha) were conducted on rainfed Vertisols of agro eco sub region (10.2) characterized by hot dry sub humid agro ecosystem. Among the 5 genotypes of G. hirsutum (Anjali, CCH 724, NISC 50, PKV 081 and CNH 120 MB) evaluated, the genotype PKV 081 was found most suitable for high density planting (1,66,000 plants/ha at 45 x 13.5 cm) in terms of yield (1921 kg/ha) morphological features, earliness, tolerance to sucking pests and boll weight. Among the 5 genotypes of G. arboreum (AKA 07, CINA 404, PA 255, PA 08, JK 5) evaluated, on the basis of yield, CINA 404 (2174 kg/ha) performed the best at

high density planting (2,22,000 plants/ha at 45 x 10 cm). However with the same spacing, other high yielding genotypes viz., JK-5 (1842 kg/ha) and AKA-07 (1815 kg/ha) were more dwarf and compact than CINA-404.

Among the spacing 60 x 30, 45 x 20, 45 x 13.5, 30 x 30 and 30 x 20 cm of *G. hirsutum* evaluated, across the genotypes a spacing of 45 x 13.5 cm (1,66,000 plants/ha) was optimum for short compact types. Among the spacing viz., 60 x 15, 45 x 13.5, 45 x 10, 30 x 20 and 30 x 15 cm evaluated, across genotypes a spacing of 45 x 10 cm (2,22,000 plants/ha) was optimum for *G. arboreum* for short compact plant types. In both *G. hirsutum* and *G. arboreum* genotypes the harvest index decreased with increasing plant density. This is turn decreased nutrient utilization efficiency. Nevertheless in all the genotypes of *G. hirsutum* and *G. arboreum*, the nutrient uptake efficiency and partial factor productivity for N increased with increase in planting density.

Standardization of nutrient requirements for cotton varieties under (HDPS)

a. *G. hirsutum*

Under HDPS *G. hirsutum*, PKV 081 produced more bolls, had higher weight and gave more seed cotton yield (1209 kg/ha) as compared to NH 615 (1050 kg/ha) and NH 452 (1049 kg/ha). Fertilizer level @ 125% RDF significantly influenced the number of bolls. Seed cotton yield (1253 kg/ha) was higher with 125% RDF compared to 100 % RDF (1082 kg/ha) and 75 % RDF (872 kg/ha). Higher nutrient uptake was observed at 125% RDF.

b. *G. arboreum*

Under HDPS higher boll weight and seed cotton yield (1981 kg/ha) was recorded with the application of 125 % RDF in the variety PA 255 as compared to 100% RDF (1607 kg/ha). NPK uptake was higher in JLA 794 compared to AKA 7 or PA 255 at all the fertilizer levels. Higher nutrient utilization of N and P was noted in PA 255. Higher dose of fertilizer at 125% RDF increased nutrient utilization efficiency in all the cultivars.

Altering cotton plant morphoframe for improving yield and resource use under HDPS

Four cotton genotypes – *G. hirsutum*- cv Anjali and PKV 081 and *G. arboreum* cv. AKA 7 and PA 255, were raised under two spacing. Eleven treatments were taken for foliar application to alter the canopy growth. Planting at narrow (30 x 30 cm) gave double the yield compared to recommended (60 x 30 cm) spacing in *G. hirsutum*. This yield enhancement was 30-40% in *G. arboreum*. Application of Maleic hydrazide (@500 ppm at 45 day) and Mepiquat chloride (@60 ppm at 45 DAS) showed promise to further enhance the yield under HDPS.

Coimbatore

High Density Planting System-*hirsutum* genotypes

Under HDPS narrow row planting at 45 x 15 cm (1, 48, 148 plant/ha) was followed for the genotypes Anjali, C-1412 and CCH-7245 and control RCH-2 Bt was planted at 90 x 60 cm (18,519 plant /ha). The genotypes were evaluated at 75,100,125 and 150 % of RDF. Light interception had been significantly influenced by genotypes and their planting methods. The highest light interception (68.9 %) recorded with CCH-7245 (planted at 45 x 15 cm) and the least one with RCH-2 Bt (17.0 %). Agronomical advantage associated with narrow row planting (45 x 15 cm) of genotypes (Anjali, CCH-7245 and C-1412) had resulted in an increase in seed cotton yield to the extent of 300-800 kg/ha over to RCH-2 Bt (Fig.15). The economic assessment indicated that narrow row planting of Anjali (45 x 15 cm) provided the highest gross return (Rs. 1,19,538/ha) and net return (Rs. 78,286/ha). Nutrient levels (75,100,125 or 150 %) did not influence the seed cotton yield significantly.

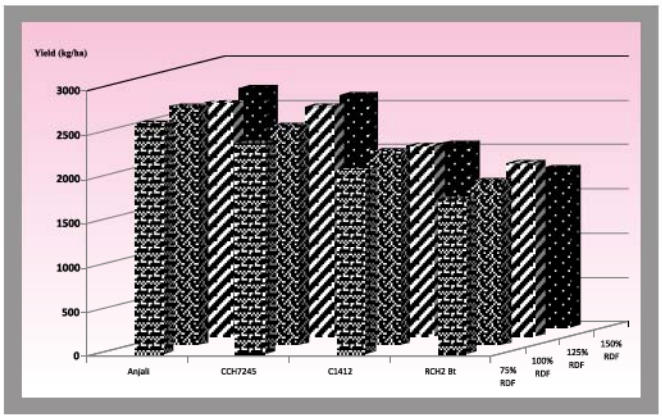


Fig.15 : Yield (kg/ha under Ultra Narrow row (Anjali, CCH7245 & C1412)

4.12: Weed Management

Nagpur

Stale Seed Bed Technique

Controlling weeds mechanically by harrowing once before sowing, or Roundup 2.5 l ha^{-1} or Roundup 2.5 l ha^{-1} + Pendimethalin 1.0 kg a.i. ha^{-1} alongwith three inter-cultures and two hand weeding produced statistically similar yields to that of farmer's practice of three inter-cultures and two hand weeding. Herbicides were effective in weed control in intercropped field bean by reducing hand weeding requirement. Stale seed bed technique, common in rainfed areas, helped Bt hybrid cotton to overcome the competition in first inter-culture by reducing 66% hand weeding requirement compared to intercrop. Cost of cultivation, net returns and FUE of Bt hybrid cotton were similar in the above treatments at par with farmers practice. The weed control efficiency was 95% compared to control due to continuous rains.

Coimbatore

Novel approach of exhausting weed seed bank before the crop emergence by Stale Seed Bed Technique (SSBT) was standardized for Bt cotton + coriander intercropping system.

SSBT and application of a mixture of glyphosate 1.0 kg + pendimethalin 1.0 kg one week after irrigation controlled the weeds effectively because the germinated weeds were killed by glyphosate and the germinating weeds were controlled by the residual action of the pendimethalin with the weed control efficiency of 86.61 % and on par seed cotton yield with SSBT and manual removal of weeds (thrice) (Table 15) .

Field experiment was conducted in RBD with nine treatment combinations to find out the suitable herbicides rotation for efficient ,economical and safe weed control method in Bt cotton RCH 20. The weed flora count recorded at 35 DAS has shown significant difference among treatments. During initial stage, the carpet weed (*Trianthema portulacastrum*) was the dominant accounting for 87% of the total weed population and application of pendimethalin as pre emergence herbicide could control the weeds effectively with weed control efficiency of up to 84.17 % while alachlor was not effective against *Trainthema*. The rotation herbicides *viz*., Phenoxy–p-ethyl 100 g and quizalofop-ethyl 50 g at 60 DAS were effective against the grassy weeds whose population increased during later part of cotton growth. None of the herbicides tried in the experiment were phytotoxic to cotton crop. The pre emergence application of pendimethalin followed by one hand weeding at 35- 40 DAS and post emergence application of either phenoxy–p- ethyl 100 g or quizalofop- ethyl 50 g on 60 DAS recorded on par seed cotton yield with hand weeding thrice (20,40 and 60 DAS).

4.13 : Soil Biology and Biochemistry

Nagpur

Impact of Bt cotton soil biological properties

Rhizosphere samples were collected at 30 days interval till harvest from Bt (Bunny, Jai and Ankur) and corresponding non Bt plots raised following normal agronomic practices. The selected soil chemical (organic carbon, pH, nitrogen, available phosphorus and available potassium) and biological parameters (soil respiration, soil urease activity, soil dehydrogenase activity (DHA), microbial biomass carbon (MBC) and soil microbial population were analysed following the standard methods. The results indicated that growing Bt cotton does not pose any ill effects on the above soil chemical and biological parameters studied, rather, interestingly, all the parameters in biological and chemical properties (except available potassium) found to increase in soil where Bt cotton were grown compared to its counterpart (non-Bt cotton) and bulk soil. There was found to be statistical significance between the Bt cotton hybrids, crop growth stages and their interactions. Most of the soil parameters studied, found to show its maximum activity between 60-90 days of crop growth which coincides with flowering period. Thus growing Bt cotton does not pose any ill effects on soil health.

Developing efficient carrier based microbial delivery system for cotton nutrition and soil health

Fifteen native bacterial isolates (*Enterobacter asburiae*-1, *Bacillus spp*., *Erwinia spp* , *Enterobacter spp*, *Acinetobacter baumannii-1*, *Pseudomonas putida-1*, *A. baumannii-2* , *E. asburiae-2* , *A. baumannii-3* , Un-cultured bacterium, *E. asburiae -3*, *A. baumannii-4* , *P. putida -2*, *Pseudomonas plecoglossicida*, *P. putida-3*) possessing good phosphorus solublizing activity, growth promotion and bio control potential has been isolated from cotton rhizosphere. The bacterial isolates were characterized biochemically and identified based on 16S rDNA. Among the isolates, higher pH reduction was recorded with *A. baumannii-2* (43.4%) followed by Un-cultured bacterium (35.5%). *A. baumannii-4* (6.7 mg/ml) followed by Un-cultured bacterium (5.3 mg/ml) showed maximum phosphorus under broth culture. Higher acid phosphatase activity was recorded with *Erwinia spp*. (127 µg PNP/ml), while higher alkaline phosphatase activity was recorded with Un-cultured bacterium (103 µg PNP/ml). High IAA production was recorded with *E. asburiae-3* (200 mg/ml) followed by *Pseudomonas putida-1* (140 mg/ml).

Table 15 : Weed control treatments on weed count, weed control efficiency and seed cotton yield

Treatments	Weeds count/m2	Weed DMP (g/m2)	WCE (%)	SCY (kg/ha)
SSBT glyphosate 1.0 kg week after irrigation	128.4 (11.32)	52.9	54.59	2339
SSBT pendimethalin1.5 kg third day after irrigation	37.6 (6.11)	19.00	83.69	3565
SSBT glyphosate 1.0 kg + pendimethalin 1.5 kg week after irrigation	26.42 (5.13)	15.6	86.61	3686
Pre emergence application of pendimethalin 1.5 kg 3 DAS	44.57 (6.66)	24.4	79.06	3402
SSBT and manual removal of weeds thrice	49.41 (7.02)	28.5	75.54	3740
Un weeded check	263.0 (16.2)	116.5	-	8.55
CD (p=0.05)	**0.55**	**4.59**		**311.2**

Figures in parenthesis are square root transformed values for statistical analysis.

Geo-referenced soil information system for land use planning and monitoring soil and land quality for agriculture

A survey was undertaken in established benchmark soil series in Black Soil Region (BSR) of India covering 6 AERs and 16 AESRs (3.0, 5.1, 5.2, 6.1, 6.2, 6.3, 6.4, 7.1, 7.2, 7.3, 8.1, 8.2, 8.3, 10.1, 10.2, 10.3) accounting for 19% (63 m ha) of total geographical area of the country to analyse the impact of management practices on selected soil biological properties (soil urease, soil dehydrogenase, microbial biomass carbon and soil microbial population) for development of land quality indicators and threshold values. From each benchmark spots, soil samples were collected from individual horizon in two pedons, one each representing farm management (FM) and high management (HM) regimes. From the analysis, high management found to recorded higher soil enzymatic and microbial activity as compared to farm management in all the BM spots studied. In general, the enzymatic and total microbial activity declines with the depth, and maximum activity (>50%) have been restricted to 50 cm.

4.14: Cotton Mechanization

Nagpur

Development, evaluation and refinement of seed bed preparation, planting, inter culture and spraying machinery for cotton production

Manually operated cotton planter

Manually operated cotton planter was developed for planting cotton seed. It is light weight, simple in operation, and delivers single seed in 30 ± 1.5 cm plant to plant spacing. The plant to plant spacing can be varied from 10 - 30 cm.

Adjustable cultivator: Adjustable cultivator was designed and developed for intercultural operation for narrow spaced cotton crop with an adjustment in the row spacing. It can be used successfully for high density planting cotton crop.

Bullock operated fertilizer attachment to bakhar: A fertilizer applicator has been modified for equal distribution of fertilizer from both tubes. A single agitator is attached above the opening for fertilizer metering. The agitator spread the fertilizer in equal proportion in both the delivery tubes.

Fertilizer Applicator

Mechanization of cotton picking operation

Testing of spindle type cotton picking machine

It was observed that geometry of crop and plant height affects the picking drum dimensions. The RPM of spindle and the linear speed of each spindle relative to the speed of cotton bolls (the latter depending on the forward speed of travel of the machine) ultimately affects the picking efficiency. The performance results of the machine having forward speed, effective field capacity, fuel consumption, total harvesting loss, mechanical picking efficiency and picker efficiency were 2.20 - 3.38 km/h, 0.278 - 0.563 ha/h, 22.0 - 24.0 l/h, 14.29 - 31.74%, 55.6 - 83.1% and 68.3 - 85.7% respectively.

Testing of commercially available manually operated small hand picking machine

Manually operated small hand picking machine was tested in CICR, farm as well as in farmer's field. It has been found that, the field efficiency of the machine was varied from 56% to 100% of the manual. It was seen that the machine efficiency was at best at par with manual picking given adequate training to the operator.

4.15: Morphoframe / Boll Load Management

Nagpur

Physiological manipulation of Bt cotton plant morphoframe for enhanced productivity

The physical nipping of plant reduced the height when compared to control. Foliar application of Maleic hydrazide (MH) also brought about the same effect by effectively inhibiting the meristem growth in both main stem and sympodial branches. The nipping or use of MH enhanced the leaf area and it was maintained higher than control on all the genotypes tested. The biomass and yield also showed a positive effect with treatments over the control. The per cent increase in seed cotton yield ranged from 6 to 25 %.

Stance, a combination of mepiquat chloride (anti- gibberellins) and cyclanilide (anti-auxin) and defoliants, Dropp Ultra (thidiazuron+diuron) and Ethrel (ethephon) were tested for their growth retarding and defoliation efficiency respectively, in 31 popular Bt Hybrids on rainfed Vertisols. Stance was sprayed at match head square stage of the hybrids @2.5 ml/5 litres of water. Stance was effective in reducing the plant height of MIST BG, RCH 314 BGII and BTH 97377and this may be attributed to the reduction in the endogenous levels of gibberellins and auxins which are responsible for apical dominance. The canopy width of Goldmine, SP 1037, MRC 6304, Platinum 144 and Brahma BGII was reduced by the application of Stance.

Defoliants, Dropp Ultra and Ethrel were sprayed @ 5 ml/12 litres of water and 60 ml/12 litres of water respectively, when 70% of the bolls were opened. Dropp Ultra performed better with 90 to 100% defoliation after 15 days of spray. Higher defoliation efficiency of Dropp Ultra can be attributed to its active ingredients *viz*., thidiazuron and diuron, with thidiazuron, inhibiting the polar transport of auxin (increasing the ethylene to auxin ratio) and diuron, blocking the electron transport chain of photosystem II, thus inhibiting photosynthesis and accelerating senescence of leaves. The decreased efficiency of Ethrel in defoliation in the present study could be because of low temperature which prevailed during the post application period. At temperatures <15.5 °C (at night), ethephon efficiency decreases, because of a temperature dependent degradation to ethylene.

Sirsa

Effect of defoliant on physiological parameters and seed cotton yield.

The effect of application of Ethrel at concentrations 1500 ppm, 2000 ppm and 2500 ppm at 145 and 160 days after sowing on Bt. hybrid RCH 134 was evaluated. The numbers of opened boll/plant were significantly higher in the crop sprayed with 2000 ppm (39.0) and with 2500 ppm (41.0) concentration of defoliant at 160 DAS than control unsprayed crop (32.7). Because of higher number of opened bolls, the yield / ha was significantly higher in crop sprayed on 160 DAS with 2000 ppm (2500 kg/ha) and with 2500 ppm (2580 kg/ha) than unsprayed crop (2147 kg/ha).

4.16: Studies on Abiotic Stress

Nagpur

Physiology of drought tolerant genotypes

Eleven *G. hirsutum* cultures were raised in pots under rainout shelter and rigorous screening of the lines for drought tolerance and yield was carried out. The drought stress was induced at the onset of flowering (75 DAS) for 15 days. The physiological parameters like water potential, osmotic potential, chlorophyll stability index and membrane stability index was studied. Among the biochemical constituents-reducing sugars, amino acid, proline and protein was studied. All the eleven lines were found to be tolerant to mid-term stress compared to the check LRA 5166.

Physiology of drought resistant transgenic cotton

Sixteen transformed plants for DREB and ZFP genes were raised in pots along with control plants of LRA 5166. The plants were grown under optimum conditions till flowering. Moisture was withheld after 75 days after sowing and plants were allowed to grow under receding moisture. The leaves of both non-transformed and transformed plant started to droop within seven days after stress induction. The transformed plants would show recovery during night and leaves were turgid in the early part of the day. This helped the plant to recover and grow normally. The leaf water potential also was maintained at higher level due to accumulation of solutes, which was not observed in case of control plants.

In the second method of screening, the leaf discs from non-stressed plants of both transformed and non-transformed were placed on PEG medium with varying degrees of stress (0, 0.4, 0.6 and 0.8 MPa). The biochemical changes induced due to stress was quantified at 0, 7 and 15 days after inoculation. The data showed that there was an inherent tolerance developed in transgenic plants due DREB and ZFP genes. The control plants showed a immediate burst in synthesis of reducing sugars, amino acids and proline, but declined by seven days. The transformed plants showed a gradual increase in solute accumulation and maintained high even after 7 days. The non-transformed discs produced very high phenolics which led to death of the tissues with stress. Of the sixteen plants, based on the biochemical and physiological factors six transgenic plants were selected for confined trails.

Leaf reddening

The project on leaf reddening was initiated during the year 2010-11 and several treatments including chemical fertilizers, hormones and insecticides. Foliar application of nutrients (viz., urea, DAP, $ZnSO_4$, $MgSO_4$, lime, potash, ascorbic acid and salicylic acid), hormones (viz., NAA, GA, mepiquat chloride, maleic hydrazide and methanol), insecticides (Monocrotophos, Chlorpyriphos, Larvin, Methomyl, Confider, Fenvalerate, Acephate and Thiomethoxam) and fungicide (copper sulphate, copper oxychloride and Bavistin) were tested. The physiological, biochemical, morphological analysis of the leaf samples were done to study the cause and effect of inputs on leaf reddening.

With the receding moisture and high light intensity the reddening of leaves was induced. Foliar application of nutrients, hormones and fungicide could not control leaf reddening, but the intensity of reddening varied. Plant applied with monocrotophos and confider showed no reddening all through the season. Foliar application of Methomyl at recommended dose showed toxicity effect and the whole plant turned red within 24-48 hours after application. The cross section of control and treated leaves showed that the insecticides were absorbed through the stomatal opening and immediately affected the guard cells. Anthocyanin was accumulated in the guard cells and with time led to the death of the cell which was very clearly visible from avacuolated cells.

A colour chart has been developed to rate the extent of leaf reddening. The chart is now being used in AICCIP for rating the extent of damage due to reddening.

Coimbatore

Alleviation of moisture stress

The effects of various combinations of nutrients were studied under moisture stress and irrigated condition in Bunny Bt cotton. Nutrient consortia spray recorded 23-25 bolls under irrigated and moisture stress condition compared to 20 bolls in control plants. *Panchakavya*, Hoagland solution and DAP 1% + KCl 0.5% could also increased the boll no significantly under irrigated condition.

Boll weight was not altered significantly by nutrient spray under moisture stress condition. Irrespective of treatments, significant differences in yield could not be recorded between irrigated and moisture stress treatment. However, a significant difference due to nutrient spray was evident on yield. For instance, spray of nutrient consortia increased the final yield significantly both under irrigated and moisture stress condition with 127.19 g and 130.50 g per plant respectively compared to 104.80 g per plant in control (Table 16). Other treatments like *Panchakavya*, Hoagland, DAP (1%) + KCl (0.5%) could also increase the final yield significantly.

Leaf reddening symptoms was comparatively less under irrigated than moisture stress condition, irrespective of treatments both at 120 days after sowing and at harvest. Among the treatments, nutrient consortia showed a distinct differences in maintaining the greenness of the leaves upto harvest followed by *Panchakavya* and DAP (1%) + KCl (0.5%). In control plants, 70-75% leaf reddening was recorded where as in treatments like nutrient consortia spray leaf reddening symptoms was to the extent of 30-35%.

Effect of heat stress on growth and development of cotton

Six Bt cotton hybrids and 3 commercial genotypes were evaluated for tolerance to heat stress in pot culture. Morphological attributes and physiological parameters were favorable under T 2 treatment (plant grown under heat stress initially for 30 days and then shifted to ambient condition). For instance, the total dry matter production at harvest was higher in T 2 suggesting that initial shock of heat stress for 30 days was beneficial to cotton for better growth and development.

Table 16 : Effect of nutrient spray on yield and yield components

	Boll number/plant		Boll weight (g)		Yield (g/plant)	
Treatment	**Irrigated**	**Stress**	**Irrigated**	**Stress**	**Irrigated**	**Stress**
Nutrient consortia *	23	25	5.53	5.22	127.19	130.50
Panchakavya (3%)	23	22	5.10	5.16	117.53	113.52
Boiled ash (5%)	21	22	5.19	5.20	108.99	114.84
Hoagland solution	24	23	5.11	5.14	122.64	118.22
Hoagland + NAA	23	22	5.22	5.03	120.06	110.66
DAP (1%) + K (0.5%)	23	22	5.22	5.24	120.06	115.28
Control	20	20	5.43	5.32	104.80	104.00
CD at 5%	2.3		NS		9.2	

* DAP 1% + KCl 0.5% + $MgSO_4$ 0.5% + $FeSO_4$ 0.25% + $ZnSO_4$ 0.25% + micronutrients

Hybrid Bt cotton appeared to be more sensitive to heat stress. Hybrids like MRC 6918 and Mallika produced less reproductive parts and dry matter under heat stress while genotypes like LRA 5166, H -777 and Anjali were more tolerant to heat stress and produced more dry matter and yield. Irrespective of Bt cotton hybrids evaluated there was a reduction of 5.5% in dry matter of reproductive parts when grown completely under heat stress condition (T 1). On the contrary there was an increase of 11.6% in cotton genotypes grown under heat stress condition. However, both Bt cotton and genotypes showed a significant increase of 27.2 and 39.7% respectively in T 2 treatments. Again, a reduction of 11.3% and 3.7% in Bt cotton and genotype was recorded for T 3 treatment (plant grown under ambient initially for 30 days an then under heat stress) indicating that genotypes could tolerate heat stress compared to Bt cotton.

The results also suggested that T 2 treatment (plant grown under heat stress initially for 30 days and then shifted to ambient condition) was beneficial for cotton.

Sirsa

Heat and salinity tolerance

With the aim to identify the heat tolerant cultivars which can improve plant stand, screening was made using 50 working collection of each *G. hirsutum* and *G. arboreum* exposing their seedlings to temperatures ranging from abiotic stress 31.0-46.6, 23.4-43.4 and 24.4-46.6 degree centigrade by sowing at different intervals. Comparatively heat tolerant lines were Stonevilla, SA 1057, SA 1078, SA 1393, SA 1427, SA 310, SA 1601 of *G. hirsutum* and CISA 361, AC 3475, AC 3134, AC 3346, AC 3026, AC 3392, AC 3065, AC 3553 of *G. arboreum*.

Similarly, with the aim to identify the tolerant genotypes for salinity which can be used for improving the plant stand under saline conditions, screening was made using 50 working collection of each *G. hirsutum* and *G. arboreum* under naturally developed saline farmers field. Out of fifty lines, only few lines could germinate and survive under saline condition. The percent plant stand in these line was very less between 10 to 25%. In *G. hirsutum* SA 1178, SA 1168, Stonevilla, SA 1393, SA 1522, SA 1101,NACA 5, RS 810, AO3N 123 and in *G. arboreum* AC 3603, AC 3194 NLL, AC 3652, AC 3736A, AC 3222, CISA 53 were comparatively tolerant.

4.17: Socio Economic Dimensions of Cotton Farming

Assessment of cotton based intercropping system

Data collected from 120 farmers of Akola in Maharashtra and Khandawa in Madhya Pradesh, indicated that all farmers in both the districts were aware about intercropping of soybean, mung, urid, cowpea with cotton. The benefits and advantages of intercropping such as additional returns, helping to suppress weeds, minimize soil erosion and increasing fertility of soil were aware by many of respondents (53.33 - 83.33 %). Knowledge assessment and adoption of cotton intercropping indicated that one third respondents (34%) were placed under full knowledge group while one fourth respondents (26%) had fully adopted various components of cotton intercropping. The overall percentage of knowledge and adoption of various aspects about intercropping was noted to the extent of 71.02 and 67.91 per cent, respectively. Medium and large holding farmers adopt more cotton based intercropping practices due to more land holding and frequent contact with extension personnel, while marginal and small farmers adopt cotton based intercropping on limited land holding and in leased area. The main constraints in adoption of intercropping were, difficulty in intercultural operations, lack of exposure and unsure about more income. The other bottlenecks were non availability of quality seed of appropriate varieties, lack of expert advice, fear of more expenditure towards intercropping. Land holding, social participation and age levels had significant impact on level of adoption of intercropping system.

Further for popularizing intercropping system through farmer to farmer's participatory learning approach, a farmer namely Sh. Vinod Raut was identified from village Weni in Hinganghat tahsil of Wardha district and trained and motivated to conduct on farm cotton + soybean and cotton + cowpea intercropping trials at his field in one acre each. Many farmers from his village and adjoining villages, as well as state agriculture department officials visited and appreciated these trials.

Agrarian distress among cotton farmers

The study conducted in two districts of Maharashtra indicated that majority of cotton farmers from distress district Yavatmal faced more sociological, economical and psychological problems and were under high level of distress as compared to progressive Jalgaon district. The sociological problems faced by the farmers were family responsibilities, family conflicts, increasing alcoholism/drug abuse. Among economical factors, the rising cost of cultivation, yield uncertainties, labour problem, inadequate irrigation facilities and increasing dependency on others in farming were important. The study also pointed out those psychological factors like worries about family responsibilities, increasing mental tension and fear of

loan repayment leads to distress. The overall contribution of psychological factors for distress among the farmers was noted to be 75.14 per cent. The other factors, include, inadequate training and exposure, lack of other earning sources, lack of perceived benefits from new technology, problems in getting crop insurance claims and lack of support systems. The study indicated that the psychological and economical factors are more severe among farmers in Yavatmal distressed district compared to progressive Jalgaon district.

Analysis of yield gap and constraints in cotton production

An attempt was made to estimate yield gap and constraints contributing those yield gaps was attempted in Maharashtra and Tamil Nadu. Jalgoan and Yavatmal districts in Maharashtra and, Coimbatore and Perambalur districts in Tamil Nadu were selected. Constraints in cotton production in these districts were identified and ranked based on the yield loss incurred due to each constraint.

Maharashtra

Results indicated that an average yield gap of 1020 kg/ha was present in the cotton production in Yavatmal district. Incidence and damage caused due to sucking pests like jassids, aphids, whiteflies, thrips, mealy bugs and mired bugs was the major constraint in cotton production which ranked first based on the yield loss. The problem of weeds ranked second among the constraints while leaf reddening ranked third. Delayed sowing due to late onset of monsoon and water logging ranked fourth and fifth positions. Other important constraints includes non availability/high cost of human labour, non availability of good quality seed, shortage/high cost as well as inferior quality of fertilizers, lack of knowledge about correct crop production practices, low price/price fluctuations of farm produce at the time of harvesting, dry spell during later stages of crop growth, deficiency of micronutrients , low temperatures during last stage of crop, reduced use of organic manures and incidence of diseases.

In Jalgoan district yield gap was estimated to be 1302 kg/ha. Incidence of sucking pests raked first followed by dry spells during later periods of crop growth and leaf reddening. Delayed sowing due to late onset of monsoon and non availability of human labour ranked fourth and fifth positions. Other important constraints includes low fertilizer usage , weed infestation, higher degree of use of non-certified seeds, deficiency of micronutrients, low price of farm produce at the time of harvesting, lack of knowledge about recommended package of practices, incidence of diseases, reduced use of organic manures and non availability of suitable machinery.

Tamil Nadu

Yield gap was estimated to be 7160 kg/h in Coimbatore district of Tamil Nadu. Weed problem was the main constraint followed by non availability of labour and untimely interculture due to shortage of labour. Damage due to sucking pests and scarcity of irrigation facilities ranked fourth and fifth positions. Other important constraints includes lack of knowledge about recommended practices, low price of farm produce at the time of harvesting, non availability of quality seeds, delayed sowing due to late onset of monsoon, dry spell during later stages of crop growth, low fertilizer usage, poor soil conditions, deficiency of micro-nutrients, lack of support systems and reduced use of organic and farmyard manures.

In Perambalur district yield gap was estimated to be 6170 kg/ha. In this district also Incidence of sucking pests ranked first followed by non availability of human labour and weed infestation. Delayed sowing due to late onset of monsoon and lack of irrigation facilities ranked fourth and fifth positions. Other important constraints include lack of irrigation facilities, untimely interculture, lack of knowledge about recommended package of practices, low price of farm produce at the time of harvesting, dry spell during flowering / boll development, lack of support systems, sub optimal use of inputs, deficiency of micro-nutrients and use of non certified seed, and reduced use of organic and farmyard manures.

Impact of Bt cotton cultivation on farm economy in India

Data was collected from 75 farmers from Dharwad, Belgaum and Raichur districts of Karnataka. Bt cotton area increased from 10.42 per cent in 2003-04 to 92.41 per cent in 2008-09. On an average, Bt cotton growers are incurring an expenditure of Rs. 37,582.62 per ha towards the cultivation expenses. Human labour is the major cost item in cotton cultivation accounting for 50.01 per cent of working expenses. Fertilizers and manures occupy second and third place accounting for 16.19 per cent and 11.09 per cent respectively of working cost. On an average cotton farmers are producing 1800 to 2200 kg of seed cotton per ha. Gross returns obtained from cultivation of cotton in one ha amounted to Rs. 52410. B:C ratio was worked out to be 1.39. B:C ratio was highest in medium farm category with 1.67 followed by large (1.55), small (1.52) and marginal farms (1.46) respectively. A reduction of 68 per cent was observed in plant protection cost in Bt cotton cultivation. Seed cotton yield in Bt cotton was 2300 kg per ha and non Bt cotton was 2100 kg per ha. An increase of 26 per cent in net returns was observed in Bt cotton cultivation when compared with non Bt cotton.

Majority of the respondents opinioned that profit increased from cotton cultivation increased, economic position improved and indebtedness decreased after taking of Bt cotton. As per the opinion employment in cotton cultivation, demand for labour, fertilizers and requirement of cash increased while demand for pesticides decreased due to Bt cotton. Similarly majority of the respondents opinioned that availability of seed, fertilizers and pesticides improved, sale price of cotton increased.

Economic implications of trade openness on Indian cotton economy

With the implementation of the agreement on agriculture in 1994, the international trade opportunities are expected to change as trade barriers are reduced and freer trade takes place. To study the implications of these changes on cotton production, the year 1994-95 was bench marked. The period 1980-81 to 1994-95 were grouped as pre-WTO period and 1994-95 to 2009-10 were grouped as post-WTO period. The post WTO period was further bifurcated into Pre Bt era (1995-96 to 2001-02) and post Bt era (2002-03 to 2009-10).

During the pre WTO period, the area of cotton was almost stagnant around 7.8 m ha. But, there was an increase in production and yield of cotton at a rate of 3.83 and 4.07 per cent respectively during the same period. The performance of cotton was quite impressive in the post WTO period. The area, production and yield had grown at 0.85, 7.35 and 6.45 per cent respectively. During the pre Bt period, cotton area decreased to 8.73 m ha from 9.04 m ha showing a negative significant growth rate of 0.86 per cent. The production and yield showed a positive growth rate of 3.44 and 4.37 per cent respectively.

Unlike pre Bt era, the post Bt era experienced an increase in area, production and yield to the tune of 4.37, 9.72 and 5.12 per cent respectively. The area increased from 7.67 m ha to 11 m ha, threefold increase in production from 13 to 33 m bales and yield from 300 kg/ha to 502 kg/ha. The influx of Bt technology has been one of the factors in the phenomenal performance of cotton in India. Though there were fluctuations, the cotton area, production and yield showed a positive trend of during overall period of analysis.

India has enjoyed a surplus of production over consumption since 2003-04, contributing to its emergence as one of the world's top exporters of raw cotton. Most important destinations for Indian cotton exports (based on value) are China (46.7%), Pakistan (20.5%), and Bangladesh (12.1%). During the post WTO period, the quantity of imports almost remained stagnant at 13 lakh tonnes and gradually reduced during post Bt era from 3.74 lakh tonnes to 0.85 lakh tonnes. The export increased from 2.89 lakh tonnes during 1999-00 to almost 14.11 lakh tonnes during 2009-10.

The trading in cotton, both domestic and international, is subject to several government interventions. The changing pattern of raw cotton exports were estimated by obtaining the transitional probability matrices for the annual export data of raw cotton (in terms of volume and value). The major cotton importers from India, i.e. Bangladesh, China, Japan, Korea, Thailand and the UK were considered for analysis. The cotton trade with the remaining countries was pooled under 'other countries'.

The analysis indicated that in pre WTO period Italy and Thailand remained, stable importers with a probability retention of 0.67 and 0.54 respectively. During the post WTO period, China and Japan remained, stable importers during pre Bt era. But after post Bt era only China remained as a stable importer of Indian cotton. Interestingly, minor importers of raw cotton, the other countries also remained importers with a probability of retention of 0.29 and 0.21 during pre and post Bt era respectively.

Comparative analysis of conventional, biotech and organic cotton production systems in India

The livelihood changes created by three different production systems in cotton farming was carried out to determine the additional benefits of each system in the social and economical arena, using the Sustainable Livelihoods (SL) concept with five identified capitals viz. natural, social, human, physical and financial capital. The study was conducted among 120 cotton growers, of them, 50% were Bt cotton farmers, 25% were non-Bt farmers and 25% were organic growers. The analysis on financial and physical capitals revealed that the Bt cotton production system was perceived by the participants to have become more economically resilient than other systems when faced with adversity. With regard to natural capital, organic production system has the perceived benefits of living in a cleaner environment as a result of reduced pesticide use. The organic farmers felt that their human and social capitals increased due to the knowledge and skills acquired through their involvement in organic farmers' associations while Bt and conventional farmers perceived no change. The analysis on sustainability level of these production systems were done using thirteen major sustainability indicators. Majority of the Bt cotton farms were found to be high with the indicators viz., production efficiency, net return, cultivated land utilization index and technology use level. Most of the organic farms were found to be significantly high with the indicators viz., low cost technology use level, employment generation capacity, farm family employment level, self reliant level, cultivated land utilization index, eco-friendly technology use level, organic recycling level, low external input use level, soil health and self sufficiency level. The cultivated land utilization index and technology use level were observed to be high with conventional cotton farms.

4.18 : Cotton Information System

Coimbatore

Indian Cotton Portal

The main purpose of the cotton portal is to bring cotton information especially Indian cotton scenario under single window system. In the present emerging trend and advancement in Information and Communication Technology especially dissemination of information, the only mass media which catch large population without any boundaries is the internet. CICR has identified the importance of this useful tool well in advance and made significant contribution for the dissemination of timely, systematic and reliable cotton production and protection technologies to the stake holders.

CICR website has been in the web of internet from 2001 onwards. In the initial phase it has some 40-50 pages site now in the year 2010-11, the cotton portal has more than 1000 pages and as much number of images covering cotton cultivation on various aspects. The cotton portal has two main sites and two sub-domains to cater the need of different stake holders. The main site www.cicr.org.in has information pertaining to National Cotton scenario, which has two sub domains viz., a)www.tmc.cicr.org.in b) www.aiccip.cicr.org.in.Recently,we have floated an exclusive sitewww.kvknagpur.org.in for the cotton farmers the contents exclusively supplied by KVK, Nagpur - the unit under CICR, Nagpur. All the sites under Indian Cotton Portal have been periodically updated with latest information and the obsolete information has been periodically reviewed and removed from the portal.

Decision support system for cotton cultivars selection

Many cotton cultivars were released over the years based on field trials but successful only in some locations or agro-climatic conditions and not so in all locations. Though the genotype underwent rigorous test procedures, recommendation/decision made for release of genotype for commercial cultivation is based on few attributes. Many a times the judgment for selection of particular genotype for specific agro climatic condition is cumbersome with complex attribute datasets. An ideal statistical tool, "Multi Criteria Decision Analysis" usually involves selection of a number of alternatives to achieve an overall result based on the suitability of those alternatives against a set of criteria. The criteria will normally be weighted in terms of their importance to the decision maker, since criteria are rarely of equal importance. With the use of this tool an attempt has been made to develop Decision Support System for selection of suitable genotype for the specific agro climatic conditions.

4.19: Seasonal Dynamics of Insect Pests and Diseases

Nagpur

Seasonal dynamics of insect pests and diseases

Field dynamics of mealybugs and mirids

Field dynamics of mealybug *Phenacoccus solenopsis* was studied in 3 cotton cropping systems. Field dynamics of mealybug *Paracoccus marginatus* and *Creontiades biseratense* have been studied in cotton + pulses –maize cotton cropping systems while population dynamics of *Campylomma livida* was studied in Cotton + pigeon pea –fallow cropping system of India. Both per cent infestation and per cent incidence of *P. solenopsis* was negligible in the current year. *P. solenopsis* population on cotton and weeds was observed in traces. A few plant infested with *Nipaecoccus viridis* was observed in later part of season. Overall, during the season mealybugs have not attained pest status.

Cropping system based Population dynamics in Cotton + Pigeon pea – Fallow cropping system

Mirid *Campylomma livida*

Population dynamics for mirid *Campylomma livida* was studied at different locations i.e. research station (RS) and five farmers' fields as cotton adjacent to vegetables of Malvaceae and Solanaceae (FF1), adjacent to water canal (FF2), intercropped with citrus and adjacent to fallow land (FF3), adjacent to weedy road (FF4) and adjacent to soybean and sorghum (FF5) with same cultivar and sowing pattern. Unprotected cotton was grown under rainfed condition whereas farmers' fields had three protective irrigations. Three sprays of NSKE, Thiomethoxam and Imidacloprid at the recommended doses were applied at 60, 75 and 90 DAS on FF1 and FF2 against leaf hoppers, whitefly and thrips. Three sprays of Thiamethoxam, Imidacloprid and Thiomethoxam were applied at 50, 65 and 80 DAS against sucking pests and bollworms on FF3. Two sprays at 60 and 90 DAS were applied at FF5 while only single spray of Imidacloprid was applied by farmer in FF4. Weekly observations were recorded with respect to nymph and adult count of mirids along with their damage to squares and bolls.

The total mirid counts were non significant between treatments. The highest population was recorded during 37thSW (6.16 per plant) in FF3 (cotton intercropped with citrus) with four sprays followed by FF2 (cotton adjacent to water canal). The mean population during the season was maximum in unprotected RS field (1.61 per plant) and minimum (1.08 per plant) in FF5 (cotton surrounded by soybean and sorghum).

Leaf hopper *Amarasca devastans*

The total leaf hopper population (Nymph + Adult) was significantly higher in RS (unprotected) and FF1 (cotton adjacent to vegetables of solanaceae and malvaceae) with mean leaf hopper population of 2.05 and 1.95 per 3 leaves respectively and was at par with FF2, FF4 and FF5. The minimum total leaf hopper count (0.90 per 3 leaves) was recorded in FF3 (cotton intercropped with citrus) with 4 sprays. The population increased from 33rd SW to 37th SW and later on 40 to 42nd SW in all the experimental fields. (Fig.16)

Cropping system based population dynamics of mirid, leaf hopper and natural enemies under protected and unprotected conditions

The pooled data of two protected fields (FF1 and FF2) with three applications of insecticides as against unprotected (RS) location revealed non-significant higher population of mirids nymph and total mirids and significantly higher spiders under unprotected condition. Leaf hopper nymphs, adults and total leaf hoppers were higher in unprotected condition with significantly higher coccinellid population. Per cent damage to squares, green bolls and total fruiting bodies was significantly more in protected condition (Table 17).

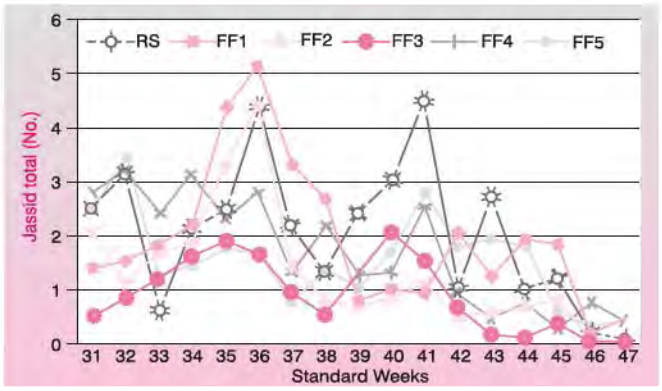


Fig.16: Population dynamics of total leaf hopper over the season in different cropping systems

Sampling methodology for assessing field population of cotton infesting mirid *Campylomma livida* reuter (hemiptera: miridae)

An experiment on the sampling methodology for assessing field population of cotton infesting mirid *Campylomma livida* Reuter (hemiptera: miridae) was carried out on genotype Bunny Bt BG II by taking eight sampling portions *viz*. terminals of branches, top one-third plant canopy, middle one-third plant canopy, bottom one-third plant canopy, fruiting bodies like squares, flowers and bolls separately and whole plants. Observations were recorded from randomly selected 5, 10, 15, 20 and 25 plants in an acre (4000 square meter) area. The pooled data (of two years 2009-10 and 2010-11) indicated counting nymphal and adult population together from top-one third plant canopy with sample size of 15 plants per acre was desirable.

Biology of *P. solenopsis* at low constant temperatures

Biology of *P. solenopsis* was studied at constant temperature of 20 and 35°C. Average fecundity was maximum at 20°C (335) while it was drastically reduced at 35°C (173). Reduced viviparity, fecundity, duration of effective reproduction (Days) and total reproduction period (Days) was seen at 35°C than 20°C. (Fig. 17).

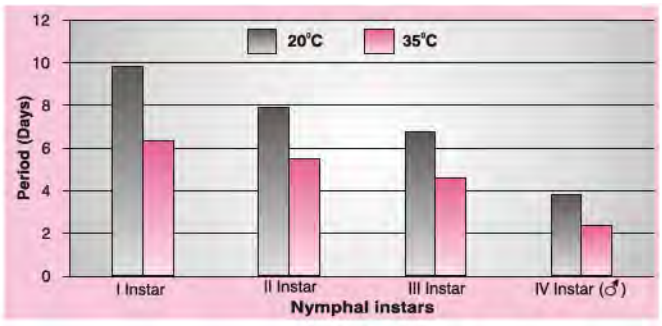


Fig. 17: Nymphal development period of *P. solenopsis* at 20 and 35 °C temperatures

Table 17: Population dynamics of mirid, leaf hopper and natural enemies under protected and unprotected conditions

S.No.	Particulars	RS (Unprotected)	Protected farmers' field	P(T<=t) two-tail
1	Mirid Nymph / plant	1.14	0.84	0.251
2	Mirid Adults/ plant	0.47	0.52	0.025*
3	Total Mirids/ plant	1.61	1.36	0.121
4	Leaf hopper Nymphs / 3 leaves	1.31	0.92	0.242
5	Leaf hopper Adults / 3 leaves	0.74	0.69	0.024*
6	Total Leaf hoppers / 3 leaves	2.05	1.61	0.080
7	Leaf hopper Grade	1.78	1.87	NA
8	Spider / plant	0.80	0.63	0.012**
9	Coccinellids / plant	0.25	0.18	0.378**
10	Total Squares / plant	11.02	14.71	0.004**
11	Per cent square damage	3.15	4.88	0.003
12	Total flowers / plant	0.66	0.81	0.027**
13	Total Green bolls / plant	7.84	18.13	0.0004**
14	Beaked green bolls due to mirids / plant	0.15	0.50	0.001*
15	Total fruiting bodies / plant	19.52	33.65	0.682
16	Per cent damage to fruiting bodies	2.33	3.47	0.022*

Biology of Leaf hopper *Amrasca devastans* at room temperature under laboratory condition

Biology of cotton leaf hopper *Amrasca devastans* was studied at room temperature. Eggs were not located as the pair of male and female adults placed on fresh cotton leaves did not mate. However fresh cotton leaves from fields with slits on their veins resulted into 1st instar nymphs. The nymhal period of instar I ranged 2-4 days with average 2.58 days. Instars II , III and IV were in the range of 1-5, 1-3 and 1-4 with average period of 2.14, 2.03 and 1.84 respectively. The total nymphal period was 8.59 days which was less than the adult period of 13.37 days. Adult period was 37% more than nymphal period. The total life cycle in terms of male and female is 21.38 and 23.19 days respectively. Female survived longer than males. The per cent mortality was highest among I instar nymphs and it was 16% followed by instar II (7.14%), adults (5.41%) and instar III.


Female


Male

Population of bollworms and *Spodoptera*

Pheromone trap moth catches for three bollworms *viz*. *Earias vitella*, *Helicoverpa armigera*, *Pectinophora gossypiella* and leaf eating caterpillar *Spodoptera litura* for two successive years revealed that moth catches reduced during 2010-11. *Helicoverpa* and PBW moth catches reduced by approximately 50% during 2010-11 as compared to 2009-10.

Pest incidence in HDPS

The mean leaf hopper nymph population was maximum on CCH-724 with spacing of 60 x 30 cm (2.80 nymphs /3 leaves/plant) followed by CNH-120 MB with spacing of 45 x 20 cm (2.54 nymphs /3 leaves/plant). The incidence on these genotypes were statistically on par but significantly different from other genotypes. The injury grade was III and II on CCH-724 and CNH-120 MB.The minimum mean population of leafhopper was on NISC-50 (1.82 Nymphs /3 leaves/ plant) with spacing of 45 x 13.5 cm followed by PKV-081 (1.91 Nymphs /3 leaves/ plant) with spacing of 45 x 13.5 cm and the genotypes were significantly superior over the others. The injury grade was I on both NISC-50 and PKV-081. PKV 081 at 30 x 20 cm spacing harboured significantly lower jassid nymphs at 75 DAS as compared to other genotypes at different spacing. (Table 18).

Table 18: Mean incidence of Jassids under HDPS (*hirsutum*)

Genotypes	Number of Jassids /3 leaves/plant					
	Spacings					
	60x30 cm	45x20 cm	45x13.5 cm	30x30 cm	30x20 cm	Mean (G)
LPK-516	2.10 (1.43)	2.32 (1.51)	2.62 (1.51)	1.87 (1.36)	1.82 (1.34)	2.15 (1.45)^{b}
CNH-120 MB	2.98 (1.73)	2.87 (1.67)	1.82 (1.67)	2.44 (1.56)	2.58 (1.60)	2.54 (1.58)^{c}
PKV 081	2.72 (1.61)	1.97 (1.39)	1.37 (1.39)	1.88 (1.37)	1.62 (1.27)	1.91 (1.36)^{ab}
NISC-50	1.74 (1.31)	1.92 (1.38)	1.76 (1.38)	2.08 (1.43)	1.58 (1.25)	1.82 (1.33)^{a}
CCH-724	3.13 (1.76)	2.97 (1.71)	2.30 (1.71)	3.35 (1.82)	2.25 (1.49)	2.80 (1.67)^{c}
Mean (S)	2.53 (1.57)^{c}	2.41 (1.53)^{c}	1.97 (1.39)^{a}	2.32 (1.51)^{abc}	1.97 (1.39)^{ab}	
	Spacing (S)		**Genotype (G)**		**Interaction (SxG)**	
SEm	0.06		0.06		0.30	
CD (P=0.05)	0.13		0.11		NS	

The data showed that spiders webs were maximum on CNH-120 MB with 8.91 webs /plot) followed by LPK-516 (8.87 webs /plot) and were superior to other genotypes but were statistically on par at each other The spider webs at spacing 30 x 15 cm (11.8 webs /plot) was maximum (Table 19).

Table 19: No. of spider webs under HDPS (*hirsutum*)

Treatments	60x15 cm	45x13.5 cm	45x10 cm	30x20 cm	30x15 cm	Mean (G)
LPK-516	4.00 (1.93)	6.67 (2.51)	6.67 (2.63)	12.67 (3.47)	14.33 (3.78)	8.87 (2.87)^{ab}
CNH-120 MB	5.55 (2.12)	6.67 (2.64)	11.00 (3.31)	10.00 (3.21)	11.33 (3.41)	8.91 (2.94)^{b}
PKV 081	2.67 (1.65)	5.67 (2.33)	5.00 (2.35)	4.67 (2.25)	13.00 (3.39)	6.20 (2.40)^{a}
NISC-50	3.33 (1.95)	6.33 (2.46)	13.67 (3.64)	11.33 (3.38)	8.67 (3.01)	8.67 (2.89)^{ab}
CCH-724	4.33 (2.16)	9.33 (3.08)	6.67 (2.58)	5.00 (2.26)	11.67 (3.47)	7.39 (2.71)^{ab}
Mean (S)	3.98 (1.96)^{a}	6.93 (2.61)^{ab}	8.60 (2.90)^{bc}	8.73 (2.91)^{bc}	11.8 (3.41)^{c}	
	Spacing (S)		**Genotype (G)**		**Interaction (SxG)**	
SEm	0.30		0.26		1.39	
CD (P=0.05)	0.68		0.53		NS	

Incidence of diseases

HDPS

In *hirsutum* cotton the incidence of *Rhizoctonia* was observed in all cultivars up to plant age of 50-60 days. Highest incidence of Alternaria was observed at plant age of 110 days. The incidence of *Myrothecium* was observed in all the genotypes at the early stage of crop growth but no significant loss was observed in any of the genotype. Grey mildew appeared in the later stage of plant growth. The first appearance was observed in the first week of September and continued up to 130 days. Significant foliar damage was observed by bacterial blight infection in *hirsutum* cotton. The incidence and severity of BLB were highly correlated (r=0.901) in case of the highly susceptible cultivar PKV-081. NISC-50 was found to be resistant against most of the pathogens. As per the incidence and severity of diseases spacing of 45 x 20 cm was superior to 30 x 30 cm.

BLB infected seedling

Myrothecium leaf spot in cotton

Myrothecium infected boll

Coimbatore

Seasonal dynamics of emerging pests and their predators in cotton in Tirupur district, Tamil Nadu

Mealybug, mirid bug and their predators were observed from 40th to 52nd standard week at weekly interval in 25 farmers' fields of five villages and in each village; five representative farmers' fields were considered. The villages are Adivalli, A. Nagoor, Virugalpatti, Virugalpatti Pudur and Raavanapuram in Tirupur district. The results revealed that the mean infestation of mealybug ranged from 32.11 to 40.66 % and the intensity of damage ranged from 1.00 to 1.06 grade. The mean infestation of mirid bug ranged from 18.16 to 27.68 % and the nymphal population ranged from 9.08 to 13.84 per 50 squares. The predominant predators were coccinellids and spiders. The former ranged from 12.22 to 16.56 and the latter ranged from 23.66 to 29.44 per 50 plants. (Table 20)

Table 20 : Seasonal dynamics of emerging pests and predators in cotton in Tirupur district

Villages	Mealybug			Mirid bug		Predators / 50 plants	
	Infested plants%	Intensity of infested plants (Grade)	No. of grade 4 plants	Infested squares %	Nymphs / 50 squares	Coccinellid	Spiders
Adivalli	37.78	1.04	-	21.36	10.68	16.56	29.44
A. Nagoor	33.67	1.00	-	18.16	9.08	14.67	25.89
Virugalpatti	32.11	1.06	-	24.60	12.30	12.22	25.44
Virugalpatti Pudur	35.22	1.00	-	18.32	9.16	13.78	25.78
Raavanapuram	40.66	1.04	-	27.68	13.84	14.35	23.66
Mean	35.89	1.03		22.02	11.01	14.32	26.04

Hybrids: NCHB 9902, MRC 6918, Ankur HB 1976; Variety : LRA 5166.

Population dynamics of Mirid bug (*Creontiades biseratense*)

Mirid bug nymphs and adults were recorded from October second fortnight to January first fortnight under cotton with pulses cropping system. Significantly minimum and maximum population of nymphs and adults were recorded during last week of November and second week of January respectively. Nymphal population was positively correlated with maximum temperature, sunshine hours, wind speed and negatively correlated with minimum temperature, RH, rainfall and rainy days. Adult population was negatively correlated with maximum and minimum of temperature and RH, rainfall and rainy days and positively correlated with sunshine hours and wind speed.

Monitoring of adult population of *P. gossypiella* through pheromone trap catch

Pheromone trap catches of *P. gossypiella* was recorded from 9.12.2010 to 28.2.2011. Average adult catch per trap per night was maximum during the last week of January (165.75/trap) and the larval population recovered from the bolls in that particular field was maximum during this period only in two non Bt hybrids of RCH 2 NBT (19.75/5 bolls) and Bunny NBT (16.75/5 bolls) (Fig.18).

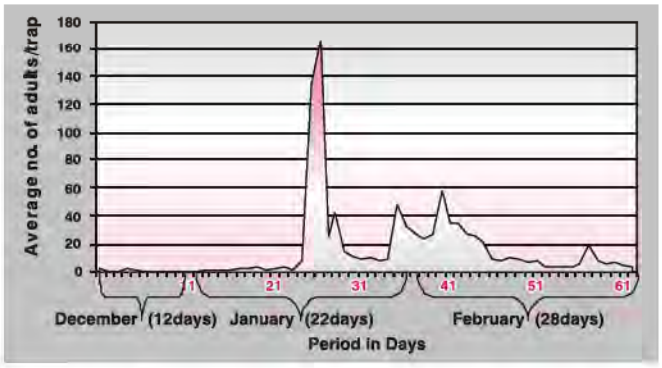


Fig. 18: Adult trap catch of *Pectinophora gossypiella* through pheromone trap

Sirsa

The surrounding weed flora played an important role in initial infestation. At location I (Modawali,), II (Fatehpuria), III (Peer khera), IV (Karamgarh) and V (Khuyia Nepalpur), mean per cent infested plants recorded were 20.31, 0.0, 20.69, 0.0 and 9.5 with 1.27, 0.0, 1.23, 0.0 and 1.28 intensity of infested plants, respectively. No infested plant with 4^{th} – grade severity was recorded. The year wise incidence of mealybug recorded across the five locations during 2008, 2009 and 2010 was 38.58 %, 15.90 % and 10.50 %, respectively with intensity of 1.54, 1.32 and 0.88.

Alternate Hosts

Weed species, *Kanghi buti*, *Xanthium* and *Parthenium sp* were found to be the major starter host for the onset of infestation on cotton season while congress grass harbored severe infestation even up to the end of cotton season in the North Zone cotton-wheat cropping system.

Parasitisation of cotton mealybug

The maximum parasitization due to the dominant parasitoid, *A. bambawalei* was 33.10 (25 SMW), 29.73(42 SMW), 48.65(27SMW) and 41.11(27SMW) per cent on-farm, location-I, location-II and location-III, respectively during 2010. Whereas mean per cent parasitisation recorded was 19.50, 17.18, 22.20 and 19.89 on- farm, location I, location II and location III, respectively.

4.20 : Biological Diversity of Insect Pests and Pathogens

Nagpur

Leaf hopper populations from cotton growing regions of India were collected as nymphs from the 2007 season onwards. Genetic diversity studies were carried out using COI, NADH1 and COII region specific primers in PCR at annealing temperatures of 60°C, 50.8°C and 60°C, respectively. Twenty five haplotypes with reference to the COI region, 4 haplotypes with reference to the COII region and 14 haplotypes with reference to the NADH 1 region were recognised. The overall transition/transversion bias was R = 6.448, R= 0 and R= 25.71 with the NADH, COII and COI regions. The North Indian and Gujarat jassid populations formed a group different from that of the South and Central Indian jassid populations when the CO1 sequnces were compared using MEGA 4 (Fig.19). Differences in the toxicity of neonicotinoids to jassid populations of Central and South India as compared to populations from North India (inferred from a study under the TMC MM1) could be attributed to these genetic differences apart from other factors such as intensity of insecticide use.

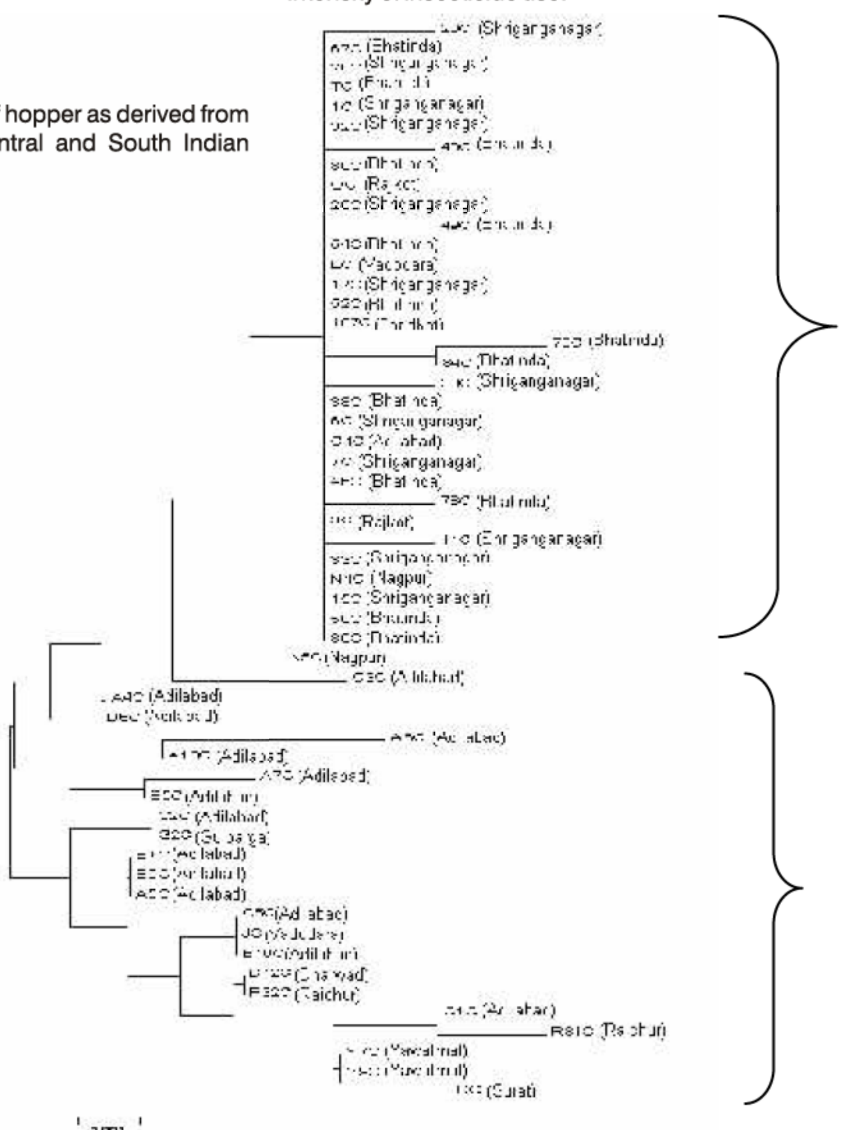


Fig. 19 : Genetic diversity of cotton leaf hopper as derived from the mt COI sequences of North Central and South Indian populations

Nineteen isolates were made from *Alternaria* infected leaf samples of *G. hirsutum* collected from different cotton growing areas of India. Three different species of *Alternaria* were isolated. Out of these, 10 isolates were belonged to Alternaria macrospora, 5 isolates to *A. alternata* and 4 isolates to *A. gossypina*. Distinct variation in sporulation, growth pattern and pigmentation was observed. The spore of *A. macrospora* were bigger in size ranged from 15-20 x 60-80 μ, where as spore of *A. alternata* and *A. gossypina* were smaller in size and ranged from 9.18 x 20-63 μ and 30-35 x 12-15 μ, respectively.

Out of 74 samples of *Alternaria* infected leaves analysed for the frequency distribution of various types of species spores 32.33, 30.33 and 37.43 per cent belonged to *A. macrospora , A. alternata* and *A. gossypina*, respectively.

All the three species of *Alternaria* spores were observed in 75.68 per cent samples analysed. However the spores of *A. macrospora* with *A. alternata* in 6.76% samples, *A. macrospora* with *A. gossypina* in 12.16% and *A. alternata* with *A. gossypina* in 1.35 % of the total samples. While 2.70 per cent and 1.35 per cent spores of *A. macrospora* and *A. alternata* were observed alone, no spore of *A. gossypina* was recorded alone.

Genetic diversity in cotton leaf curl virus

The incidence of disease was highest in Rajasthan (70%) followed by Haryana (36%) and Punjab (28%), Sriganganagar remained the hotspot. Substantial genetic variations exist among different strains of CLCuV collected from North Indian cotton growing belt and there is no relation between genetic diversity (with reference to βDNA variations) and geographical distribution (Fig. 20).

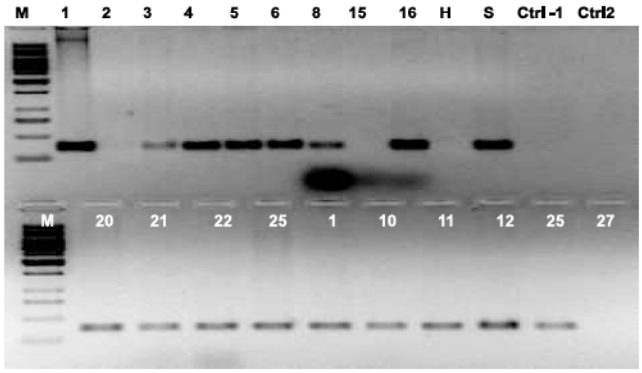


Fig. 20 : Detection of CLCuV in cotton using βDNA specific primers (1= H1098, 2= RCH-134, 3= HS-6, 4= Ganga nagar Agati, 5= KCH 707, 6= unknown hybrid line, 8=Bt farmer's field, 10=unknown-Chormar, 11= Bt unknown, Chormar, 15= NBT lines from RAU SGN,16= Bihani-61, H=NBT HAU, 20=6488 Bt, 21=farmer's field and 22 = Bt 6488, 25= Bt unknown, Bhasu, Punjab and 27 =MR3 6317, Kamgarh, Punjab respectively).

First report of Cotton leaf roll dwarf virus in India

For the first time the cotton leaf roll dwarf virus (CLRDV) has been identified by RT-PCR analysis with coat protein gene specific primers and subsequently sequencing the RT-PCR product(Fig.21). The phylogeny with other RNA virus showed that it belongs to Luteovirideae family.

Loss appraisal of cotton due to grey mildew

Four Bt and non Bt hybrids each, were evaluated for the loss appraisal of grey mildew disease of cotton under protected and inoculated conditions. The higher incidences of 37.09 and

Fig. 21: Detection of Luteovirus in cotton using RT-PCR (L= DNA ladder1= Control, 2=RCH-2-1, 3= RCH2-2, 4=RCH2-Bt, 5=JKCH 99Bt, 6=RCH2 NBT, 7=JKCH 99NBt-1, 8= JKCH 99Bt-2, 9=Jai NBT, 10=RCH2-3.

36.19 per cent grey mildew responsible for the maximum loss of 15.17 and 14.36 per cent in hybrid Jai Bt. and Ganga kaweri Bt. under unprotected condition, respectively. This was followed by Bunny BG II and Bunny Bt. with an average loss of 12.43 and 12.72%. However minimum loss of 7.97 and 10.36% was recorded in H-10 and NHH-44 with the lowest incidence of 28.14% respectively. Early senescence in Bt hybrid could be one of the resons for the higher loss of seed cotton yield due to grey mildew.

Coimbatore

Survival strategy for reniform nematode in soil

Survival of nematode in desiccated, moist and host free soil was studied under field condition. Maximum survival per cent was recorded in moist soil. At fortnightly intervals nematodes were extracted from soil and inoculated on to cotton roots to check their infectivity. Infectivity was reduced with increase in duration. In the absence of main crop, cotton survival of nematode in weeds were noticed. This clearly indicated the role of weeds as an alternate host to reniform nematode under field condition.

Standardisation of protocol for the identification of nematode infection in cotton under farmers field condition

A protocol by using Indian ink for the identification of nematode infection in cotton under farmer's field was standardized. Soaking roots in water (two minutes) with few drops of Indian ink resulted in the absorption of dye by egg masses of reniform nematode that would show up as small dots on roots which can be easily identified. This method can be easily demonstrated under farmers field condition as Indian ink is cheap.

Disease incidence

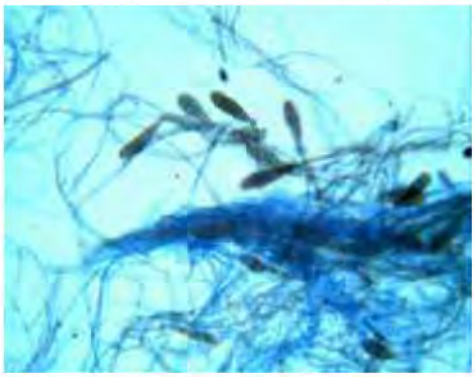
Observations were carried out at monthly intervals for leaf spot incidence in germplasm collections of 123 *barbadense* lines. Incidence of grey mildew was negligible. Bacterial leaf blight was not observed in these entries. Per cent disease incidence of leaf spot ranged from 0 to 38%. Thirty four entries (out of 123), mostly NDGB lines (29 nos.) were found free of foliar symptoms. Maximum disease incidence of 38% was observed in one of the EC lines, EC 617855.

Isolation of pathogenic fungi and bioagents

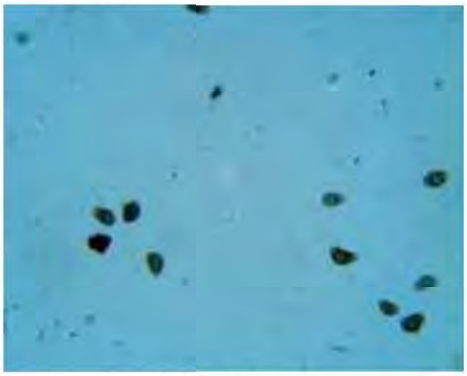
Infected leaves were collected from diseased cotton varieties/lines showing leaf spot symptoms and isolations made on potato dextrose agar medium. *Alternaria* sp., *Fusarium* sp. and *Rhizoctonia* sp. were isolated.

Ten isolates of *Alternaria* spp., four isolates of *Drechslera spp*., three isolates of *Fusarium sp*., two isolates of *Colletotrichum* sp., and five isolates of Curvularia sp. were obtained. One of

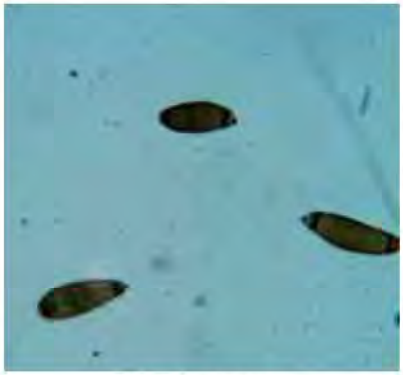
the *Fusarium* sp. isolate was from wilt affected plant sample received from TNAU. Isolations from leaf spot affected Bunny BG yielded *Alternaria* sp. alone. Two isolates of *Trichoderma spp*. and an isolate of *Pseudomonas* sp. were isolated from soil samples of CICR.



Alternaria sp.



Curvularia sp.



Drechslera sp.

Sirsa

A new species of mealybug i.e *Droschia spp*. was recorded in few plants of Jai Non Bt.

One parasitoid was recovered from the north zone pink bollworm collection and was identified at Entomology Division, IARI, New Delhi as *Brachymeria lasus* (Hymenoptera: Chalcididae)

Spodoptera exigua- After *Spodoptera litura*, *Spodoptera exigua* has also been reported from Bt cotton fields. Its damage to Bt cotton foliage was noticed but in BG-II, though it was observed but without any damage

Mealybug , Droschia spp

Spodoptera exigua

4.21: Isolation and Identification of New Genes and Gene Sources for Pest Management

Nagpur

Identification of species specific miRNA or siRNA in cotton insect pests for pest management through RNAi based technologies.

Cotton bollworms tolerate gossypol using a cytochrome p450 enzyme that was identified as cyp6AE14 in the American bollworm, *Helicoverpa armigera* and the pink bollworm, *pectinophora gossypiella*. Primers specific for *Helicoverpa cyp6AE14* were designed and the PCR product was cloned into TA vector to be mobilized into *E.coli* DH5a cells. The plasmid was digested with restriction enzymes EcoRI and SalI. Similarly the PSV2 vector was also digested. The two were ligated and the recombinant plasmid was used for *in-vitro* transcription (dsRNA). Primers containing T7primer binding site were designed for the amplification of dsRNA. The PCR product using this set of primer could be directly used for *in-vitro* transcription. Bioassays with *H. armigera* were performed using 5µg dsRNA/ml of artificial diet in diets containing gossypol at a concentration of 2mg/g of diet.

Identification of new gene products toxic to insects

Evidence was provided that the Ahmedabad strain toxic to *H. armigera* putatively belonged to the *cry2A* class of Bt. AP1 and AO1 are standard strains for *cry9*. The Ahmedabad strain does not contain the *cry9* gene as seen in Fig.22. HD1 is a standard strain for *cry2A* and *cry1* class of Bt genes. The Ahmedabad strain putatively contains the *cry2A* class of Bt genes and does not carry Bt genes of the *cry1* class (Fig.23a and 23b) In addition, native Bt strains from soil samples of Jalna, Barrackpore and Pasighat were tested for their toxicity against *H. armigera* and strains from Jalna, belonging to the *cry2A* class, demonstrated a growth regulating effect against 2 day old *H. armigera*, while it was lethal to *Spodoptera litura*.

Cloning and characterization of potent toxin gene from heat tolerant isolate developed of EPN, *Heterorhabditis indica*

For molecular characterization of bacterial symbiont associated with heat tolerant entomopathogenic nematode,

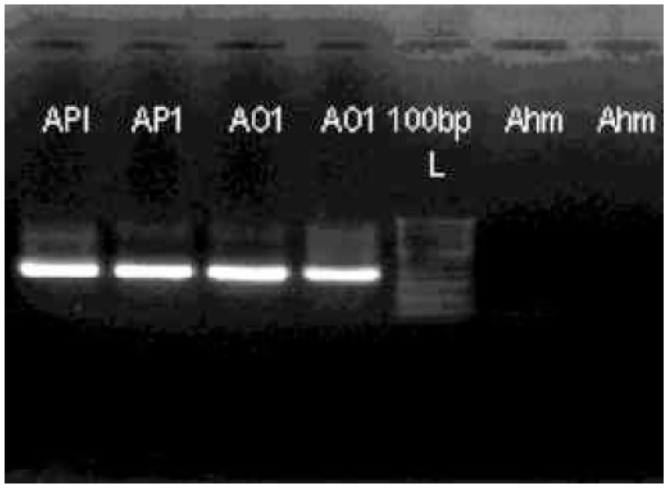


Fig. 22 : PCR amplicons generated using *cry9* specific primers with native and standard Bt strains

Heterorhabditis indica, 16s ribosomal RNA was amplified using oligonuceotide primers (5'GGA GAG TTA GAT CTT GGC TC3' and 5'AAg GAG GTG ATC CAG CCG CA3'). The sequence amplified was 1550 bp and has been cloned in pGEM-T vector for sequencing.

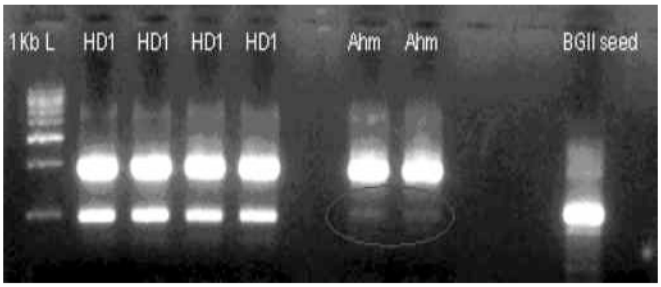


Fig. 23a : PCR amplicons generated using *cry2A* specific primers with native and standard Bt strains.

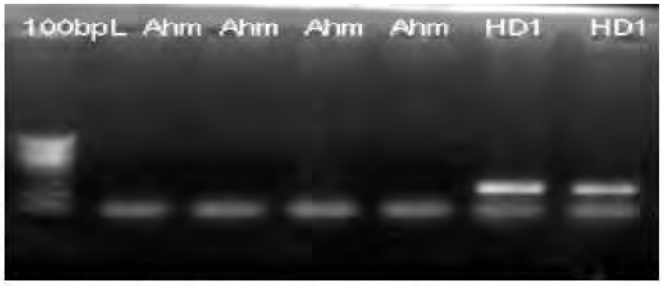


Fig. 23b : PCR amplicons generated using *cry1* specific primers with native and standard Bt strains.

Primers designed for amplification of toxin gene

F 5' TACC AATA TGTTAATTG TGGAC 3' R 5' CCA TCA TTTCAC ATA ACCG 3'	F TACTTGCTCA GACATTTCTCTATGG R TTATTTAATGGTGTAGCG
F 5' TTCG AATA CCAA TATG TTAA TTGT GGAC 3' R 5' CCA TCA TTTCAC ATA ACCG 3'	F 5-ACCATACGCATCGGACAAAC-3 R 5_-CGTAGCGGTTATTCACTCTTCT-3
F 5' ATTACCAATATGT TAATTGTGG 3' R 5' TCATCATATATTTTATAATG	F 5-GGTCTAGAATGTAAAGGC-3_) R 5_-GGAAGGACGGAAAGT
F 5' GGTCTAGAATGTAAAGGCAACAC-3') R 5'-GGAAGGACGGAAAGTGGAGA-3'	F 5'TACCACTGACAATACGTTTAT 3' R 5'CGGTTACTGACGATTGCTG
F (5'-ACCATACGCATCGGACAAAC-3') R 5'-CGTAGCGGTTATTCACTCTTCT-3'	F 5' TCATGAAATACGTCCTAAGTGG 3' R 5' AAA TATGT AAAACTATGGG GTTC
F GCTAACACTCAGCGATGG R CCTAATGTGACCCCTACG	F 5' ACCTTAACTAATACAGACTTAG' R 5' AA AGAAAAGAAATTTACGCGTG
F TCAGACTGATGCCAAAGG R CCATCAATAGTTCCTGCC	F 5' TGTAGTTACAAGAAAGAACC R 5' ATGTCTAAATACAAATTAAACC
F5' TACTTAGTTGAGCGGTCAGG R 5' GCCATGCTCAGTTACTGC	F5' CTTATACTATACTCAGGCAG R 5' ATTGCAAGATATTAATTACAAAG

Insecticidal toxin genes Tcc2, TcdA, TcdB, TcdAb and TcdA2 amplified using primer pairs designed (Fig. 24a). The amplicon size ranged between 750-1000bp. These were also cloned and sequenced.

Toxin amplicons of D6TcdA2, GI TcdB and G5 TcdA2 were cloned. Positive clones were confirmed using colony PCR followed by EcoRI digestion of isolated plasmid (Fig.24b). The sequences had 95% similarity with *Photorhabdus* toxins having oral and intrahaemocoleic toxicity.

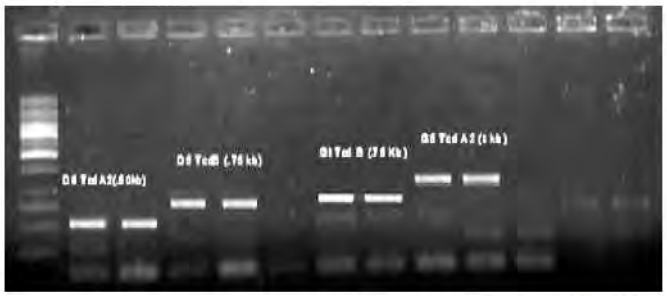


Fig. 24a

E16S GI (1.5kb) GI TcdB(.75kb)

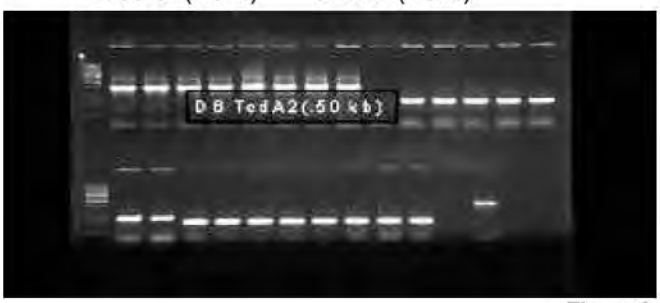


Fig. 24b

Fig. 24 a & b: PCR amplicons of insecticidal toxin genes

4.22 : Development of New Methods, Tools and Protocols

Development of stochastic model to assess bollworm resistance development for dual gene Bt transgenic plants

Development of insect resistance to Bt cotton can significantly diminish the returns and benefits that are currently being derived from the technology. Considering the widespread use of Bt-cotton in India, it is very important to consider stringent implementation of IRM strategies to mitigate the onset development of bollworm resistance to the *cry1Ac*, *cry1Ac+cry2Ab* and *cry1C* genes deployed. A stochastic model was developed to assess bollworm resistance development for dual gene Bt transgenic plants. Parameters on genetic, biology, ecology and other aspects, generated from CICR, were considered for modeling. Genetic studies of response of *H. armigera* to transgenic Bt-cotton showed that the effective dominance was also inherited as a semi-dominant trait. Studies on inheritance of *cry1Ac* resistance in *Helicoverpa armigera* showed that the values of estimates of dominance were found to range between 0.40 – 0.57. Resistance was found to be monogenic, autosomal and inherited as a semi-dominant trait. The initial frequency of resistant alleles was estimated from 2001-2010 using an F2 screen test on 180-225 isofemale lines of *H. armigera* each year. We detected up to eight *cry1Ac* resistance conferring alleles in one of the populations collected from central and south India. A Bayesian analysis of the data indicated that the frequency of resistance alleles was 0.0013 to 0.009 in India, with 95% probability, and a detection probability of >80%. The survival of *H. armigera* was correlated to the variable expression of *cry1Ac* in leaves and other fruiting structures. Increasing levels of *H. armigera* survival were correlated with the toxin levels decreasing below 1.8 µg/g in the plant parts. Genotype independent seasonal decline of the *cry1Ac* toxin levels was observed in all the hybrids. The data were integrated into algorithms to develop stochastic models to facilitate the development of IRM for Bt Cotton in India. Critical factors that have the greatest influence on resistance are identified through stochastic modeling and IRM strategies can be developed only based on these. Studies were conducted to understand the ecology, genetics, biology, and resistance risk of the cotton bollworm *Helicoverpa armigera* to *cry1Ac* and *cry2Ab*. The data were integrated in an algorithm to convert all the real-time data into a stochastic model called 'Bt-Adapt-II' for India that can be used to identify the most critical factors that influence resistance development and thus develop resistance management strategies.

The following equations were used in modeling resistance to *cry1Ac* and *cry2Ab*. The frequency of resistant allele (p) and the susceptible allele (q = 1–p) was designated as p_1 and q_1 for *cry1Ac* and p_2 and q_2 for *cry2Ab* respectively. The net increase in population density (X) is a function of fecundity (F), natural survival rate of eggs (α), natural survival rate of larvae (β), survival rate after insecticide exposure (λ) and survival rate after exposure to Bt-crop. Dominance of the resistant allele was represented by h_1 for *cry1Ac* and h_2 for *cry2Ab*. Values of h range between 0 for fully recessive and 1 for dominant. If R and S are alleles for resistance and susceptibility respectively, the survival rates of the three genotypes on the dual gene Bt crop (*cry1Ac+cry2Ab*) are defined as L_1 for RR (resistant homozygote) of *cry1Ac*; L_2 for RR (resistant homozygote) of *cry2Ab*; K_1 for SS (susceptible homozygote) of *cry1Ac*; K_2 for SS (susceptible homozygote) of *cry2Ab* and corresponding L, K or h values of *cry1Ac* or *cry2Ab* substituted in the equation Lh + (1–h)K for RS (heterozygote). The recursion equations for surviving insect density $Xi^{"'}$ on the i^{th} crop and resistant allele frequency of *cry1Ac* ($P_x^{"'}$) and *cry2Ab* ($P_y^{"'}$) after exposure to the dual gene Bt-crop (*cry1Ac+cry2Ab*) would be:

$$Xi^{"'} = \{L_1p_1^2L_2p_2^2 + 2L_1p_1^2[L_2h_2+K_2(1-h_2)]p_2q_2 + 2L_2p_2^2[L_1h_1+K_1(1-h_1)]p_1q_1 + 4[L_1h_1+K_1(1-h_1)]p_1q_1[L_2h_2+K_2(1-h_2)]p_2q_2 + L_1p_1^2K_2q_2^2 + K_1q_1^2L_2p_2^2 + 2K_2q_2^2[L_1h_1+K_1(1-h_1)]p_1q_1 + 2K_1q_1^2[L_2h_2+K_2(1-h_2)]p_2q_2 + K_1q_1^2K_2q_2^2\}XF\alpha\beta\lambda$$

$$P_x^{"'} = \{L_1p_1^2L_2p_2^2 + L_1p_1^2[L_2h_2+K_2(1-h_2)]p_2q_2 + L_2p_2^2[L_1h_1+K_1(1-h_1)]p_1q_1 + 2[L_1h_1+K_1(1-h_1)]p_1q_1[L_2h_2+K_2(1-h_2)]p_2q_2 + L_1p_1^2K_2q_2^2 + K_2q_2^2[L_1h_1+K_1(1-h_1)]p_1q_1\}XF\alpha\beta\lambda/Xi^{"'}$$

$$P_y^{"'} = \{L_1p_1^2L_2p_2^2 + L_1p_1^2[L_2h_2+K_2(1-h_2)]p_2q_2 + L_2p_2^2[L_1h_1+K_1(1-h_1)]p_1q_1 + 2[L_1h_1+K_1(1-h_1)]p_1q_1[L_2h_2+K_2(1-h_2)]p_2q_2 + K_1q_1^2L_2p_2^2 + K_1q_1^2[L_2h_2+K_2(1-h_2)]p_2q_2\}XF\alpha\beta\lambda/Xi^{"'}$$

All other equations were similar to the ones used in the stochastic model Bt-Adapt developed by Kranthi and Kranthi (2004) Current Science, Vol. 87, No. 8, 1096-1107.Stochastic model outputs indicated the need to initiate proactive insect resistance management (IRM) strategies in addition to the currently recommended 5-row non-Bt cotton refuge per acre of Bt-cotton, especially in some parts of the country with special focus in parts of Gujarat, AP and Maharashtra, in view of the subtle disturbances observed in the baseline in these regions. Using the 'Bt-Adapt' model it was inferred that one of the most important strategies in Bt resistance management would be to reduce the Bt cotton surviving population of *H. armigera* through any pest management practices. The extent of reduction in the surviving population, which represents resistant genotypes, would determine the longevity of the technology utilization. In light of the results and the output derived from 'Bt-Adapt-II', it is pertinent to develop resistance management strategies appropriate for Indian conditions either by conserving susceptibility by minimizing toxin exposure or getting rid of resistant RS and RR genotypes by using either high dose of the same toxin or by using other unrelated toxins. Practical IRM strategies appropriate for Indian conditions have been designed based on the model output.

Mass rearing of Pink bollworm (PBW) in the lab

PBW colony was established in the laboratory from field collections and its developmental biology was compared on two test diets in the F_2 generation.The monophasic diet was prepared using 100g of cotton seed flour of a pink bollworm susceptible genotype and larvae were reared from neonates till pupation on a single diet. The pink bollworm population was reared up to 3 generations on both diets and developmental parameters were compared. It was observed that larval and pupal weight as well as adult emergence was numerically more on monophasic diet as compared to biphasic diet.

The biphasic diet posed the following problems : non-availability of mature Bhendi with seeds, fungal growth around the seed within 3 days, non- uniform use of the same Bhendi genotype across labs especially for bioassays, malformed late instar larvae that were not seen with the use of monophasic diets.

Coimbatore

Evaluation of new formulation of Acephate 95 SG along with standard Acephate 75 SP and six standard insecticides against sucking pests of cotton

A field experiment was conducted to assess the effectiveness of a new formulation (Acephate 95% SG) of Acephate along with standard Acephate 75 SP and six standard insecticides (Imidacloprid 200SL, Acetamiprid 20SP, Thiomethoxam 25WG, Dimethoate 30EC, Triazophos 40EC, and Fipronil 5SC) used in cotton eco-system in a Randomized Block Design (RBD) with three replications. Imidacloprid, Acephate 75 SP (750 g), Acetamiprid, and Acephate 95% SG (562.5 g) were effective against leaf hopper and brought out a reduction of 53.2, 51.0, 37.2 and 35.0 % respectively. Aphids, mealybug and whitefly incidences were very low. There were no significant differences in reduction of predators (Coccinellid and Spiders) among the treatments. All the treatments increased the Seed cotton yield significantly by 9.6 to 20.1 % over control. However, Acephate 75 SP (750 g), Acephate 95 % SG (750 g) and Acephate 95% SG (562.5 g) recorded 25.0, 20.1 and 19.9 % higher yield over control.

Standardization of artificial rearing and screening techniques for bioassays against *P. gossypiella*

Cotton seed based artificial diet has been standardized for rearing pink bollworm *P. gossypiella*. The ingredients of the diet are easily available and cost effective. Basic ingredients of the diet are cotton seed flour (processed) and chick pea flour with carbohydrate, protein, fat sources, multi vitamin, anti microbial agents and agar as thickening agent are used as other ingredients. Micro centrifuge tubes of 1.5 or 2 ml size were used as rearing containers. Individual neonate larvae are released on each piece of the diet inside the tube and the lids are closed tightly. This prevented the larval escape and diet dehydration. The per cent recovery of the insect reared on diet is recorded as 95.56%. Egg hatchability, adult emergence is 100% and pupal malformation is nil. Egg, larval and pupal periods were recorded as 4.8 ± 0.632, 25.10 ± 0.994, and 7.9 ± 0.88 days, respectively. Larval and pupal weight were recorded as 21.40 ± 3.63, 18.00 ± 2.73 mg, respectively.

4.23: Host-Plant Resistance to Insect Pests and Diseases

Nagpur

Incidence of Pink bollworm larvae on Bt and non Bt cotton

The pink bollworm population was recorded at 15 days interval on three popular hybrids MRC-6301 Bt, MRC 7301 BG-II and AKH-8828 non Bt starting from 115 days after sowing during *kharif* 2010-2011. The MRC-6301 Bt and MRC-7301 BG II hybrids exhibited with zero larval population, nil exit holes and zero per cent locule damage throughout the crop growth period as compared to non Bt hybrid. The mines on epicarp were noticed on Bt hybrids from 145 DAS with 3.00/25 green bolls on MRC- 6301 and MRC-7301 BG II. The maximum larval population was noticed on AKH - 8828 non Bt hybrid with 23.00 larvae/25green bolls at 175 DAS. The minimum incidence of pink bollworm population was recorded on AKH -8828 non Bt with 1.00 larvae/25green bolls at 130 DAS.

Locule damage due to pink bollworm was noticed on cotton hybrids from 130 DAS and recorded up to 175 DAS.The maximum locule damage was recorded on AKH -8828 non Bt hybrid (29.00%) at 175 DAS but minimum incidence was noticed at 130 DAS (2.04%). Incidence of pink bollworm, was absent on Bt hybrids. Lowest moth catches were noticed on 14/10/2010 with 1.74 moth/trap/week. Maximum catches were recorded on 4/02/2011 with 14.58 moth/trap/week (Fig. 25).

Exit hole caused by PBW

Locule damage by PBW

Open locule damage by PBW

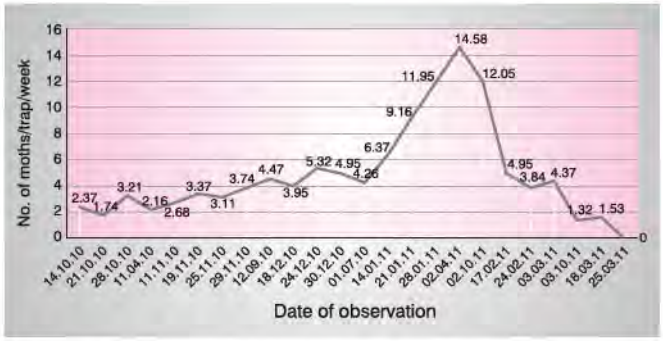


Fig. 25 : Pheromone trap catches of pink bollworm

RNAi mediated crop protection against root- knot nematode

Root-knot nematode genes especially genes that encode oesophageal gland proteins were taken up for their amenability to RNAi, synthesis of primers to amplify these parasitism genes and their sequencing and synthesis of dsRNA corresponding to these genes and testing dsRNA to see if these elicit RNAi *in vitro* using protocols available in the literature.

Root-knot nematode females, males and juveniles were extracted from infested cotton root and RNA extracted. Quality of RNA was confirmed and cDNA synthesized. Based on sequences of oesophegeal parasitism genes in data bases,

primers were synthesized for ten parasitism genes. dsRNA for these parasitism genes was synthesized using Ambion megascript kit. Evaluation of dsRNA for parasitism genes against reniform nematode was carried out *in vitro*.

Out of dsRNA synthesized for 10 parasitism genes, dsRNA for three genes Protein 40, Aminopepetidase and pectate lyase reduced reniform nematode penetration by 37-46%. Out of these two genes protein 40 and Aminopeptidase have also been found to reduce penetration of root-knot juveniles by 40 and 53% respectively. This indicates that the two genes Protein 40 and Aminipeptidase have potential for their use in RNAi mediated management of phytonematodes.

Partial reduction in root-knot nematode penetration and galling with RNA interference

Coimbatore

Resistance to insect pests in *Gossypium spp*.

Cultivar association with emerging pests in Bt Cotton hybrids released for South zone

Twenty eight Bt cotton hybrids (27 BG II & 1 BG I) were studied for their association to major sucking pests in unprotected field condition. The results revealed that, three cultures *viz*., MRC 7583 BG II, Akka BG II and Ankur 5642 BG II were tolerant to leaf hopper and they recorded leaf hopper injury grade of 1.0 and the population ranged from 4.26 to 5.20 per 3 leaves as against 2.30 grade and 13.61 leaf hoppers per plant in DCH32 (Check hybrid). These entries recorded significantly higher yield of 1645, 1611 & 1435 kg/ha as compared to check hybrid DCH 32 which recorded 1088 kg/ha. Three entries *viz*., SP 911 BG II, SP1037 BG II and Ankur 1976 were tolerant to mealybug and recorded 0.2 to 0.4 grade level of infestation and population range of 0.06 to 0.30 per plant as against 2.7 grade and 117.6 mealybugs per plant in the check hybrid MRC 7351 during the peak squaring phase. Aphid and mirid bug incidences were very low. The above mealybug tolerant entries recorded significantly higher yield of 2013, 1662 and 1546 kg/ha as against 1704 kg/ha in MRC 7351.

Screening of advanced genotypes (breeding materials) and germplasm accessions for their reaction to major pests and seed cotton yield

Fifty eight entries (47 advanced genotypes + 11 germplasm accessions) were screened under field condition for their reaction to leaf hopper, leaf roller and bollworms.

Seven *hirsutum* genotypes *viz*., CCH 809, CCH 815, LRA 5166, CCH 819, CCH 820 and CCH 825 were found tolerant to leaf hopper and recorded less than 1.0 grade injury as against 2.37 injury grade in the susceptible culture, ICGH 630.

Six entries *viz*., ICGH 341, 370, 410, 474, 480 and 630 were identified as tolerant to bollworms and recorded higher yield ranging from 71 to 111 g / plant as compared to check varieties – Suvin, LRA 5166, Suraj, Surabhi and MCU5VT which recorded seed cotton yield of 13, 32, 40, 31 and 28 g/plant respectively.

Twenty three entries *viz*., CCB 20, CCB 23, CCB 24, CCB 25, CCB 26, CCB 27, CCB 28, CCB 29, CCB 31, CCB 32, CCB 33, CCB 34, Suvin (C), CCB – 1-1, CCB 5, CCB 11, PIMA 121, SUDON 436, ICB 125, GSB 39, CCB 17, CCB 18 AND ICGH 370 were found free from leaf roller as against standard varieties LRA 5166, MCU5VT(C) and Suraj (C) which recorded 57.5, 60.0 and 67.5% infestation, respectively.

Leaf roller larvae

Leaf roller infested cotton plant

Monitoring for the occurrence of *P. gossypiella* on Bt hybrids and NBt hybrids

Three BG, BG II and NBt hybrids of RCH, MRC and Bunny were monitored for the occurrence of *P. gossypiella* during different stages of the crop gowth. Number of surviving larvae recorded on NBt hybrids were significantly higher as compared to the larvae present in the BG and BG II hybrids. Mean number of larvae/5 bolls were 0.36, 0.21, 0.93, 1.21, 0.21 and 0.32 in RCH 2, RCH 530 BG II, MRC-6918, MRC-7201 BG II, Bunny BG and Bunny BG II respectively. Though all the hybrids were on par with each other MRC 7201 BG II recorded numerically higher number of larvae than other hybrids. Mean number of dead larvae recorded was nil in NBt hybrids. However RCH2, RCH

530 BG II, MRC 7201 BG II and Bunny BG II were on par and recorded significantly higher number of dead larvae of 2.14, 2.32, 1.93 and 2.75/5 bolls respectively followed by MRC 6918 (1.04) and Bunny BG (0.82), respectively.

Sirsa

Determining cultivar association with emerging pests

A total of 132 hybrids released and approved for North Zone for 2010 were evaluated for their association with emerging and key pests. The hybrids were not significantly different with respect to jassid and thrips population but were significantly different for whitefly population. The mean incidence of leafhopper / 3 leaves on the basis of 6 fortnightly observations varied between 0.58 (MRC-7017) to 1.40 (MAXXCOT). The maximum population of whitefly on the basis of 6 fortnightly observations was recorded in case of Jai-Bt (9.63 whitefly/ 3 leaves), RCH-134BG-II (9.25 whitefly/ 3 leaves) and Jassi- BG-II (9.06 whitefly/ 3 leaves) where as the lowest population was recorded in case of MRC-6301 (4.81 whitefly/ 3 leaves) followed by Solar-77 (4.91 whitefly/3 leaves). Mean thrips population / 3 leaves based on 6 observations ranged between 5.48 (Solar-77) to 19.70 (Mist).

On the basis of 4 location data, the hybrids having good yield/potential, tolerance to sucking pests and CLCuD were recommended for sowing in North Zone. The hybrids identified MRC-7361, SP-7007, SP-7010, SWCH-4711, Bioseed-6488, PCH-877, Ankur-3028, Bioseed-6488 BG-II, Shakti-9, VBCH-1008 (Mist), MRC-6304, NCEH-31, JKCH-1, VBCH-1518 BG-II, VBCH-1534, RCH-605, NCH-855 BG-II, NCH-905, MRC-7017 BG-II, VICH-307, Bioseed-6317, Bioseed-2113, VICH-309 BG-II, MRC-7031, NCEH-6, Bioseed-6588 BG-II, MRCH-6025, RCH-569 BG-II, PCH-401 and Bioseed-6588.

Screening of breeding material 42 (301-342) entries of Br 02a lines and 33 entries (651-683) of Br 22 revealed that none of the lines was either highly resistant /susceptible to sucking pests.

4.24 : Identification of Germplasm Sources of Resistance to Insect Pests and Diseases

Nagpur

Screening of Germplasm Sources of Resistance to Insect pests

A total number of 3,610 of core collection, exotic collection of germplasm accessions of *G. hirsutum* and HDPS were screened under field condition for their reactions to insect pests on cotton. Out of the 462 are observed to be tolerant to sucking pests.

Identification of BLB and grey mildew resistant lines/cultures

The most virulent race 18 of *Xanthomonas axanopodis* pv. *malvacearum* and leaf infusion made from grey mildew infected leaves was used for spray inoculation of cultures and lines of *G. hirsutum* developed by utilizing resistant sources. The cultures / lines were evaluated for resistance against bacterial blight and grey mildew under field conditions.

Out of 14 cultures, seven cultures were observed to be resistant to bacterial blight and grey mildew. Two cultures exhibited the resistance to bacterial blight and moderately resistant reaction to grey mildew. Whereas, three cultures were resistant to bacterial blight but susceptible to grey mildew and two cultures were susceptible to bacterial blight and grey mildew. These cultivars were superior in plant quality parameter of 7.60 19.29 bolls/plant with an average yield of 13.20 -38.50 gm/plant.

Out of 76 lines of *G. hirsutum*, 18 lines exhibited the resistant reaction to bacterial blight and grey mildew under field condition. However, 28 lines were resistant to bacterial blight and 5 lines resistant to grey mildew. These lines have been identified for better plant quality parameters of 7 -30 bolls/plant with an average boll weight of 2.00 -3.50 gm/boll.

4.25 : Biological Control

Nagpur

Diversity of bioagents of mealybugs

Bioagents from diverse groups have been recorded against different species of mealybugs across India. Among them *Aenasius bambawalei* Hayat was found to be the prominent parasitoid present all over India throughout year with parasitization potential from 5-100 percent. Other parasitoids also recorded a parasitization ranging from 2-22 per cent. Beetle species such as *Cheilomenes sexmaculata*, *Rodolia funida*, *Scymnus*, *Nephus regularis*, etc. are present in different ecosystems, so indiscriminate use of insecticides can be avoided. In preliminary laboratory studies conducted at CICR, Nagpur, the predatory beetle, *Cryptolaemus montrouzieri* (Mulsant), which is a naturalized predator of mealybugs in India, was found to feed voraciously on *Phenococcus solenopsis*. This beetle can be released, prior to the cotton season, on weeds and perennial trees where mealybug colonies are found, and during the season on infested cotton plants. Bioagents recorded on different mealybugs are summarized as below (Table 21).

Identification of biocontrol agents for control of foliar diseases of cotton

Six bacterial isolates useful in controlling foliar pathogens of cotton have been identified using 16SrRNA sequences (Fig.26). Three belonged to *Pseudomonas aeruginosa*, two to *Bacillus subtilis* and one to *Ochrobactrum anthropii*.

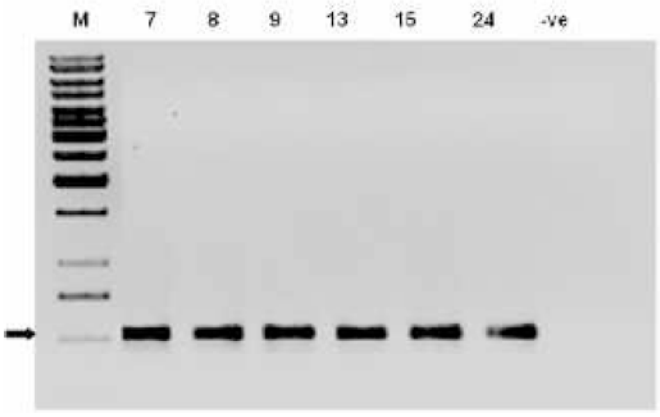


Fig. 26: PCR amplification of 16SrRNA of Bacterial isolates (7,8,9,13,15 & 24) and '–ve' control)

Evaluation of bacterial isolates for antifungal activity

The fast growing and virulent strain of Myrothecium leaf spot pathogen *Myrothecium roridum* was used as test pathogen for evaluating the efficacy of six native bacterial isolates isolated from the rhizosphere of cotton eco-system. The 24 hrs old culture of the bacterial isolates was used for evaluation by dual culture method in in vitro condition. The inhibition was

Table 21 : Diversity of bioagents of mealybugs and their distribution in India

Name of bioagents	Host mealybug	% parasitization	Distribution
Parasitoid			
Aenasius bambawalei Hayat	*P. solenopsis*	5-100	All over India
Metaphycus sp.	*P.solenopsis*	7-10	Central India
Aprostocetus bangaloricus Narendran	*P. solenopsis*	4-10	Central India
Encyrtus aurantii (Geoffroy)	*P. solenopsis*	2-9	Central India
Prochiloneurus pulchellus Silvestri*	*P. solenopsis*	5-10	Central India
Anagyrus dactylopii (Howard)	*P. solenopsis*	5-7	Central India
Anagyrus mirzai Agarwal and Alam	*P. solenopsis*	3-9	Central india
Homalotylus albiclavatus (Agarwal)	*P. solenopsis*	5-10	Central India
Anagyrus kamali Moursi	*P. solenopsis*	5-10	Central India
Chartocerus kerrichi (Agarwal)	*P. solenopsis*	6-9	Central India
Pachyneuron leucopiscida Mani	*P. solenopsis*	5-9	Central India
Promuscidea unfasciativentris (Girault)*	*P.solenopsis/ N. viridis*	7-22	Central India
*Prochiloneurus aegypticus**	*P.marginatus*	2-9	South India
Predator		**%Predatory potential**	
Cryptolaemus montrouzieri (Mulsant)	*P. solenopsis*	40-50	All over India
Crysoperla carnea (Stephens)	*P. solenopsis*	20-40	Central India
Cheilomones sexmaculata (Fabricius)	*P. solenopsis*	20-30	All over India
Scymnus sp.	*P. solenopsis*	20-30	All over India
Rodolia funida	*P. solenopsis*	10-20	Central India
Nephus regularis (Sicard)	*P. solenopsis*	10-20	Central India
Gitonides perspicax Knab	*N.viridis*	33-90	Central India
Spalgis epius Westwood	*P.marginatus*	55-66	South India

***Hyperparasitoid**

compared with the growth of the fungal pathogen in control plates. All the six bacterial isolates were found effective with an inhibition of 62.86 – 73.00 per cent with 25.50 – 32.75 mm. inhibition against *Myrothecium roridum* under *in vitro* conditions. The maximum inhibition of 70.00 – 72.00 per cent was recorded with an inhibition zone of 25.80 -32.75 mm in isolate no. 7 and 8, respectively. However remaining four isolates were also effective and inhibited the pathogen 62.80 – 67.60 per cent with an inhibition zone of 25.50 – 27.75 mm.

Development of farmer friendly formulation of fluorescent Pseudomonas

The 24 hrs old bacterial cultures of native bacterial isolates (10^6 cfu / ml) No 7 and 8 identified as *Pseudomonas aeruginosa* were multiplied in nutrient broth and mixed separately and thoroughly in 1 kg carrier of vermicompost, FYM and Talcum powder.The bacterial population was monitored at an interval of 5 days till 50 days of inoculations. Vermicompost (2.9 -5.7 x 10^{12} cfu /g) and FYM (3.6 -8.7 x10^{11} cfu /g) can be used as a carrier for multiplication of flurocent *Pseudomonas* PGPR and has potential in plant growth promotion as well as induction of defence against pathogens.

Effect of bacterial cultures on growth promotions of cotton seedlings

Two effective bacterial cultures *Pseudomonas aeruginosa* (Isolate nos. 7 and 8) were inoculated to study their influence on seedling survival and subsequent seedling growth in cotton. These cultures were multiplied separately in three different carrier viz. vermicompost, FYM and talcum powder. The seed bacterization of susceptible cultivar LRK-516 was carried out @ 40 gm / kg of seed and sown in 30 cm earthen pots. Seedling survival, root shoot length and dry weight of root and shoot was recorded on 30th day after sowing.

The bacterial inoculation was found to be superior in suppressing the proliferation of the pathogen and thereby enhancing the seedlings survival and the growth parameters over control. Culture No. 8 was found to be most effective in enhancing the germination (14.99 -29.99 %), root shoot length (21.16 – 39.00%) and root length (15.10 -27.35%). The increase in and dry weight of shoot was 19.78 – 45.05 per cent and dry weight of root 38.89 – 58.33 per cent was recorded with culture No. 8.. However as a carrier vermicompost was effective in enhancing the germination from 14.99 – 24.99 % and length of shoot, length of root, dry of shoot and dry weight of root to 21.16 – 39.00% , 20.00 – 20.82%, 8.79 – 45.05% and 8.39 – 58.33%, respectively.

Management of foliar diseases through bio-agents and SAR inducing chemicals

Seed treatment with four bacterial bio-agents,*viz. Pseudomonas fluorescence* TNAU, *P. fluorescence* CICR, *P. aeruginosa* CICR 7 and *P. aeruginosa* CICR 8 @ 40 gm/kg of seed plus foliar spray @ 0.4 %. The SAR inducing chemicals salicylic acid and iso- nicotinic acid were also spread @ 50 ppm and compared with the foliar application of Propiconazole @ 0.1 % thrice during the season.

Seed treatment and foliar application of *P. aeruginosa* (CICR 8) was observed to be significantly effective in reduction of

bacterial blight (62.16%), alternaria leaf spot (57.31%), Myrothecium leaf spot (48.36%) and grey mildew (64.14%) over control. Salicylic acid recorded a reduction of 50.25, 51.62, 56.07 and 71.55 per cent of bacterial blight, alternaria leaf spot, myrothecium leaf spot and grey mildew, respectively.

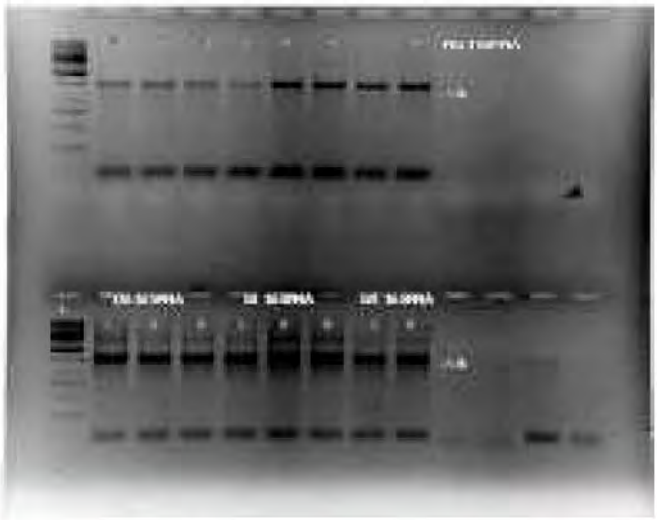
Development, validation, utilization and / or commercialization of biopesticides and bioinoculants

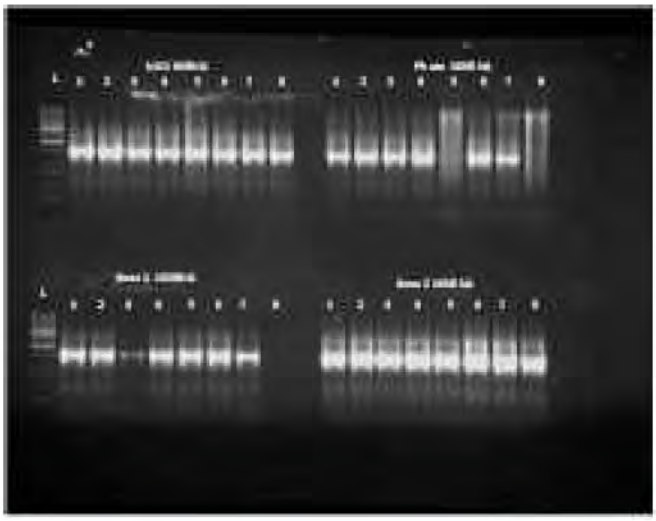
Nagpur

Biochemical and molecular characterization was carried out for four isolates (NG, D6, G1 and G5) of bacteria *Photorhabdus* symbiotically associated with entomopathogenic nematodes and were found effective against insect pest including mealybug.

Amplification of 16sRNA for molecular characterization

16s ribosomal RNA sequence of bacterial symbiont using oligonuceotide primers (5'GGA GAG TTA GAT CTT GGC TC3' sense and 5'AAg GAG GTG ATC CAG CCG CA3' was amplified. The sequence amplified was around 1550 bp and has been cloned in pGEM-T vector for sequencing.





Biochemical Test	Bacterial isolates			
	Ng	D6	G1	G5
Colony Morphology on Nutrient Agar	Smooth surface Opaque	Small pinpoint round	Small pinpoint round Crater formation	Small pinpoint round
Gram Stain	+ve rod shaped 	-ve Coccus 	+ve rod shaped 	+ve rod shaped 
Pigmentation	-ve	-ve	-ve	-ve
Levan production	-ve	-ve	-ve	-ve
Methyl Red	+ve	+ve	-ve	+ve
Voges-Proskauer Test	+ve	+ve	+ve	+ve
Starch hydrolysis	-ve	-ve	-ve	-ve
Oxygen requirement	Facultativly anaerobic	Facultativly anaerobic	facultativly anaerobic	facultativly anaerobic
H2S Production	-ve	-ve	-ve	+ve
Indole Production	-ve	-ve	-ve	-ve
Nitrate reduction	-ve	-ve	+ve	+ve
Urease Test	+ve	+ve	+ve	+ve
Arginine Hydrolase Test	-ve	-ve	-ve	-ve
Citrate test	+ve	+ve	+ve	-ve
Catalase formation	-ve	-ve	-ve	-ve
Gelatinase test	+ve	-ve	+ve	+ve
Motility	-ve	+ve	-ve	+ve highly
Amino Acid decarboxylase	-ve	-ve	-ve	-ve
Tyrosinase	-ve	-ve	-ve	+ve
Oxidase	-ve	-ve	+ ve	- ve
B Galactosidase	-ve	-ve	-ve	-ve

Carbohydrates fermentation studies were carried out with the four bacterial isolates for 21 carbohydrates

Carbohydrates	NG	D6	GI	G5
Adonitol	Weakly Positive	Negative	Negative	Weakly Positive
Arabinose	Negative	Weakly Positive	Negative	Negative
Cellobiose	Negative	Positive	Negative	Positive
Detrose	Positive	Positive	Negative	Positive
Dulcitol	Negative	Negative	Negative	Positive
Fructose	Positive	Positive	Negative	Positive
Galactose	Positive	Positive	Negative	Negative
Inositol	Negative	Negative	Negative	Weakly Positive
Inulin	Negative	Weakly Positive	Weakly Positive	Weakly Positive
Lactose	Negative	Negative	Negative	Weakly Positive
Mannose	Negative	Negative	Negative	Negative
Maltose	Positive	Positive	Negative	Positive
Mannitol	Negative	Negative	Negative	Weakly Positive
Melibiose	Negative	Negative	Negative	Weakly Positive
Raffinose	Positive	Weakly Positive	Negative	Weakly Positive
Rhamnose	Negative	Weakly Positive	Positive	Weakly Positive
Sucrose	Positive	Positive	Negative	Positive
Salicin	Positive	Positive	Negative	Positive
Sarbiotol	Negative	Weakly Positive	Weakly Positive	Weakly Positive
Trehalose	Positive	Positive	Weakly Positive	Positive
Xylose	Negative	Negative	Negative	Weakly Positive

Optimum Temperature Conditions; The four isolates (NG, D6, GI, G5) grew best at 37°C.

Coimbatore

Evaluation of effective biopesticides for eco-friendly management of major sucking pests in Bt cotton

Treatments with Pest Guard L (1%), *Metarhizium anisopliae* (CICR, R.S, Coimbatore) and *Lecanicillium lecanii* (CICR, R.S, Coimbatore) brought out a reduction of 80.7, 71.6 and 71.4% respectively as against 54.4% reduction in control. Treatments were not harmful to the predators of coccinellids and spiders. There were no significant differences in seed cotton yield among the treatments (Table 22).

Table 22 : Evaluation of biopesticides and insecticide against emerging pests and their predators & seed cotton yield (kg / ha)

Treatment	Dose/ha	Leaf hopper pop/3 leaves	Mirid bug pop/5 squares	Coccinellid pop/plant	Spider pop/plant	Seed cotton yield (kg/ha)
1. *Metarhizium anisopliae* (CICR, RS, Coimbatore)	1500 g	2.13	0.53	0.01	0.88	1844
2. Pest Guard L (1%)	2.5 lit	1.93	0.27	0.08	0.74	1722
3. Pest Guard J (1%)	2.5 lit	2.07	0.60	0.01	0.61	1923
4. *Metarhizium anisopliae* 1.33 x 108 (NBAII, Bangalore)	500 g	2.07	0.60	0.08	1.21	1872
5. *Verticillium lecanii* 1.66 x 108 (NBAII, Bangalore)	500 g	1.67	0.67	0.14	0.74	1702
6. Neem oil (0.5%)	1.25 lit	2.00	0.87	0.01	0.88	1789
7. *Lecanicillium lecanii* (Ta (CICR, RS, Coimbatore)	1500 g	1.80	0.40	0.14	0.81	1884
8. Control (un sprayed)	-	1.53	0.67	0.14	0.74	1973
9. Control (water sprayed)	-	1.87	0.47	0.08	0.68	1817
10. Profenophos Curacron (0.05%)	500 ml	1.73	0.20	0.28	0.94	2116
SEd		**0.11**	**0.32**	**0.17**	**0.17**	**50.93**
CD(P=0.05)		**NS**	**NS**	**NS**	**NS**	**N.S**

Population: 6 days after treatment; Spray taken up on 125 DAS; Hybrid: RCH2Bt; Date of Sowing: 03.09.2010.

First Record on the establishment of the parasitoid *Acerophagus papayae* Noyes & Schauff on *Paracoccus marginatus* in cotton

Establishment of parasitoid *A. papayae* on mealybug *P. marginatus* in cotton was recorded at CICR, RS, Coimbatore. High intensity of parasitisation and adult emergence were recorded on twigs alone and twigs with leaves, respectively as compared to leaves alone. Per leaf average population of live and mummified mealy bugs were 15.05 ± 17.66 and 0.98 ± 0.82 respectively. On twigs 5.70 ± 2.83 and 41.90 ± 28.70 of healthy and mummified mealy bugs respectively were recorded. Average adult emergence in shoots with leaves and leaves alone were recorded as 6.60 ± 4.12 and 2.00 ± 2.05, respectively. The adults that emerged (Image 1) were found to be highly active with good host searching ability. Off-seasonal release of the parasitoids on alternative hosts will help in the establishment and act as reservoirs of parasitoids for further suppression of the pest on cotton.

Isolation and identification of nematode suppressive soil

Based on preliminary survey, nematode suppressive soils were collected and one isolate of *Psuedomonos flourescens* and *Bacillus subtilis* were identified. Effect of bacterial cells and culture filtrate of both bacteria were tested on hatching and mortality of Reniform nematode. In both bacteria, nematode mortality was directly proportional to the concentration of bacteria and filtrate used. When *B. subtilis* cells were tested, a maximum of 90% reduction in nematode hatching and 87.50% mortality was recorded at 72 hours after inoculation. When culture filtrate of *B. subtilis* was tested, undiluted filtrate recorded 100% reduction in hatching and 88.10% nematode mortality.

Effect of *Pseudomonas fluorescens* cells and cell free extract on hatching and mortality of reniform nematode

Effect of *Pseudomonas fluorescens* cells and cell free extract on hatching and mortality of reniform nematode was tested under laboratory condition. *P. fluorescens* cells at 10^8 cfu/ml caused a maximum of 75% reduction in nematode hatching and 80.30% reduction in mortality. Culture filtrate of P. *fluorescens* recorded maximum of 100% reduction in egg hatching. This clearly indicated the nematicidal and ovicidal effect of bacterial antagonists against reniform nematode in cotton.

Effect of plant products on mortality of reniform nematode

Effect of nine plant products on mortality of reniform nematode was tested under *in vivo* condition. Among them Anonas *comosus* recorded maximum of 99.00% mortality at 72 hours after inoculation which was on par with *Chromolena odorata* and *Mimosa invisa*.

Antimicrobial property and mode of action of bacterial symbiont

Antimicrobial property of *Xenorhabdus stockiae*, bacterial symbiont of native entomopathogenic nematode, *Steinernema siamkayai* was tested against *Fusarium oxysporum* and *Alternaria alternata* by using dual culture method. When tested against *F. oxysporum* and *A. alternata* a clear zone of growth inhibition was noticed at 48 and 72 hours after inoculation .

Biochemical characterization of bacterial symbiont of nematodes

The activity of three enzymes *viz*., chitinae, protease and lipase produced by X. stockiae was tested to know the pathogenicity mechanism. Enzyme production by primary and secondary cells and their metabolites were tested. Primary cells and their metabolites recorded more chitinase activity than secondary cells and their metabolites. But secondary cells and their metabolites recorded more protease activity. Activity of lipase in primary and secondary phases of *X. stockiae* was tested. Irrespective of duration, primary phase recorded more lipase activity than secondary phase.

Pathogenicity of bacterial symbiont of native entomopathogenic nematode to major insect pests of Cotton

Pathogenicity of *X. stockiae* to major insect pests of cotton viz., Mealy bug, *Paracoccus marginatus*, *Spodoptera litura*, *Sylepta derogate* and other pests like *Galleria melonella* and *Corcyra cephalonica* was tested under laboratory condition. Both primary and secondary cells and their metabolites were pathogenic to test insects. When *P. marginatus* were treated with bacteria, initially slight degradation of waxy coating was noticed and at four days after inoculation complete removal of wax was noticed which is mainly due to the production of lipase by *X. stockiae*.

Susceptibility of three different instars, *viz*., second, third and late instars of *S. litura* were tested against *X. stockiae*. The results revealed that the second instars are more susceptible than third and late instars which was noticed in all durations (Fig.27).

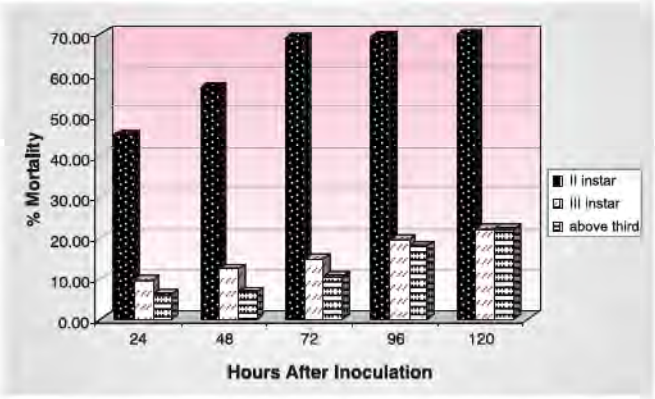


Fig. 27: Susceptibility of different instars of *S. litura* to *X. Stokiae*

Development of talc based formulation of a native entomopathogenic fungus, *Lecanicillium lecanii*

A protocol for mass multiplication of *L. lecanii* with locally available materials was standardized. Based on virulence data, *L. lecanii* multiplied on Sorghum grains, Sabourard Dextrose Broth with Yeast Extract (SDY Broth) and Potato Dextrose Broth (PD Broth) were formulated in Talc and stored at Room Temperature (27 ± 1°C) and Refrifgirator (9 ± 1°C). Viability of spores and virulence was monitored at monthly intervals for six months. There were three replications for each treatment. Mortality of Mealy bug, *Paracoccus marginatus* was recorded and LT_{50} was calculated by using Probit analysis. Among different formulations tested, *L. lecanii* multiplied on SDY Broth and formulated in Talc supported maximum viability and virulence. Among two storage temperature tested, formulation stored at 9 ± 1°C supported maximum viability and virulence. In general, spore viability was reduced with increase in storage duration and temperature. At the end of six months, a maximum of 70% spore viability was recorded in *L.lecanii* multiplied on SDYB and formulated in Talc (Table 23).

Table 23: Effect of formulation, storage temperature and storage period talc based formulation of *Lecanicillium lecanii*

Formulation	Storage temperature (°C)	Spore viability (%) at different days of storage						Mean
		30	60	90	120	150	180	
Sorghum +Talc	27 ± 1	82.00	79.33	62.67	46.00	40.00	36.00	65.90
	9 ± 1	94.00	92.00	74.33	65.67	62.33	56.33	
SDY	27 ± 1	96.33	90.67	88.67	74.00	66.00	59.67	81.22
Broth+Talc	9 ± 1	98.00	94.33	84.00	79.67	73.33	70.00	
Potato Dextrose	27 ± 1	97.00	80.33	70.33	62.67	59.67	53.67	72.56
Broth +Talc	9 ± 1	97.00	86.67	76.33	64.33	60.33	62.00	
Mean		94.11	87.22	76.06	65.39	60.28	56.28	
Temperature	27 ± 1	69.19						
	9 ± 1	77.26						
CD (P=0.05)	Formulation = 0.88		Temperature = 0.72		Storage duration =1.24			

Development of oil in water emulsion based formulation of a native entomopathogenic fungus, *Lecanicillium lecanii*

Oil in water emulsion based formulation of *L. lecanii* was developed and stored at 27 ± 1°C and 9 ± 1°C. Spore viability was recorded upto 6 months of storage. Oil in water emulsion formulation stored at 9 ± 1°C recorded maximum of 78.33% spore viability at the end of six months of storage (Table 24).

Table 24 : Effect of oil based formulation of *L. lecanii* on spore viability

Storage temperature	Spore viability at different days of storage						Mean
	30	60	90	120	150	180	
27 ± 1°C	94.33	82.00	71.00	60.00	60.00	58.00	70.89
9 ± 1°C	96.00	89.00	87.00	85.00	80.33	78.33	85.94
Mean	95.17	85.50	79.00	72.50	70.17	68.17	
CD (P=0.05)	Temperature =1.33 ; Duration=2.31 ; sTemperature x Duration = 3.26						

When two formulations of native entomopathogenic fungi *viz*., *Lecanicillium lecanii* and *Metarhizium anisopliae* were tested against *P.marginatus*, oil in water emulsion formulation recorded maximum mortality. Among two fungi tested, *L. lecanii* was found to be virulent. Effect of storage on virulence of *L. lecanii* formulated in talc and oil were tested for six months. At the end of storage period oil and talc based formulation recorded LT_{50} of 10.21 (9.21 – 11.33) and 10.31 days (9.43 – 11.29) as against 10.37 (9.53 – 11.30) in unformulated spores.

Enzyme activity on entomopathogenic fungus

Pathogenesis related important enzyme activities viz., protease, lipase and chitinase were quantified on entomopathogenic fungus, *Beauveria bassiana*, *Metarhizium anisoplea* and *Verticilium lecanii*. Influence of carbon sources as nutrient broth containing five different carbon sources (Dextrose, Glucose, Sucrose, Starch and Chitin) were compared for the enzyme activity.

Among the different sources, chitin added medium shows higher enzyme activity than other sources. Among the entamopathogens, *M. anioplea* shows high enzyme activities followed by *B. bassiana* and *V. lecanii*. Mass production of these enzymes from entamopathogenic fungus having high industrial value.

Isolation of indigenous endophytic *B. bassiana*

To isolate indigenous endophytic *B. bassiana* from the cotton plants, stems and leaves were collected and after the disinfection process, placed in Petri dishes containing selective medium. Tissues were examined four days later, and any fungal growth was subcultured onto individual plates containing medium for subsequent identification.

The experiment was organized as a completely randomised design. During the process of isolation of endophytic *B. bassiana*, many other fungal endophytes were observed. These fungal cultures identified by fungal identification service.

Fungus isolated as endophytes:

i. *Fusarium solani* (Mart.) Appel and Wollenweber emend. Synder and Hansen
ii. *Fusarium oxysporum*
iii. *Fusarium sp*.
iv. *Penicillium piceum* Raper and Fennel
v. *Aspergillus flavus*
vi. *Aspergillus terrus* gr.
vii. *Geotrichum candidum* Link.
viii. *Pestalotiopsis uvicola* (Speg.) Bissett
ix. *Nigrospora sphaerica* (Sacc.) Mason

Among these, *Fusarium solani* and *Fusarium oxysporum* were predominant and are incidentaly entomo pathogenic.

Artificial inoculation of *B. bassiana* inoculum as endophyte

Colonization of cotton seedlings by *B. bassiana* was determined at thirty days after inoculation with *B. bassiana*. A total 20 plants and 400 plant pieces were examined for each treatment. The colonization frequencies calculated from number of plant pieces colonized out of total number of plant pieces. *B. bassiana* was not recorded from the control plants. Foliar application and soil drenching treated plants showed colonization of *B. bassiana*. The seed treatment methods were not given any significant colonization of *B. bassiana*. Foliar application method recorded colonization percentage of 32 at 10^8 concentrations (Fig. 28).

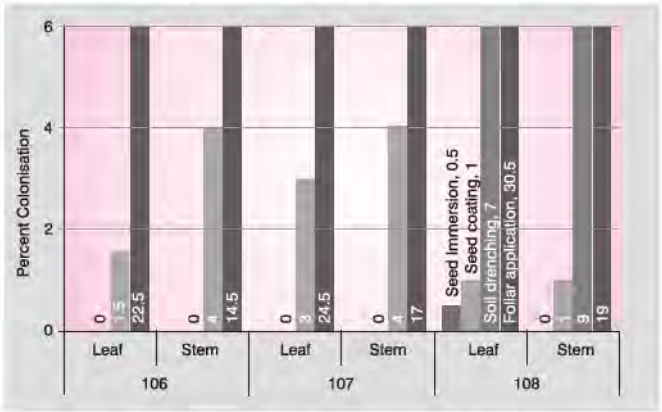


Fig. 28 : Colonization frequencies of *B. bassiana*

Difference in establishment and pathogenicity in Bt and non Bt cotton

There were no significant differences in levels of endophytism of *B. bassiana* between Bt and Non Bt cotton from 10^6 to 10^8 concentration.

Sirsa

Studies on inoculum source and economic thresholds of cotton leaf curl virus disease showed that White fly population/ three leaves and CLCuD incidence was high during the season in north zone. The maximum incidence of white fly was observed in Haryana followed by Rajasthan and Punjab (per three leaves -7.9 to 14.5 in Haryana; 7.6 to 12.2 in Rajasthan and 4.3 to 6.0 in Punjab). Similar trend in CLCuD incidence was also noted (52.5 to 69% in Haryana; 44.0 to 55.1% in Rajasthan and 26.7 to 29.8% in Punjab). *Bhakari* (*Tribulus terresteris*), *Itsit* (*Trianthema monogyna*), *Tandala* (*Digeria avensis*), *Gutpatana* (*Xanthium strumarium*), *Kanghi buti* (*Abutilon sps*) and *Peeli buti* (*Sida sps*) were the main weeds in north zone with white fly population ranging from 0.4-1.8 per three leaves in Haryana, 0.1-1.0 per three leaves in Rajasthan and 0.0 – 1.1 per three leaves in Punjab. Twelve weeds were collected from north zone and analyzed using PCR for detection of cotton leaf curl virus. *Jungli Palak* (*Spinacea spp*), *Bathu* (*Chenopodium album*), *Tamatari* (*Solanum nigrum*) and *Lantana weed* (*Lantana camara*) showed positive reaction towards CLCuD detection after DNA isolation and PCR using coat protein primer. The effect of Percent Disease Index (PDI) on seed cotton yield, reduction ranged from 1.86 to 43.52% with 5% to 60% graded PDI in case of Bt hybrid Bioseed -6488 BG, 1.54 to 27.45% in NCEH-6 and 1.95 to 37.01% on Bt hybrid RCH-134. Economic threshold limit of disease based on CLCuD Grade showed that the percent reduction in seed cotton yield ranged from 20.00 to 55.00% in Bt hybrid 6488, 8.47 to 35.59% in RCH-134 Bt and 12.5 to 48.61% in Jai.

Biological control to strengthen IPM

Among various insecticides and biopesticides, imidacloprid (53.63%) resulted in maximum reduction in leafhopper population and *neem oil + nirma* powder resulted in maximum (52.95%) reduction in whitefly population. Maximum thrips population was reduced by biopesticide, Pest Guard L50EC (45.37%). The biopesticides and entomopathogens were found safer to generalist predators.

Development and validation of IPM/IRM strategies for Bt cotton hybrids carrying different events against sucking pest complex, the average leafhopper population based on 9 fortnightly observations ranged between1.02 to 1.31/3 leaves,whitefly 2.49 to 4.93 / 3 leaves in different hybrids carrying different events sown under IPM conditions. The average thrips population recorded in different hybrids was 3.49 to 9.69/3 leaves under IPM practices. Under RPP (Recommended package of practices) the leafhopper population recorded between 1.37 to 1.73/3 leaves, whitefly between 4.20 to 5.96/3 leaves and thrips between 7.29 to 10.69/3 leaves in different hybrids sown.From Bt cotton hybrids carrying different events no rosette flower was noticed but from Non Bt it appeared from 36SMW onwards. The cost: benefit ratio of 1: 1.98 and 1:1.59 respectively in IPM and RPP plots, respectively. Increase in net profit in IPM over RPP was 24.90%.

Bioassay with *cry1Ac*, *cry2Ab* and *cry1C* to *Earias vitella*

A total of 35 bioassays were conducted with different toxins received from CICR, Nagpur (*cry1Ac*, *cry2Ab* and *cry1C*) on F1 generation of the field collected population from the different location. The larval populations of spotted bollworm (*Earias vitella* and *Earias insulana*) were collected from Haryana 3 locations (Sirsa, Hisar and Fatehabad) Punjab 2 locations (Faridkot and Bathinda); and Rajasthan 1 location (Sri Ganganagar) during the month of September, October and November 2010. Collection of larvae of *Helicoverpa armigera* and *Spodoptera litura* were also collected and the populations in the form of pupae were sent to Nagpur.

Pink bollworm larval recovery from North Zone

Monitoring for PBW incidence in Bt cotton was conducted in North Zone (Faridkot, Sriganganagr, Sirsa and Hirsar) through examinations of 150 green bolls at three times during 140, 160 and 175 DAS. At 140 DAS no larval recovery from Bt cotton was recovered from any of the location but fromNon -Bt Bioseed-6488 from the 150 bolls observed from Sirsa location showed recovery of 10 PBW larvae with a percentage of 6.67. At 160 DAS, from Bt cotton collected bolls no larval recovery was observed but the % recovery of pink bollworm larvae from the Non- Bt bolls received from Faridkot was 10.34%, from Sriganganagar on Non- Bt variety the % larval recovery was 36.64% , from Hisar on Non- Bt hybrid 12.60% recovery and from Sirsa on Non Bt Bioseed 6488 larval recovery was 26.67%. At 175 DAS no larval recovery , 36.49% larval recovery of PBW was observed from 74 bolls received from Faridkot on Non- Bt Variety, from Sriganganagar, the % larval recovery was 21.33%, from Hisar the % larvae recovered from Non Bt was 5.88 and from Sirsa Non Bt Bioseed, the % larvae recorded were 80.00.

Adult moth catch of cotton bollworms in pheromone traps

As per the pheromone trap catches mean male moth catch per

trap per week during the 2010 were 4.30 for pink bollworm, 10.90 for American bollworm, 2.41 for spotted boll worm and 37.25 for tobacco caterpillar (Fig. 29 and 30).

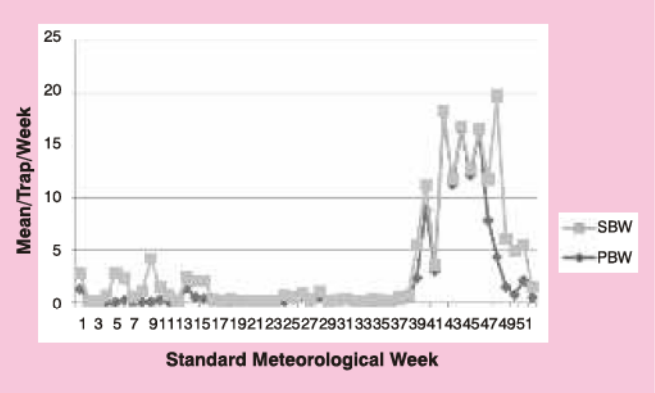


Fig. 29 : Pheromone trap catches of Spotted bollworm, *Earias* spp. (SBW) and Pink bollworm, *Pectinophora gossypiella* (PBW) recorded

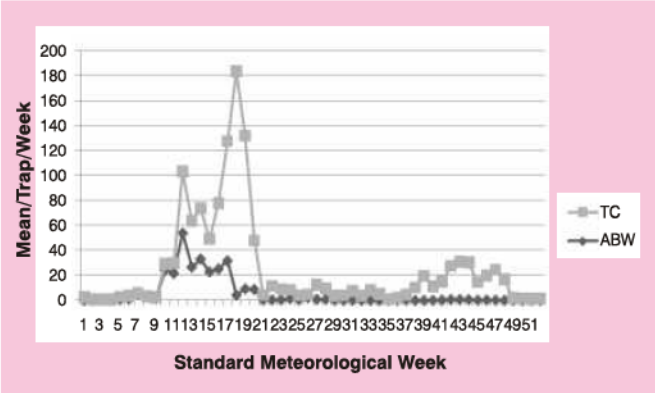


Fig. 30 : Pheromone trap catches of American bollworm, *Heliothis armigera* (ABW) and tobacco caterpillar, *Spodoptera litura* (TC) recorded

4.26 : Integrated Pest Management

Nagpur

New botanicals, products of the inducible resistance were formulated and tested for use in sucking pest management of cotton pests in multilocation trials. Pest Guard J50EC, Pest Guard L50EC and Pest Guard O50EC were tested at 3 locations (Nanded, Sirsa and Guntur) predominantly against the leaf hoppers. The formulations were similar in their toxicity to leaf hoppers across centres and were effective upto 14 days after spray at Nanded (Table 25).

Table 25 : Efficacy of Pest Guard Formulations against sucking pests of cotton at 3 locations

Location	Test insect	Genotype	Molecule	Percent reduction after first spray			Percent reduction after second spray		
				3DAS	7DAS	14DAS	3DAS	7DAS	14DAS
Nanded (as compared to water spray)	Leaf hopper	Bunny Bt	Pest Guard J50EC	75.9	80.0	71.2	69.2	89.5	97.3
			Pest Guard L50EC	77.5	80.5	70.3	75.5	88.2	98.1
			Pest Guard O50EC	79.1	82.3	73.5	77.1	86.3	99.2
	Whitefly		Pest Guard J50EC	58.2	60.6	66.8	66.8	72.1	80.7
			Pest Guard L50EC	64.2	56.7	77.3	72.3	80.2	84.0
			Pest Guard O50EC	68.6	71.0	75.3	75.3	81.3	84.7
Sirsa (as compared to pre- spray count)	Leaf hopper	IT-905 (NBt)	Pest Guard L50EC	-	49.2	-	-	60.15	-
			Pest Guard O50EC	-	46.6	-	-	47.24	-
	Whitefly		Pest Guard L50EC	-	51.5	-	-	57.9	-
			Pest Guard O50EC	-	49.6	-	-	58.7	-
	Thrips		Pest Guard L50EC	-	47.0	-	-	42.0	-
			Pest Guard O50EC	-	47.0	-	-	40.1	-
Guntur (as compared to water spray)	Leaf hopper	RCH BGII	Pest Guard J50 EC	-	31.0	-	-	35.6	-
			Pest Guard L 50EC	-	23.8	-	-	37.8	-

Yield differences were insignificant at Sirsa but were significant at Guntur and Nanded. Yield increased by 50% with both molecules over control at Guntur but were inferior to the insecticidal check, Acephate75SP that recorded 1800 kg/ha as compared to 13Q in Pest Guard treated plots. Yield increased by 29.6% (Pest Guard J50EC), 30.5% (Pest Guard L50EC) and 41.9% (Pest Guard O50EC) over control (with water spray, 760 kg/ha) at Nanded. Mealy Kill 50EC was submitted for biosafety testing at Shriram Institute of Industrial Research, New Delhi, since biosafety a mandatory requirement for registration.

A record of host plants of mealybug *Phenacoccus Solenopsis* Tinsley in three cotton agro-ecosystems of India

A record of 166 host plants belonging to 51 families comprising 78 weeds, 27 ornamentals, 18 trees, 17 vegetables, 12 field crops, 8 fruit plants and 4 spice plants was made in three cotton agro-ecosystems of India. Host plants were categorised belonging to Malvaceae (10.24%) followed by Asteraceae (9.64%), Fabaceae (9.04%), Amaranthaceae (6.63%), Euphorbiaceae (6.63%), Solanaceae (6.02), Poaceae (4.22) and Lamiaceae (3.61%). There were 43, 63, 51, 100 host plants seen to be prevalent during cotton season while 45, 86, 80 and

121 host plants were recorded during off season in North, Central, South and in overall India, respectively. Rainfed cotton agro-ecosystem harboured highest number of host plants followed by equal number of host plants in South and North Zone. Host plants *Trianthema portulacastrum* Linn. (Aizoaceae); *Parthenium hysterophorus* Linn. (Asteraceae); *Carica papaya* Linn. (Caricaceae); *Hibiscus rosa-sinensis* Linn. (Malvaceae); *Lycopercicon esculentum* Mill. (Solanaceae) were common hosts in all the three cotton agro-ecosystems. Among the host plants, *Hibiscus rosa-sinensis* Linn., *Abutilon* spp., *Malvastrum coramandelinum* Garcke (Malvaceae), *Lantana camara* (Verbenaceae); *Withania somnifera* (Solanaceae) harboured this pest round the year and acted as a persistent source of spread of mealybug to cotton and other crops. Besides cotton, papaya and tomato; cultivated crops viz., sunflower, brinjal, cluster bean and green gram were found to be severely infested in North Zone; chilli, okra, brinjal and potato in Central Zone while potato in South Zone. Promoting pigeon pea intercropping and discouraging weeds especially Acmella uliginosa (SW.) Cass., *Helianthus* sp., *Parthenium hysterophorus* Linn., *Pentanema indicum* (L.) Y. Ling, *Taraxacum officinale* Linn., *Xanthium strumarium* Linn. (Asteraceae); *Abelmoschus ficulneus* (Linn.), *Abutilon indicum* Sweet, *Malvastrum coramandelinum* G., *Sida cordifolia* Linn. (Malvaceae); *Euphorbia heterophylla* Linn, *Euphorbia hirta* Linn., *Phyllanthus amarus* Linn. (Euphorbiaceae); *Corchorus trilocularis* Linn., *Triumfetta rhomboidea* Linn. (Tiliaceae), *Trianthema portulacastrum* Linn. (Aizoaceae), *Asteracantha longifolia* Nees (Acantheceae), *Digera muricata* (Linn.) (Amaranthaceae), *Clitoria ternatea* Linn. (Fabaceae), *Boerhavia diffusa* Chois.(Nyctaginaceae) and *Portulaca oleracea* Linn. (Portulacaceae) during cotton season as well as off-season, form important management stratergies.

Bt cultivars with multiple tolerances

The Bt cultivars showing multiple tolerance to sucking pests, reddening, wilt and also high yield performer were recorded from the data as under :

Tolerance to leaf hoppers and whitefly : The cultivars which were tolerant to leaf hopper and whitefly were Ankur Jai BG II, Ankur - 3034 BG II, Ankur - 3042 BG II, Ankur - 3070 BG II, Anvitha Bt (NCS-910),Atal BG II, Bunny 2 Bt, Classic Bt II (PCH 882 BT-II), Express fusion Bt, JK Durga Bt, Madhura Bt (PCH-77 Bt), Menaka Bt II (PRCH-331 BG II), MRC - 7301 BG II (Mahyco), Namaskar Tulsi - 117 BG II, Ryan Bt (PRCh-712), SP - 504 BG II, SWCH 4708 BG II, Vanaja Bt NCS-907 Bt, Veda 2 BG II (Solar-60 BG II), VICH - 301 Bt (BG II), VICH - 303 Bt (BG II), VICH - 304 Bt (BG II), VICH - 311 Bt (BG II), VICH - 312 Bt (BG II) and VICH - 314 Bt (BG II).

Tolerance to leaf hoppers, whitefly and thrips : The cultivars showing tolerance to leaf hoppers, whiteflies and thrips were Ankur Jai BG II, Ankur - 3034 BG II, Anvitha Bt (NCS-910), Atal BG II, Bunny 2 Bt, Classic Bt II (PCH 882 BT-II), Express fusion Bt, Madhura Bt (PCH-77 Bt), Menaka Bt II (PRCH-331 BG II), Namaskar Tulsi - 117 BG II, Ryan Bt (PRCh-712), SWCH 4708 BG II, Vanaja Bt NCS-907 Bt, VICH - 301 Bt (BG II), VICH - 303 Bt (BG II) and VICH - 312 Bt (BG II). However, cultivars which also found tolerant to aphids were SWCH 4708 BG II, Vanaja Bt NCS-907 Bt, VICH - 301 Bt (BG II), VICH - 303 Bt (BG II) and VICH - 312 Bt (BG II).

Cultivars tolerant to all sucking pests except aphids : The cultivars which were found tolerant to all sucking pests (*viz*. leaf hoppers, whitefly, thrips and mirid bugs) except aphids under study were recorded as Ankur Jai BG II, Atal BG II, Bunny 2 Bt, Classic Bt II (PCH 882 BT-II), Express fusion Bt, Madhura Bt (PCH-77 Bt), Menaka Bt II (PRCH-331 BG II), Namaskar Tulsi - 117 BG II, Ryan Bt (PRCh-712), SWCH 4708 BG II (also tolerant to aphid), Vanaja Bt NCS-907 Bt (also tolerant to aphid), VICH - 301 Bt (BG II) (also tolerant to aphid) and VICH - 312 Bt (BG II) (also tolerant to aphid).

Cultivars tolerant to leaf reddening : Atal BG II, Ankur Jai BG II , MRC - 7301 BG II , VICH - 303 Bt (BG II), Ankur - 216 BG II , Ankur - 3042 BG II, VICH - 304 Bt (BG II) , Paras Krishna BG II, Uttam Bt 2 ((NCS-860 Bt 2) , Express Fusion Bt were found to be tolerant to leaf reddening.

Cultivars that performed superior in all aspects : The cultivars tolerant to sucking pests including leaf hoppers, leaf reddening with high yield potential were : Ankur Jai BG II, Ankur – 3042 BG II, Atal BG II, Express Fusion Bt (NCEH – 14 Bt) and VICH – 303 Bt (BG II).

Evaluation and validation of IPM/IRM strategies for Bt cotton against sucking pest complex

An experiment was carried out at experimental field of CICR to evaluate and validate Integrated Pest Management (IPM)/Insect Resistance Management (IRM) strategies in comparison with recommended packages of practice (RPP) of University of the region (Dr PDKV Akola) for Bt cotton against sucking pests during 2010-11. Six genotype *viz*., Bunny, Bunny Bt, Bunny Bt BG II (Nuziveedu seeds), Express Fusion Bt (Nath seeds), Paras Krishna (Monsanto genetics), JK Durga Bt (JK seeds) were sown in 2 acres field with individual plot size 282 m^2 and plant population 784 in Split Plot Design.

Cost Benefit in IPM over RPP

All the genotypes with IPM interventions found to be superior over RPP counterpart as well as untreated check except express Fusion Bt. The net benefit varied from Rs.4599 to Rs.26549 depending upon potential of genotype. The highest benefit was obtained in Bunny adjacent to Pigeon pea (Rs.26549) followed by Paras Krishna Bt adjacent to Pigeon pea and Okra (Rs.16499), Bunny Bt BG II adjacent to Pigeon pea and Okra (Rs.10549), Bunny Bt (Rs.9149), JK Durga Bt adjacent to Okra (Rs.4599).

Sirsa

Insecticide Induced Resurgence

The experiment conducted for insecticides induced resurgence for commonly used insecticides against sucking pests revealed that in cumulative of 10 sprays, no resurgence in jassid population was recorded consistently but in some of the treatments like Acetamiprid 20 SP + Thiomethoxam, Triazophos and Buprofezin inconsistent resurgence of jassid was recorded. The resurgence (8.29%) in whitefly due to fipronil was recorded after 10 weekly spray applications but in case of individual spray round, the 2nd spray resulted into maximum resurgence (77.31% after one day and 47.89% after seven day of spray application) in whitefly population.

Insecticide Resistance Management

Nagpur

Sucking pest resistance monitoring

Resistance monitoring was carried out with 5 insecticides against leaf hoppers collected from 21 locations on cotton across India were carried out at 7 centres. Resistance to Imidaclorprid was high with resistance ratios of 5450 fold in jassid populations of Wardha (2009-2010) and 6200 fold in

Haveri (2010-2011). Resistance to Thiomethoxam was 2500 fold in populations of Indore in 2009-2010 and 11300 fold in Haveri district of Karnataka in 2010-2011. An increase in the highest resistance ratios of the two years (Haveri 11,200 fold in 2010-2011 as against 2500 fold with Indore populations in 2009-2010) was numerically high but this increase is attributed to the lowest LC_{50} obtained in 2011 (Hisar, 0.00001ml/L) as compared to 0.0002ml/L (LC_{50} for Junagarh populations) in 2009-2010. Coimbatore, Junagarh and Hisar leaf hopper populations were susceptible to all the insecticides tested of which Hisar and Coimbatore continued to be susceptible in 2010-2011. Broadly, Central India leaf hopper populations were resistant to the neonicotinoids as compared to leaf hopper populations of North India. Cross resistance between the two molecules, Imidacloprid and Thiamethoxam exists as indicated by positive correlation between the LC_{50} values of a particular location to the two insecticides.

Resistance monitoring was also carried out with conventional insecticides acephate and monocrotophos. The highest resistance ratio with acephate was observed with populations of Junagarh (1890 fold) in 2010-2011 as compared to 110 fold with populations of Indore (110 fold in 2009-2010). The LC_{50} of acephate with Junagarh populations was 945 fold higher this year compared to the previous year.

The highest resistance ratio was observed with monocrotophos in populations of Surendranagar (57 fold) in 2009-2010 as compared to 1340 fold resistance with populations of Bhatinda (2010-2011). The LC_{50} of monocrotophos with Surendranagar populations was 1340 fold higher this year compared to the previous year.

A field trial was carried out in 4 hot spots of neonicotioid tolerance namely Nagpur, Wardha, Khandwa, Dharwad and two locations where neonicotinoid resistance was moderate (Raichur, Surat) and one location where neonicotinoid tolerance was minimum (Coimbatore) to study the relationship between leaf hopper tolerance to Imidacloprid and Thiamethoxam and seed treatment with these chemistries. Using common genotypes, seed treated and distributed from a single location it was observed that leaf hopper susceptible genotypes were protected from leaf hoppers upto 17-25 days after sowing at Guntur while protection was offered upto 55 days after sowing in Gujarat. It was thus confirmed that resistance to neonicotinoids existed and demonstrated geographical variability in the Indian leaf hopper, *Amrasca devastans*.

Bollworm resistance monitoring to Bts

Geographic populations of the spotted bollworms, *Earias insulana* and *E.vittella*, the American bollworm, *Helicoverpa armigera*, the pink bollworm, *Pectinophora gossypiella* and armyworms *Spodoptera litura* and *S. exigua* were subjected to bioassays with toxins of released transgenes at 4 centres namely CICR, Nagpur (all lepidopterans) Coimbatore (pink bollworm) Sirsa (spotted bollworms) and Lam Farm, Guntur (*Spodoptera litura*). *cry1Ac* (MON531), *cry2Ab* (MON15985x) *cry1C* (Event 1924), *cry1Ac+cry2Ab* (MON 15985) were the released transgene toxins that were evaluated using MVPII, *cry2Ab* corn leaf powder and Xentari^{R} as sources of *cry1Ac*, *cry2Ab* and *cry1C*, respectively. Neonates were used for all assays except for *H.armigera* where white stage larvae were used.

There were no significant shifts in the toxicity of *cry1Ac* to populations of *Earias vittella* and *E. insulana*, especially from North India since the introduction of Bt cotton. Five populations of *E. vittella* from Central India demonstrated a 100 fold increase over the baseline LC_{50} values and this is attributed to the use of 2 day old larve at CICR Nagpur. *cry2Ab* was evaluated against 3 populations and the LC_{50} values against Earias ranged between 0.187 ug/ml of diet to 1.482 ug/ml of diet. *cry1C* was evaluated against 4 populations of North India and the LC_{50} against *E. vittella* ranged from 0.107 ug/ml of diet (Bhatinda populations) to 0.695 ug/ml (Hisar populations). *E. insulana* was 10 fold more tolerant to *cry1C* as compared to *E. vittella*.

Interspecific variation in the toxicity of *cry2Ab* was observed with *Spodoptera* with *S. exigua* being several folds more susceptible to the toxin as compared to *S.litura*. Five populations of *Spodoptera* litura were evaluated using *cry2Ab* and *cry1C*. *cry2Ab* LC_{50}s could not be determined hence its toxicity expressed as MIC50, ranged from 2.08 ug/ml of diet to 6.22 ug/ml of diet. The LC_{50} of *cry1C* ranged from 0.31 to 0.84 ug/ml of diet, thus proving to be more effective than *cry2Ab* against *Spodoptera litura*.

H. armigera from 33 locations representing 25 cotton growing districts were subjected to baseline monitoring studies. The LC_{50}s ranged from 0.016 ug/ml (Sriganganagar) to 0.937 ug/ml (Nagpur) with a variability of 59 fold. *H. armigera* of North India showed a variability of 42 fold with the highest LC_{50} observed from Sirsa populations (0.673 ug/ml of diet). The LC_{50} for populations of Central India ranged from 0.023 ug/ml of diet (Buldana) to 0.937 ug/ml (Nagpur) with a variability of 40.8 fold while populations from Coimbatore represented South India. Seven populations' demonstrated LC_{50} values lower than the world susceptible strain. Nineteen populations of *H. armigera* were subjected to bioassays with *cry2Ab*. *cry2Ab* caused larval mortality during the bioassay period in populations of Nagpur, Wardha, Junagarh, Amravati and Hingoli while it exerted a growth regulating effect on the other populations. The EC_{50} values were lowest with Sirsa populations (0.043 ug/ml) and highest with populations of Junagarh (49.22 ug/ml of diet) with a variability of 1145 folds across the country. *cry1C* demonstrated LC_{50} values ranging from 1.085 ug/ml of diet (Yavatmal) to 5.680 ug/ml of diet (Surat) with a variability of 5.2 fold. EC_{50} values ranged from 0.011 ug/ml of diet (Buldana) to 0.605 ug/ml of diet (Yavatmal) with a variability of 55 fold across the country.

Amongst the toxins, *cry1Ac* still continues to be the most effective toxin followed by *cry1C* against *H. armigera* as both toxins cause larval mortality in insect bioassays. *cry1C* was the most effective toxin against *Spodoptera litura*. All toxins were effective against *Earias sps*.

Field monitoring of pink bollworm in India

For resistance monitoring of pink bollworm, larvae were collected from 36 districts of India. The number of green bolls dissected from the samples of 2,082 larvae/18359 green bolls on non Bt, 630 larvae/11039 green bolls were collected from Bt and 146 larvae/2280 green bolls on BG-II were observed across the India. In North and South India population of Pink bollworm was absent on Bollgard and Bollgard II (Fig.31). In Central India survival of PBW on some Bt cotton genotypes (BG and BG II) were noticed at 175 to 180 DAS.

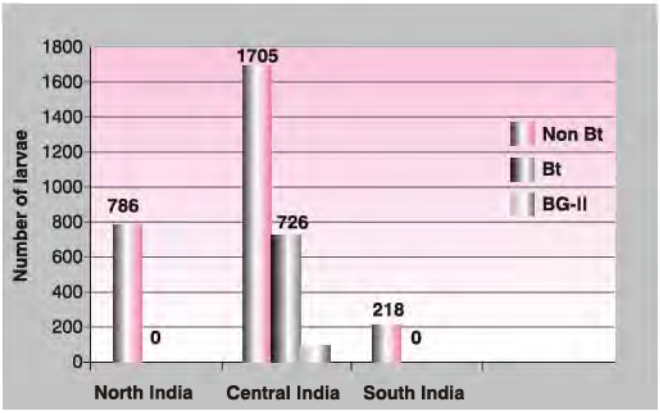


Fig. 31: Monitoring of pink bollworm in India

Mortality of *cry1Ac* diagnostic dose on PBW

Sixteen bioassays carried out demonstrated 100% mortality with 10 ppm while 1 ppm demonstrated more than 75% mortality (Fig.32). At 1 ppm the susceptible population recorded 100% mortality.

Coimbatore

Bioassay with Cry toxins

Bioassays were conducted with *cry1Ac* at 0.1, 1 and 10 ppm concentrations on F1 generation of the field collected population of Pink boll worm *P.gossypiella* from Dharward, Coimbatore and Nandyal. Population collected from Dharwad recorded LD_{50} and LD_{90} values were 0.060 and 0.092 respectively. Coimbatore population recorded LD_{50} and LD_{90} values of 0.058 and 0.089, respectively and bioassay conducted on Nandyal population indicated LD_{50} and LD_{90} values of, 0.069 and 0.105 values respectively.

Pest scenario in IRM villages

Overall IRM fields showed reduction in population of aphids (68%), Leafhoppers (37%), thrips (32%), whiteflies (25%) and mirid bug (17%) when compared to Non IRM fields. Natural enemies *viz.*, *coccinellids*, spiders and *Chrysopa* averaged 0.44, 0.37 and 0.12 per plant respectively in IRM fields, whereas it was 0.41, 0.29 and 0.10 in non participatory fields.

Population dynamics and Alternative Hosts of mealybug species

On station field experiments : Population dynamics of mealybug species *viz.*, *Paracoccus marginatus* and *Phenacoccus solenopsis* were observed under cotton + cowpea intercropping system. *P. marginatus* only appeared during this season. The Percent Incidence (PI) & Severity Index (SI) of *P. marginatus* ranges from 02 to 80 and 1.00 to 2.07 respectively. Higher SI and PI recorded during the month of January and February. SI, PI of *P. marginatus* were negatively correlated with minimum and maximum temperature, rainfall, sunshine hours, wind speed and positively correlated with sunshine hours.

On Farm Field Experiments : Population dynamics of *P. marginatus* and *P. solenopsis* were studied under five cropping systems *viz.*, sole cotton, intercrop with cowpea, surrounded by non-target crop (tomato, cotton field surrounded by weedy road and fallow land with weeds. *P. marginatus*, among the five system, cotton field adjacent to weedy road recorded with highest mean PI (48.08) and SI (2.06) followed by sole cotton (PI- 41.15 and SI -1.07) and field surrounded by fallow land with weeds (PI- 41.54 and SI- 1.13).

Alternate Hosts : There are 148 alternate hosts were recorded including weeds, ornamentals, vegetables and fruit trees were recorded as alternate hosts of the cotton mealybug *viz.*, P. *marginatus* and *P. solenopsis*. Infestation of the mealybug was categorized based on visual observation. Among the host plants, plants belonging to *Solanaceae*, *Malvaceae*, *Asteraceae* and *Euphorbiaceae* family were the favorable hosts for cotton mealybug.

Growth parameters of mealybug on cotton

Growth parameters of cotton mealybug *viz.*, *P. marginatus* and *P. solenopsis* were observed at 20°C and 25°C under controlled condition. Observations on the survival of each individual till its natural death was recorded daily. From its observations, life and fecundity table was constructed (Table 26).

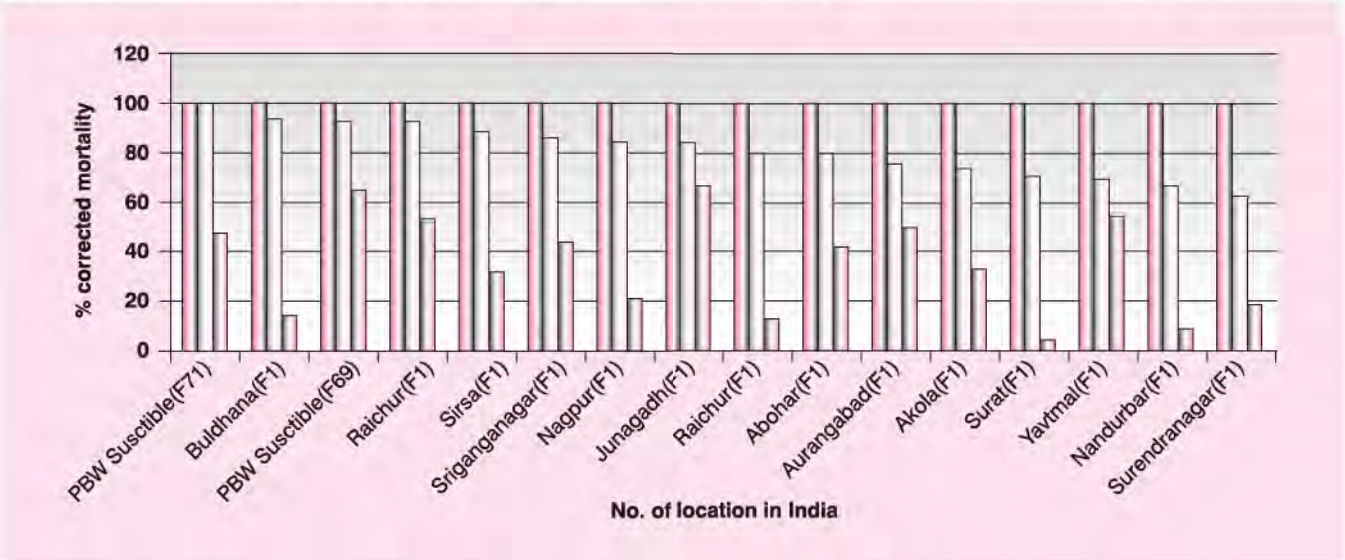


Fig. 32 : Percent corrected mortality of cry1Ac diagnostic dose on PBW (Non Bt)

Table 26 : Population growth parameters of mealybug on cotton

Parameter	*P. marginatus*		*P. solenopsis*	
	20°C	25°C	20°C	25°C
Gross reproduction rate (GRR)	252	474	274	501
Net reproductive rate (Ro)	23.62	110.28	38.28	130.79
Mean length of generation (Tc)	41.36	28.56	43.37	31.38
Innate capacity for natural increase (r_c)	0.0764	0.1647	0.0840	0.1553
True intrinsic rate of increase (r_m)	0.0765	0.1652	0.0869	0.1638
True generation time (T)	41.34	28.47	41.94	29.75
Finite rate of increase (λ)	1.08	1.18	1.09	1.17
Doubling time (DT)	9.06	4.19	7.98	4.23
Annual rate of increase	1.33×10^{12}	1.54×10^{26}	5.95×10^{13}	9.23×10^{25}

Sirsa

A total of 1770 farmers in twenty villages of Sirsa and Hisar were selected under IRM program covering 4393 ha area. Field workers were trained at regular intervals and dissemination of window based IRM technologies like promotion of sucking pest and leaf curl tolerant Bt hybrids, emphasis on refugia planting, early need based intervention of neem sprays, avoidance of broad spectrum insecticides in the beginning and ETL based sprays of insecticides. A reduction in insecticide spray (20.7 -39.5%) over non-IRM villages was noted in two districts. There was reduction in insecticide consumption also to the tune of 33.2%. Cost of insecticide spray reduction was observed at Rs1264/- and 1399/- per hectare in Hisar and Sirsa respectively. Percent increase in yield was also observed in IRM villages over non-IRM upto 13.6% and net profit in IRM villages as compared to non-IRM villages was Rs. 13718/- and 13976/- per hectare at Sirsa and Hisar respectively.

5. Technology Assessed and Transferred

Nagpur

Integrated Nutrient Management

Integrated Nutrient Management (INM) of 60:13:26 kg NPK per hectare with application of 8 kg boron and 10 kg Zn was demonstrated on ten farmer's field .The average seed cotton yield of 1001 kg/ha was registered with INM practice as against farmers practice of 911 kg/ha under rainfed condition.

Intercropping of cotton with soybean

Twelve demonstrations were conducted on inter-cropping of cotton + soybean under rainfed condition in comparison with sole cotton as well as sole soybean. Mean seed cotton yield harvested from cotton + soybean intercrop (947 kg/ha) and sole crop (1017 kg/ha) did not suffer significant loss. However, average yield difference was noticed to 6.84% but additional yield from soybean (445 kg/ha) helped realize higher gross returns with increase in profitability of 14.99% and an average additional benefit of Rs. 6863 per hectare.

Foliar application of DAP and $MgSO_4$ to control reddening

Eleven demonstrations were conducted with foliar spraying of 2.0 per cent DAP during boll development stage and spraying of 1% $MgSO_4$ and 1% urea during flowering stage as soon as reddening symptoms appear in the leaves. The foliar application has increased the seed cotton yield up to 1075.27 kg/ha as compared to farmers practice (952.27 kg/ha).

Crop pest surveillance and advisory for cotton in Maharashtra

Crop pest surveillance was carried out in 29 districts of Maharashtra comprising of 75 subdivisions. Under the project IPM strategies have been formulated in advance and circulated among all the stakeholders for further dissemination. Guidance and assistance in monitoring for surveillance and advisory work was provided. Field visits were carried out particularly in area where pests showed heavy infestation and remedial measures were suggested. The team at CICR kept constant watch on online data entry and advisory was issued. During the season low to moderate infestation of leaf hopper was recorded in all the districts, however, heavy infestation was recorded in Aurangabad and Wardha districts. Leaf reddening was severe during 39-46th standard week in the districts Ahmednagar, Akola, Amravati, Aurangabad, Beed, Buldhana, Jalna, Latur, Nagpur, Nanded, Nasik, Parbhani, Wardha and Washim.

NAIP Cotton Value Chain - An innovation for higher economic returns to farmers and allied stake holders

Nagpur

During 2010-11, 33 farmers were adopted in two identified villages, Nandura and Loni from Yavatmal district. With the adoption of cotton production technologies for Bunny Bt grown on 66 acres, total seed cotton yield of 440 quintals was produced and procured by CIRCOT, Mumbai. Higher seed cotton yield (2350 kg/ha) was recorded in closer spacing (75 x 60 cm) followed by INM practices (2165 kg/ha) as compared to farmers' practice (1190 kg/ha). Technology on protective irrigations (two times) with 90 x 60cm spacing produced higher yield of seed cotton (2400 kg/ha).

Coimbatore

Adoption of integrated cotton production technologies of CICR in the last two years and successful implementation of programme of NAIP project established an increase of ELS cotton area from 6 to 140 acres in that selected village. As per the specific objectives of production component of the project, ELS cotton production was executed in a 100 acre of land in the year of 2010-11. The mean yield of 8.96 q/acre was harvested, which was 46.8 and 61.6% higher than base line year (6.1 q/acre) and non project farmers (5.5 q/acre), respectively. However, mean cost of cultivation increased to 70.8% in 2010-11 in comparison to baseline years (Rs 7, 317/acre). The mean average gross return of Rs. 63,616 and net return of Rs. 51,123 were calculated per acre with benefit cost ratio of 5.1 in 2010-11. The baseline survey values had gross return of Rs. 18,220 and net return of Rs. 10,903 per acre with benefit cost ratio of 1.67. The economics revealed that higher of 249 and 61.6 % gross return, 368 and 103 % of net return realized in 2010-11 respectively in comparison to baseline year and non project farmers.

Demonstration of low cost drip irrigation system in cotton

Low cost poly-tubes drip system with polytubes of 150 micron was demonstrated at NAIP Project implemented village. Polytubes were punctured at single side at regular intervals (60 cm) and placed within the pair (60 cm) of paired rows planted cotton. Polytubes were laid in such a way that punctured holes face towards bottom side of the earth for water delivery. Polytube drip system (150 micron) was cheaper by 57.8% in comparison to existing drip system. The demonstration indicated, water saving to the tune of 30-45% and yield increase of 20-40%. The economics of adoption of low cost system found that higher gross return (Rs. 82,147/acre) and net return (Rs 48,812 /acre) realized as compared to conventional method of irrigation, which calculated gross return of Rs.63,190/acre and net return of Rs. 31,955/acre.

Demonstration of multitier cropping system

Multitier vegetable intercropping including radish, vegetable cowpea and coriander with cotton was demonstrated at NAIP project implementation village. RCHB 708 Bt Hybrid cotton was planted at 120 x 60 cm. Two ridges at 60 cm apart were formed making 120 cm. Cotton, radish, vegetable cowpea and coriander were planted on 4 sides of the 2 ridges in sequence. Periodic harvest of intercrops (coriander at 35 DAS, radish at 45 DAS and vegetable cowpea at 75 DAS) resulted in less competition to sole cotton. Demonstration of Multi-tier cropping system, cotton intercropped with radish, vegetable cowpea, coriander realized gross return of Rs. 85,138/ha and net return of Rs. 63,958/ha, whereas sole cotton system registered the gross return of Rs 63,619/ha and net return of Rs, 51,122/ha.

Front line Demonstrations in Cotton

Coimbatore

During the year 2010-11, CICR, Regional Station, Coimbatore conducted seventy five demonstrations on cotton production technology, one unit demonstration on cotton IPM and one unit demonstration on cotton farm implements in the villages

Vazhukkuparai, Meenaktchipuram, Kumarapalayam, Pachapalyam and Chattakalpudur of Madukarai block of Coimbatore district. The technologies demonstrated under cotton production technology were improved variety Suraj, Bt cotton hybrids RCH 2Bt, RCH 20Bt and RCH 530Bt BG II, RCH 625Bt and RCH 708Bt with improved package of practices, intercropping with cowpea and green gram, application of bio-fertilizers, pre emergence application of weedicides, management of micronutrient deficiencies, management of mealy bugs and stem weevil and soil test based nutrient management. The demonstration resulted in average yield enhancement of 1951 kg/ha as compared to the local farmers' practices (1464 kg/ha). One unit demonstration on cotton IPM was demonstrated in 50 hectares using the IPM module developed by the institute. Implements like power weeder, roto slasher and rotavator were demonstrated under the component of demonstrations on farm implements.

Sirsa

Fifty front line demonstrations were conducted during 2010-11 in Sirsa. Thirty FLDs were conducted on demonstration of *G. arboreum* varieties CISA-310& CISA-614. The demonstration recorded average yield 1720 kg/ha (CISA-310) and 1610 kg/ha (CISA-614), whereas, under farmer practice average yield of 1300 kg/ha for CISA-310 and 1310 kg/ha for CISA-614 recorded and which shows 24 and 18% increase in yield achieved by FLD over Farmer practice, respectively. Seed production of hybrid CICR-2 (GMS based intra *arboreum* hybrid) by 16 farmers produced on an average hybrid seeds of 443 kg/ha and income per ha (@Rs. 500/kg) amounts to Rs. 2, 21,500. Seed production of *G. arboreum* varieties CISA-310 & CISA-614 by four farmers gave average yield under FLD is 1131 kg/ha with income (@Rs. 50/kg) of Rs. 56,550/ha.

Impact analysis of IRM strategies

During the year 2010-2011, the IRM strategies were successfully implemented in 15 villages of Gudimangalam Block at Tirupur district. In total 188 farmers from 15 villages covering an area of 143 ha were covered under the project TMC-MM II-IRM. Implementation of IRM strategies resulted in reduction of number of sprays from 7 to 4 and plant protection cost from Rs.7,248/ha to Rs. 4,483/ha besides an increase in yield from 32.3 to 33.4 q/ha between Non IRM and IRM farmers.

Yield difference and additional financial benefit

Increased yield	1.1 q/ha
Reduction in sprays	3
Reduction in Insecticide usage	1271 g a.i/ ha
Savings on plant protection	Rs. 2765 / ha
Increased profit	Rs. 9056/ ha
Savings by the farmers of IRM village	Rs. 12,91,343/-

Sirsa

Crop Management Practices

An area of around 50 acres was selected in three villages Nejadela, Khurd and Jhonpara with 24 farmers and Bt cotton hybrid Bioseed-6488 BG was planted. The farmers were trained in best management practices like application of fertilizer based on soil test, maintenance of proper plant stand through gap filling from a separately raised nursery of seedlings, training on identification of pests and beneficial pest and need based interventions based at economic threshold levels. Farmers were also trained about the various contaminants and trash and benefits of clean picking at their own fields. The B:C ratio of project farmers was 1.88 compared to 1.19 in case of non project farmers. In terms of quality also the trash content in the lint of project farmers was reduced to 2.4% when compared with non projects farmers at 5%. The procurement of seed cotton and its ginning in TMC approved factory was carried out followed by tagging of individual bales and making of yarn. The process of preparation of finished goods like towels and other apparels is in progress.

6. Education and Training

6.1: Training Received

6.1.1: International Training

Name of the scientist	Name of the course	Place	Period
Dr K Rathinavel	International programme on Plant Variety Protection and DUS testing for Indian Experts	National Institute of Agricultural Botany (NIAB), Cambridge, UK	June 28 - July 9, 2010

6.1.2: National Training

Name of the scientist	Name of the course	Place	Period
Dr.K.P.M. Dhamayanthi	Training programme on Molecular Cytogenetics and Tissue Culture Techniques	CSK Himachal Pradesh Agriculture University, Palampur	Apr. 12- 26, 2010
Dr. D. Kanjana	90th Foundation Course for Agricultural Research Service (FOCARS)	NAARM, Hyderabad	Apr.20- Aug.17, 2010
Dr. V. N. Waghmare	Molecular tools for crop improvement	ICRISAT, Patancheru, Hyderabad	May 10-21, 2010
Dr. Anuradha Narala	91st Foundation Course on Agriculture Research Management	NAARM, Hyderabad	May 11 to Sept. 7, 2010
M. Sabesh	Training programme on Strengthening Statistical Computing	CIFE Mumbai	Jul. 11 to Aug.14, 2010
Dr. Annie Shiba A. Sampath kumar	92nd Foundation course for Agricultural Research Service (FOCARS)	NAARM, Hyderabad	Sept. 1 to Dec. 29, 2010
Dr. G. Balasubramani	IPR and WTO issues	TIFAC, Gurgaon	Sept. 6-10, 2010
Dr. Anuradha Narala Dr. K. P. Raghavendra	Technology Diplomacy	CUTS International Jaipur	Oct 4-8, 2010
Dr. M.V.Venugopalan	Cropping System Models: Applications in Land Resource Management	ICRISAT, Patancheru, Hyderabad	Oct. 18-22, 2010
Dr. S. M. Palve	Training course on Application of molecular markers for crop improvement	ICRISAT, Patancheru, Hyderabad	Nov.8-19, 2010
Dr. Anuradha Narala	Researchers training programme on SAS	Dept. Of Agricultural Statistics, BA College of Agriculture, Anand Agricultural University, Anand	Dec. 18-23, 2010
Mr. M. Saravanan	IPR and WTO issues	TIFAC, New Delhi	Dec. 27- 31, 2010
Dr. Annie Shiba Dr. A.K. Mukherjee, Dr. C.B.Naik, Mr. Sampath Kumar	National Training Programme on Molecular characterization of GMO's and its purity testing	CICR, Nagpur	Jan. 18 - Feb. 7, 2011
Dr. M.V.Venugopalan Dr. A.H. Prakash	RISAT UP training programme	Regional Remote Sensing Centre, Nagpur	Feb. 14-19, 2011
Dr. D. Kanjana	Training programme on Geoinformatics in land resource management	NBSS & LUP, Nagpur	Mar. 9-29, 2011
Dr. M. Amutha	Short term course on Molecular tools and Techniques in Plant and Animal Biotechnology	Bharathidasan University, Tiruchirapalli	Mar. 11-25, 2011

6.2 : Training Imparted

Nagpur

National training on molecular characterization of GMO's and its purity testing

A National Training on "Molecular Characterization of GMO's and its Purity Testing" for 21 days was conducted at CICR, Nagpur from 18.01.11 to 7.02.11. The training was inaugurated by Dr. M. M. Pandey, Honorable DDG (Agril. Engineering), ICAR. In his inaugural address he expressed that it is appropriate to conduct such kind of training in the era of GMOs / Bt crops to identify and check spurious seeds coming to the market. He also lauded CICR for inventing Bt Detection kits to help the farmers as well as the Seed Testing officials.

This training was attended by 30 candidates of various departments from all over India. The programme included Theory and Practicals covering –Bt detection methods, Molecular Characterization of GMOs and Seed purity, Seed laws and related issues. It also included field visits to Ankur, Daftari private seed companies and Magar Sangrahalaya, Wardha. The Course Coordinators of this training Programme were: Dr. P. R. Vijaya Kumari, Dr. Sandhya Kranthi, Pr. Scientists and Dr. G. Balasubramani, Sr. Scientist, CICR, Nagpur. The Valedictory function was graced by the presence of Shri. D. Kanakaratnam, IPS, Joint Commissioner of Police, Nagpur.

Model training course on integrated cotton based farming system

Eight-day National Model Training Course on Integrated Cotton Based Farming System sponsored by Directorate of Extension, Govt. of India, Ministry of Agriculture & Cooperation, New Delhi was organized from 25th October to 1st November 2010 at CICR, Nagpur with a view to enhance technical know-how of senior and middle level extension personnel of State Agricultural Departments, to impart new knowledge, skills and sensitize the participants in new research concepts on judicious use of input to cotton based cropping system. Eighteen participants from the states of Tamil Nadu, Karnataka, Andhra Pradesh, Rajasthan, Madhya Pradesh and Maharashtra attended. The participants were exposed to various aspects of cotton production, protection, processing, intercropping, farming system concepts & models, biotechnological approaches, seed production issues, weed management, post harvest management, economics of cotton farming and dissemination strategies. Considering current emerging problems such as rising cost of production, erratic climatic behaviour and non-remunerative single farming system, the lectures on use of associated enterprises with cotton such as integration of horticultural crops, livestock, fisheries, dairy, sericulture, poultry etc. were also covered for the benefits of farmers as it adds additional income, employments, profit and helps in improving overall economic condition of the farmers. The participants were also exposed to demonstration at various experimental fields including farmer's field in village Padgavari in Ramtek tahsil, laboratories and machinery workshop of CICR, NRCC and GTC. In all, 34 speakers including six guest speakers and 28 institute faculties provided excellent opportunities to share views and exchange each other experiences. The participants were supplied with course material like compendium of literature notes, books, and bulletins for further dissemination among various users. The course was conducted by Dr. S.M. Wasnik, Principal Scientist (Extension).

Training on cotton production technology

Two training programmes of one day each was organized on cotton production technology for FLD beneficiary farmers at villages Khursapur and Dhondgaon (Samudrapur tahsil) of Wardha district in Vidharbha region of Maharashtra. The training programme was attended by 82 farmers including 63 male and 19 female farmers. Dr. S. M. Wasnik, Principal Scientist (Extension) coordinated the programme. Also, imparted training to 38 extension workers of State Agri. Dept from Vidharbha at Samudrapur in Wardha district on 20/10/2010

Coimbatore

Training on sustainable cotton production

A one day farmers training program on "Sustainable Cotton Production" was inaugurated by Dr. T. Surulivelu, Acting Project Coordinator (Cotton) and Head, Regional station, Coimbatore under the project TMC MM-II -Insecticide Resistance Management. Dr. B. Dhara Jothi, Senior Scientist and District Coordinator of the project highlighted the Insecticide Resistance Management on cotton and explained the detailed activities of the project.

7. Awards and Recognitions

- Dr. K. R. Kranthi, Director, CICR was honoured with a special Bremen Award by President of the Bremen Baumwollborse, Wolfgamg vogt-Jordan in Germany during the 30th International Cotton Conference, held in Bremen, Germany from March 24-27, 2010.
- Dr. M. Amutha, Scientist, CICR, Regional Station Coimbatore received JUNIOR SCIENTIST OF THE YEAR - 2010 award from International Board of Awards of National Environmental Science Academy, New Delhi, India.
- Dr. S. N. Rokde received first prize [Dr. Madrewar Supplementry Business Award] for the article entitled," *Ushmyache mhshinvar honare dushparinam aani upay*"in Marathi language and published in Baliraja magazine.

8. Linkages and Collaborations

Areas of Linkages	Institution
NATIONAL	
Fibre testing and quality evaluation	CIRCOT, Mumbai
Multi-location testing of promising cultures, Bt Cotton evaluation	AICCIP (21 centers)
Germplasm collection maintenance and plant quarantine clearance	NBPGR, New Delhi
Seed technological research and breeder seed production	NSP
Development of cry1A (a) gene construct	NBRI
Supply of gene construct and molecular evaluation of transgenic plant.	NRC Plant Biotechnology, New Delhi
DNA finger printing of cotton	NRC DNA Finger Printing, New Delhi
Efficacy of lectins on sucking pests	NIMITLI project with NBRI, Bose Institute, Kolkata, NII, New Delhi, Delhi University, New Delhi, UAS, Dharwad, JK seeds.
Technology for pink bollworm management	State department of Agriculture, Haryana, KVKs, CCS HAU, Hisar, NCIPM etc
INTERNATIONAL	
Insect transgene detection kits	Indo- Australian Project with TERI, CEASAR

9. All India Coordinated Cotton Improvement Project

CROP IMPROVEMENT

National Trials

- Nine National Trials that included, four North Zone trials, eight Central Zone trials and seven South Zone trials were conducted during the year 2010-11 in 221 locations.
- In irrigated national trials, *G. hirsutum* cultures *viz*., F 2228 was promising in North zone whereas, MR 786 was promising in both Central and South zones.
- In the preliminary intra-*hirsutum* hybrids trial, the hybrids FHH 200, BHH 624 and RAHH 951 ranked first respectively in North, Central and South Zone.
- All the twelve *G. barbadense* cultures recorded higher seed cotton yield over the common check variety Suvin in both Central and South zone locations. The entry GSB 40 and GSB 41 ranked first in terms of seed cotton yield in Central and South zone respectively.
- In the preliminary interspecific hybrids (*G. hirsutum* x *G. barbadense*) trial, the hybrids GSHB 929 and ARBHB 1011 were promising in Central and South Zone, respectively.
- Promising *G. arboreum* genotypes -RG 585 and JLA 505 have been identified for promotion in different zone. Similarly desi hybrids like Simulai, RAJDH 444 and NACH 18 showed promise in different zones.
- In Central zone locations, the *G. hirsutum* genotype GBHV 164 was promising and occupied the top rank under rainfed situations, whereas in South Zone locations, CPD 168 was the best culture.
- In the preliminary intra-*hirsutum* hybrids trial under rainfed conditions, the hybrid NHH 421 was promising in both Central and South Zone locations.
- *G. herbaceum* culture GBhv 288 was found to be superior to the zonal check variety G. Cot 23 in Central Zone.

Zonal Trials

North Zone

- In the *G. hirsutum* Preliminary Varietal Trial, six cultures showed promise and F 2164 recorded the highest seed cotton yield of 2686 kg/ha.
- In the Coordinated hybrid trial, all the five test hybrids performed better than both the check hybrids and RAJHH 743 (3021 kg/ha) was the best hybrid.
- *G. arboreum* genotypes CAD 3 and RG 542 were promising.

Central Zone

- In irrigated trial, culture CCH 2623 was the best in the Preliminary Varietal Trial and the genotype BS 279 was superior in the Coordinated Varietal Trial. In rainfed trials, GISV 218 was promising.
- In the Coordinated hybrid trial, the hybrid RAHH 259 was superior in *intra-hirsutum* category and RAHB 189 was the best in interspecific (*G. hirsutum* x *G. barbadense*) hybrid category under irrigated conditions.
- In the Coordinated intra-*hirsutum* hybrid trial, the hybrid NHH 206 was the best and MRDC 233 was the best in desi hybrid group under rainfed conditions.
- GAM 141 was the best performing genotype in the coordinated varietal trial of *G. arboreum*.

South Zone

- The *G. hirsutum* genotype, GSHV 155 was the best in Preliminary Varietal Trial and BS 279 was superior in Coordinated Varietal Trial under irrigated conditions.
- The hybrid NSPL 423 was the best entry under irrigated conditions in Coordinated hybrid trial.
- In inter-specific hybrid category, highest seed cotton yield was recorded in genotype JKCHB 217.
- Under rainfed situation, the genotype NHH 59 was found superior.
- In *desi* category, *G. arboreum* variety CNA 1007 and the hybrid MRDC 233 were the best performing entries.

CROP PRODUCTION

- Agronomic requirements like spacing and optimum fertilizer dose for *hirsutum* variety H-1300, intra-*hirsutum* hybrid SVHH-139, *arboreum* variety FDK-124 and *desi* hybrid FMDH -7 were worked out for North Zone. Similarly, agronomic requirements were worked out for hirsutum varieties *viz*., GJHV 374, GSHV 152, GTHV 02/45, TCH 1705, P 72-9-37, intra-*hirsutum* Hybrids *viz*., ARCHH 8188, GGCH 70 and Inter-specific Hybrids viz., JKCHB 214 and RAHB 170 in Central Zone locations under irrigated situations and in rainfed conditions for *hirsutum* varieties *viz*., NH 630, GTHV 0/35, KH 155, GSHV 01/26 and *desi* hybrid – GGCH 81. In South zone, agronomic requirements for *intra-hirsutum* hybrid – KDCHH 712 and interspecific hybrids *viz*., JKCHB 214, RAHB 170 under irrigated conditions, *desi* hybrids NACH 12 and GGCH 81 and *desi* variety CNA 1003 in rainfed situations were worked out.
- For optimization of nutrient requirement and plant geometry for Bt cotton, RCH–134 Bt was used at Ludhiana, Sirsa and Sriganganagar of North Zone. The normal spacing showed its superiority at Sriganganagar but wider spacing is seen favourable at Ludhiana and Sirsa. The 100% R.D.F seems to be optimum at all the locations.
- In Central Zone, for RCH –2 Bt, normal spacing seems to be optimum with 100% RDF at Khandwa, Surat and Akola, while 125% RDF was suitable at Nanded, Indore and Rahuri. In south zone, normal spacing with 125% RDF was seen optimum for Bunny Bt. Besides these, effective integrated weed management strategy has been worked out in different locations.
- Foliar feeding of secondary/micronutrients with $MgSO_4$@ 1.0% + $ZnSO_4$ @ 0.5% at Kanpur and Banswara, $MgSO_4$ - 1.0% at Faridkot and $FeSO_4$ - 0.5% at Ludhiana gave significantly higher seed cotton yield in North Zone. Similarly in Central and South Zone, spray of $MgSO_4$@ 1.0% + $ZnSO_4$@ 0.5% gave significantly higher seed cotton yield.
- In a study with foliar application of KNO_3 to increase yield and yield attributes, full dose of MOP at sowing and four sprays of 2% KNO_3 at Kanpur were effective in North Zone, whereas in Central and South Zones, three sprays of 3% KNO_3 at Nanded and Banswara, four sprays of 3% KNO_3 at

Indore, four sprays of 2% KNO_3 at Rahuri and two sprays of 3% KNO_3 at Siruguppa gave significantly higher seed cotton yield.

- Under crop canopy management studies, narrow spacing of 60 x 30cm combined detopping after 55 DAS recorded higher seed cotton yield at Khandwa.
- The plant height, stomatal conductance, relative water content, transpiration rate, number of bolls, biomass, boll weight and yield was significantly reduced due to moisture stress in genotypes of *G. hirsutum*.
- Seed cotton yield decreased with the increase of Ethrel concentration and maximum yield reduction was observed when Ethrel was applied at 130 DAS as compared to 145 DAS in different concentration. Per cent defoliation was higher when Ethrel was applied at 145 DAS as compared to application at 130 DAS for all concentration.
- Parawilt affected plants recovered with the timely treatment of Cobalt chloride.
- Free amino acid and proline content were higher in the leaf under rainfed condition as compared to irrigated condition, while reducing sugar and protein declined under rainfed condition. The higher amount of free amino acid and proline might have helped in building the osmotic potential for the tolerance.
- The high oil containing genotypes CSH-7106 (26.01%), B-58-1290(26.50 %), 3HS (25.55%) and F-1861 (25.02%) has been identified at Dharwad which can be used in breeding programme to increase the oil content keeping the present level of fatty acid composition intact.
- Highest oil content was recorded in G. Cot. Hy 10 (20.0%) followed by entry no. 9117 (19.67 %) and it was lowest in entry no.9112 (16.03 %). *Gossypol* content in different genotypes ranged from 0.3 to 0.5 per cent. Maximum protein content was recorded in G.Cot. Hy10 (25.6%).
- Different biochemical parameters *viz*., total chlorophyll content, chl a: chl b ratio, anthocyanin content and nitrate reductase activity were studied at boll developmental stage and all these parameters showed significant variation in response to various leaf reddening management applications.
- Biochemical parameters like reducing sugars, tannins, total phenols and orthodihydroxy phenols were studied in leaf and square tissues of thirty four entries which indicated progressive decreased in squares as compared to leaf.
- *Cry1Ac* expression was found to be significantly variable among the Bollgard I and Bollgard II hybrids and also between different parts like leaf, squares and boll rind. The leaves of the Bt cotton hybrids were found to have highest levels of endotoxin protein expressed compared to squares and boll rind.
- The *cry1Ac* expression decreased drastically over the crop growth with endotoxin level falling below the critical level of 1.9 μg/g after 110 DAS.

ENTOMOLOGY

North zone

- Population dynamics study revealed that jassid population was at higher level (8.5 to 33.0 / 3 leaves) in Ludhiana, at moderate level (5.8 to 8.8/ 3 leaves) in Hisar and below threshold level throughout the season in Faridkot and Sriganganagar. Whitefly was in higher level only in Sriganganagar (31.2 to 35.8 / 3 leaves), while thrips were below threshold level in all the centres.
- There were no incidences of *H. armigera* and *S. litura* in Sriganganagar, Faridkot and Ludhiana. Sriganganagar and Ludhiana had moderate to higher level of Spotted bollworm (5.0 to 9.5 larvae / 5 plants). Pink bollworm was at higher level (2.0 to 6.2 / 20 green bolls) only in Sriganganagar and almost no incidence was noticed in Faridkot and Ludhiana

Central Zone

- Except Khandwa in all other centres *viz*., Akola, Banswara, Junagadh, Bhawanipatna, Nanded and Rahuri high population of jassid was recorded ranging from 7.8 to 47.1 / 3 leaves. Junagadh recorded higher thrips population (33.2 to 63.6 / 3 leaves), while Banswara had higher whitefly population (32.6 to 35.6 / 3 leaves). Junagadh also had higher aphid population (35.0 to 64.0 / 3 leaves). Very low intensity of mealybug damage was observed in Junagadh, Surat and Rahuri and it was absent in other centres.
- *H. armigera* bollworm was at moderate level (3.0 to 8.0 larvae/5 plants) in Akola, Bhawanipatna, Junagadh, Khandwa, Rahuri and Surat while *Earias* bollworm was at higher level (4.0 to 10.0 larvae / 5 Plants) in Bhawanipatna and Rahuri. Pink bollworm was at higher level in Junagadh (6.4 to 5.6 larvae / 20 green bolls), Surat (5 to 9.4), Rahuri (4 to 8) and in Akola (3.4 to 6.4).

South Zone

- Jassid population was at higher level in Lam (13.8 to 52.7 / 3 leaves), Srivilliputur (10.2 to 18.4), Coimbatore (6.0 to 15.7), Dharwad (6.2 to 13.2) and Raichur (6.9 to 13.2). Aphid was at higher level in Lam (2.6 to 52.7 / 3 leaves) while thrips were higher in Dharwad (37.0 to 41.0 / 3 leaves).
- The intensity of mealybug infestation was 2.0 to 4.0 grade in Coimbatore and 1.0 grade in Srivilliputur. Mirid bug population was at higher level in Dharwad (10.0 to 29.0 / 25 squares).
- *H. armigera* was at higher level in Dharwad (5.3 to 10.2 larvae / 5 plants) and at moderate level in Raichur (2.2 to 4.6). *Earias* bollworm was at moderate level in Srivilliputur (2.0 to 4.0 larvae / 5 plants) and at higher level in Dharwad (4.3 to 8.2). Pink bollworm was at higher level in Dharwad (5.0 to 23.0 larvae / 20 green bolls), Nandyal (6.0 to 9.0), Raichur (2.8 to 4.4) and Srivilliputur (2.0 to 5.0).
- Acephate 75 SP (750 g) and the new formulation of Acephate 95 % SG (562.5 & 750 g) were effective against major sucking pests (Jassid, aphid, thrips and whitefly) and resulted in higher yield ranging from 63.3 to 76.0 %, followed by Imidacloprid (57.3 %) and Acetamiprid (51.1 %) in North zone.
- Acephate 95 % SG and Acephate 75 SP (750 g) were effective against major sucking pests (Jassid, whitefly, thrips and aphid) and gave higher yield by 52.0 to 59.6 % over control in Central zone.
- Acephate 75 SP, Thiomethoxam, Acetamiprid and Acephate 95 % SG were effective against major sucking pests (Jassid, aphid, thrips and whitefly) and resulted in higher yield by 35.0 to 38.0 % over control in South zone.
- Profenophos, chlorpyriphos and Buprofezin were effective against mealybug and resulted in higher yield in North,

Central and South zone. Biopesticides *viz*., Mealy Kill, Mealy Quit, *M. anisopliae*, *B. bassiana*, *V. lecanii* were moderately effective.

PLANT PATHOLOGY

- Cotton leaf curl disease (CLCuD) appeared in epidemic form in Ferozepur district of Punjab on RCH BG II and non descript susceptible genotypes resulting in considerable yield losses. In Rajasthan, out of six districts the disease was present in two districts only i.e., Sriganganagar and Hanumangarh, the traditional cotton growing belt of state. Cotton in the remaining four districts *viz*., Nagour, Jodhpur, Alwar, and Palli were completely free from leaf curl. Sriganganagar district had a higher average disease intensity compared to Hanumangarh district. CLCuD was observed in traces at farmer's fields in different Bt cotton hybrids in Haryana.
- Number of bolls (40.9% & 31.4%) and seed cotton yield (41.9% & 41.4%) were significantly reduced by CLCuD in RCH 134 in farmer fields and MRC 6304 Bt at research farm, respectively, when the DI was 100.0 with mixed infection grades in Faridkot dist. Whereas reduction in seed cotton yield ranging from 8.0 to 77.6% in different severity grades were noted in Bt cotton hybrid RCH 134 at Abohar.
- Low rainfall, high temperature and moderate relative humidity during the vegetative phase of crop favoured high population build up of white fly early in the season with available virus inoculum and some susceptible Bt cotton hybrids especially in the hot spots led to higher disease incidence.
- Bacterial blight was reported as important disease in Central zone in Khandwa in Madhya Pradesh (32.3%), Maharashtra (Vidahrbha- 5.5-21.11%, Nanded 2.2-16.2 %) and in South zone in Karnataka (5.0-15.0 %) and Andhra Pradesh (27.0%).
- *Alternaria* blight was serious in Gujrat's Saurashtra area (2.0-25.0%), Bharuch (5-60%), Khandwa in Madhya Pradesh (48.2%) and Maharashtra's Rahuri (0-29.3 %) and Nanded (3.0-21.5%) and in South zone in Karnataka (5.0-15.0%) and Tamil Nadu (10.0-26.0%). *Myrothecium* was severe in Madhya Pardesh (39.3%). *Cercospora* was reported to be severe in Tamil Nadu (12.0-50.0%).
- *Grey mildew* occurred in Maharashtra in the irrigated areas (14.6-21.0%). In south zone it was severe in two states i.e., Karnataka (upto 30.0%), and Andhra Pradesh (upto 23.3%).
- Tobacco Streak Virus incidence upto 28.06 % was observed in Andhra Pardesh in January.
- Tetraconazole 11.6% w/w ME at 3 doses, @ 900 ml/ha, 800 ml/ha, 650 ml/ha tested showed the lowest PDI of *Alternaria*. Maximum yield increase of 22.97% was observed in Tetraconazole 11.6% w/w ME @ 900ml/ha followed by 15.14% at 800 ml/ha.
- Seed treatment with *Pseudomonas fluorescens* (TNAU) @ 10 g/kg seed plus foliar spray @ 0.4% on 60 and 90 DAS gave good disease control of 53.73% followed by SAR inducing chemical (Salicylic acid) @ 50ppm on 60 and 90 DAS with disease control of 50.75% in case of *Grey mildew*.
- Five sprays of carbendazim at 35, 50, 65, 80 and 95 days after sowing showed reduction of *Grey mildew* PDI from 14.46 to 5.61 and reduction of yield loss upto 27.51%.
- Five sprays of COC (0.3%) + SS 500 ppm at 35, 50, 65, 80 and 95 days after sowing showed reduction of bacterial blight PDI from 28.06 to 14.26 and reduction of yield loss upto 22.85%.
- Five sprays of Propiconazole (@ 0.1%) at an interval of 35, 50, 65, 80 and 90 DAS at Khandwa showed reduction of *Myrothecium* leaf spots PDI from 22.36% to 7.56% and reduction of yield loss up to 40.66 percent.
- Four sprays of Propiconazole (@ 0.1%) at an interval of 15 days starting from 75 days after sowing has given a good disease control of leaf rust at Dharwad (47.46%) with maximum seed cotton yield of 3598 kg/ha as compared to 3071 kg/ha in control.

10. Krishi Vigyan Kendra

Training Achievements

Seventy three short duration (1 to 3 days) on campus and off campus training courses were conducted in different disciplines for practicing farmers, rural youth and extension functionaries. In all 1888 participants including 491 SC/ST participants benefited from the training programme conducted by Subject Matter Specialists (SMS) of KVK, as details below;

Disciplines	No. of courses	No. of Participants	SC/ST participants
Crop Production	14	514	96
Horticulture	14	335	67
Plant Protection	15	426	108
Veterinary Sci.	15	321	111
Home Science	15	292	109
Total	73	1888	491

Similarly, 10 sponsored training courses were organized for 1 to 3 days duration in different disciplines *viz*., Crop Production, Horticulture, Plant Protection, Veterinary Science and Home Science for farmers and extension functionaries deputed by State Agriculture Department of Maharashtra, ATMA, CIPM Nagpur, MAFSU Nagpur, MCED & ICDS Nagpur. In all 376 participants attended these courses.

On Farm Trials for Technology Assessment and Refinement

Technology Assessed

- In order to improve reproductive performance and milk production in cow, KVK assessed the performance of feeding vitamin-mineral mixture @ 30 g/cow/day in the diet of cross bred Jersey cows under stall-fed livestock production system in adopted villages. The result showed significant increase in milk yield from 8.50 to 10.20 l/cow/day, whereas, 100% conception rate, net returns (Rs. 27,860/cow/yr) and B:C ratio (2.60) was observed as compared to conventional practice (without inclusion of mineral mixture and deworming).
- To combat mineral deficiencies and problem of low milk yield in cow, KVK assessed the performance of supplementation of chelated mineral @ 30 g/cow/day in the diet of cross bred jersey cows under stall-fed livestock production system in adopted villages. The results revealed significant increase in milk yield from 8.90 to 10.10 l/cow/day without occurrence of repeat breeding problem with net returns (Rs. 27,180/cow/yr) and BC ratio (2.28) as compared to traditional method of livestock feeding with locally available feeds and fodder.
- Assessment trial was conducted on high yielding variety of Onion (Akola Safed) in Ranmangali and Manori villages on 10 farmer's fields covering four hectare area. An significant increase in yield (20.35%)was recorded over local variety with additional net return of Rs. 9120/- per ha.
- Assessment trial was conducted on Biocontrol of semi-loopers in soybean in villages Pipra and Manori on eight farmer's fields covering an area of 3.2 hectare. Foliar application of *Beaveria bassiana* @ 1.0 kg/ ha. followed by 2nd spray of azadiractin 1500 ppm @ 25 ml/10 l of water at ETL reduced the semi-looper population and substantially increase the grain yield by 9.95% over farmer's practices.
- Assessment trial on optimization of plant density in Bt Cotton was conducted on 5 farmer's field with 2.50 hectare area. It was observed that Bt Cotton at plant spacing of 120 cm x 45 cm recorded significantly higher seed cotton yield (2027 kg/ha) as compared to 90 cm x 90 cm and 150 cm x 60 cm plant spacing.
- The newly released variety PKV Tara of pigeon pea was assessed on 5 farmer's fields with an area of 2.50 ha. PKV Tara recorded significantly higher grain yield of 15.10 q/ha than conventional pigeon pea varieties ICP 8863 and BSMR 736.

On Campus Crop Demonstrations : Twenty five crop demonstrations on cotton, pigeonpea, soybean, *Lathyrus sativa*, linseed, fodder Jowar (Maldandi), fodder Maize, berseem, vegetables viz. onion, brinjal, radish etc., fruits and flowers were undertaken on KVK's instructional farm during *kharif* and *rabi* season as well as in technology park. The production and protection technologies of these crops were demonstrated on an area of 0.2 - 0.4 ha for each crop. Large number of farmers, farmwomen and extension functionaries from Nagpur district of Maharashtra and other states visited these demonstrations.

Kisan Mobile Advisory Services (KMAS) : KVK, Nagpur has launched Kisan Mobile Advisory Services (KMAS) for the benefit of the farmers of Nagpur district. Advisory messages on agriculture and allied technologies on the mobiles of the farmers who are registered with KVK are regularly being sent.

Development of KVK's website : Website with domain name: www.kvknagpur.org.in has been developed and launched in January 2011.

Technology Park at KVK : Technology Park has been established in KVK's instructional farm for depicting cropping pattern of Nagpur district. The area of technology park is protected by erecting chain linked fencing around it to safeguard the crops from predators.

Osmanabadi Goat unit : An amount of Rs. 84,138/- generated by selling of 17 Osmanabadi bucks and 26 females to five beneficiaries of Nagpur district. The beneficiary farmers are seeking advisory services through mobile and personal contacts. The Osmanabadi bucks sold to the farmers are bringing about genetic improvement in local goats.

Fruits, Vegetables and flowers demonstration unit : Fruits, vegetables and flowers demonstration units with high yielding varieties and production technology were established for the benefits of farmers and Extension Functionaries. An amount of Rs. 48,603/- was generated by auctioning of guava fruits and selling of vegetables and flowers.

Soil testing at KVK : 75 soil samples from beneficiaries of five tahsils were tested for its PH, EC and major nutrients viz. N,P and K and appropriate recommendations were given to the farmers.

Front Line Demonstrations

Nineteen technologies were demonstrated in the discipline of crop production, plant protection, horticulture, livestock production and home science under Front Line Demonstrations on farmer's field of adopted villages namely Manori, Pipra, Saisar, Ranmangli and Dongargaon. Several extension activities like field days, field visits of farmers to FLD demonstrations, group discussions, scientists-farmers meet, etc. conducted for effective implementation of FLDs. Data on certain production parameters as well as feedback from farmers and visitors were recorded.

FLD on Crops

Sr. No.	Crop	Technologies Dermonstrated	No. of Farmers	Area (ha)	Yield (q/ha)		% Increase over FP
					Demonstration	Farmer's Practice	
1	Cotton	Drip Irrigation	5	2.5	38.6	25.5	51.37
2	Cotton	Plant Spacing	5	2.5	18.70	40.6	28.08
3	Cotton	Pesticide application	5	2.5	14.46	13.0	11.23
4	Cotton	INM	10	4.0	16	13.15	21.67
5	Cotton	Integrated Crop Management	10	4.0	17.2	13.6	26.47
6	Soybean	INM	25	10	22.5	17.5	28.57
7	Wheat	AKW 3722	7	3.0	37.5	30.6	22.54
8	Chickpea	JAKI9218	12	4.8	12.6	10.3	22.33
9	Wheat	RAJ 4037	7	3.0	32.7	27.1	20.66
10	Linseed	NL 260	13	5.2	10	7.3	36.90
11	Cotton	IPM	25	10.0	16.25	13.2	23.12
12	Redgram	Production Technology	30	12.0	16.15	13.17	22.63
13	Chickpea	Production Technology	30	12.0	14.16	10.64	33.08
14	Chickpea	*Helicoverpa* management	20	8.0	13.75	12.5	10.00
15	Brinjal	Shoot & fruit Borer Management	15	6.0	160	118	35.59
16	Chilly	Thrips Management	15	6.0	110.0	89.5	22.90
17	Tomato	Varietal(PKM-1)	10	4	88.45	75.85	16.61
18	Okra	Varietal(Utkarsha)	10	4	55.5	47.5	16.84
19	Farm women	Drudgery reduction	10	18	47 m^2/h	35 m^2/h	34.20

FLD on Livestock Enterprises

Under Veterinary discipline, three FLDs on 40 cows and 40 local goats were conducted on the farm of 30 farm families in the villages namely Dongargaon, Tas and Ranmangli. The details are as follows:

Enterprise	Breed	No. of farmers	No. of animals	Performance parameters /indicators	Average yield		% change in the parameter	Cost benefit ratio of demo
					Demo.	Local check		
Dairy farming (Urea treatment of paddy straw)	Jersey Cross	10	20	Av. Milk yield lit/cow/day	6.20	4.20	47.62	1:2.10
Dairy farming (Control of mastitis)	Jersey Cross	10	20	Av. Milk yield lit/cow/day	9.10	6.40	42.19	1:2.30
Goats	Local	10	40	Weight gain Body coat	3.9 kg Healthy & shining	2.4 kg Dull, rough- & alopecia	62.5 -	1: 2.26

Celebration of 'Technology Week' : Technology Week was organized on 14 -19 Feb, 2011 and information of the areas of local importance viz. crop production, crop protection in various cropping system, animal husbandry and drudgery reduction in farm women were especially provided to the farmers. Large number of participation of farmers and extension workers in villages was ensured through personal invitation.

Organized '*Kisan Mela*' : Organized a *Kisan Mela* at village Pipra in Nagpur on February 25, 2011. Dr. G. Malvi, Retd. Professor (Agronomy), Dr. Sharnagat, Retd. Prof. and Head Dept. of Entomology and Dr. Nandanwar, Asso. Prof.

(Entomology) addressed the farmers the pest problems, identification and its management, INM for higher production. More than 200 farmers including cotton, vegetable growers and livestock owners participated and benefited through information provided by the experts. KVK also organized *Krishi Mela* at Burujwada, tahsil of Saoner on February 17, 2011 and about 100 farmers participated in this mela.

Organized '*Kirtankar Mela*' : *Kirtankar Mela* was organized at village Pipra, Tq. Umred, Dist. Nagpur on February 18, 2011 and more than 200 farmers were participated. Dr. Peshkar Retd. Professor (Entomology) demonstrated the farmers on cotton cultivation through his innovative style of *kirtan*.

Health Camps for Livestock: Livestock Treatment and Vaccination camp was organized in Ranmangli village of Bhivapur tahsil on February 21, 2011. More than 200 goats were immunized against *Enterotoxaemia* disease. Allied animals were also treated and recommended medicines for their recovery. More than 15 participants benefited by seeking treatments for their livestock.

Diagnostic Survey : Thirty diagnostic surveys was undertaken in adopted villages and other non adopted villages of Nagpur district and suggest the remedies to overcome specific problems in crops, citrus orchard and animals covering more than 90 ha cropping area and 120 animals in 21 villages of six tahsils of Nagpur district.

Participation in Exhibitions

1. State and National level Agricultural Exhibitions "*Dhammachakra Pravartan Din*" from 16th to 18th October 2010 at *Dikshabhoomi*, Nagpur, organized by Joint Director of Agriculture, Nagpur Division. More than 2500 farmers visited to exhibition stall of KVK during exhibition and many participants actively interacted with resource persons.
2. State level Agricultural Exhibition at RRC, Amravati on the occasion of "Dr. Panjabrao Deshmukh Birth Anniversary" from 27th to 29th October 2010 organized by Dr. PDKV, Akola. More than 30000 farmers visited to stall during exhibition and interacted with technical person present in the stall to get the expert knowledge.
3. "*Rashtriya Kisan Mela*-2010" organized by National Research Centre for Citrus, Nagpur from 4th to 5th March 2011. More than 1000 farmers visited the stall and appreciated the activities of CICR, visitors showed keen interest in Bt. Detection Kit & transgenic Bt. straight varieties of cotton.
4. "Agrovision – 2011" A State level exhibition organized at Reshimbagh Ground, Nagpur from 4th to 7th March 2011.
5. Agri-Expo-Harit Kranti-2010 held, at Baramati Distt. Pune during Nov. 1-4, 2010. The exhibition was inaugurated by Shri Sharad Pawar Hon'ble Union Agriculture Minister, Govt. of India,

Scientific Advisory Committee Meeting : The 15th SAC meeting of KVK Nagpur was conducted on October 27, 2010 under the chairmanship of Director, CICR, Nagpur. More than 15 members from agriculture and allied departments participated in the SAC meeting and assessed the work of KVK and recommended future extension activities of KVK for different crops and livestock.

Recruitment of staff : Three posts i.e. Programme Assistant (Lab Technician), Programme Assistant (Computer) and Driver in KVK were filled up during 2010-11.

Visitors : 971 visitors including practicing farmers, farm women, rural youths and extension functionaries visited the instructional farm, technology park, goat unit, fruit cafeteria and vermicompost unit of KVK, CICR, Nagpur.

11.1 : List of Publications

Papers Published in Research Journals

- Acharya L., Mukherjee A.K. and Panda P.C.(2010). Validation of generic status of different taxa in the subtribe Cassiinae (*Leguminosae* : *Caesalpinoidae*) using RAPD, ISSR and AFLP markers. Int. J. Plant Physiol. Biochem. 2(2) 18-28.
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- Gopalakrishnan, N., Prakash, A.H. and Balachandran, Y.L. (2010). Differential metabolic and rapd expression during early fibre development in normal and its lintless mutant of cotton (*Gossypium hirsutum* L.). Indian Journal of Plant Physiology, 15(4): 373-377
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Technical Bulletins

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2. Usha Rani S., Sabesh M., Shankaranarayanan K. and Gopalakrishnan N. (2010) Frequently Asked Questions in Cotton (Tamil). Technical Bulletin No. 1/2010. CICR, Regional Station, Coimbatore.
3. Gopalakrishnan N., Manickam S., Sabesh M. and Usha Rani S., (2010). All India Coordinated Cotton Improvement Project – In the Service of Indian Cotton Farmers -Technical Bulletin, CICR, Regional Station, Coimbatore.
4. Sankaranarayanan K., Manickam S., Nalayini P., Sabesh M. and Gopalakrishnan N. (2010). Innovative Production Technologies for ELS Cotton, Technical Bulletin No. 3/2010, Central Institute for Cotton Research, Regional Station, Coimbatore.
5. V.S. Nagrare, Sandhya Kranthi, Rishi Kumar, B. Dhara Jothi, M. Amutha, A.J. Deshmukh, K.D. Bisane and K.R. Kranthi "Compendium of Cotton Mealybug" by CICR publication, 2011/1.

11.2 : List of On-going Projects

Sr. No.	Name of Project	Principal investigator (PI)/ Project Leader (PL)/ Project Associate (PA)/ CCPI/	Duration
	INSTITUTE		
	Crop Improvement		
1.	Improvement of tetraploid and diploid cottons for fibre properties through population improvement approaches.	V. N. Waghmare (PL) Vinita Gotmare (PA)	2000-2015
2.	Conservation, characterization and utilization of wild species, races of cultivated species, perennials and synthetic polyploids of *Gossypium.*	Vinita Gotmare (PL) G. Balasubramani (PA)	2008-2013
3.	Collection, conservation, evaluation, documentation and maintenance of germplasm of cultivated species of *Gossypium.*	Punit Mohan (PL), S. Manickam (PA), V. S. Nagrare (PA), R. A. Meena (PA) A. B. Dongre (PA), R. K. Deshmukh (PA) V. Santhy (PA), P.R.Vijayakumari (PA) Vinita Gotmare (PA), M. Chakrabarti (PA) K. P. M. Damayanthi (PA), K. Rathinavel (PA) K. P. Raghvendra (PA)	2006-2013
4.	Breeding of upland cotton for improved fibre quality and resistance to biotic stress (bollworms and jassid).	S. M. Palve (PL), M. K. Meshram (PA), V. Gotmare (PA)	2005-2012
5.	Development of heterotic pool for superior medium staple in tetraploid cotton (*G. hirsutum*).	S. M. Palve (PL)	2006-2013
6.	Development of improved male sterility system through induced mutation	S. B Singh (PL), O. P. Tuteja (PA)	2008-2011
7.	Development of drought tolerant genotype with good fibre quality.	S. B. Singh (PL), A. H. Prakash (PA)	2008-2013
8.	Development of mapping population for different economically important traits.	P. K. Chakrabarti (PL), V. N. Waghmare (PA), S. M. Palve (PA), S. B. Singh (PA), Vinita Gotmare (PA), T. R. Loknathan (PA) P. R. Vijayakumari (PA), Punit Mohan (PA) S. Manickam (PA)	2008-2012
9.	Development of transgenic cotton resistant against major diseases of cotton.	P. K. Chakrabarty (PL) S. B. Nandeshwar (PA)	2009-2012
10.	Studies on genetic enhancement of *hirsutum* cotton.	T. R. Loknathan (PL)	2002-2012
11.	Development of heterotic pools in *G. arboreum* and *G. hirsutum*.	S. K. Verma (PL), O. P. Tuteja (PA), S.L. Ahuja (PA)	2008-2012
12.	Development of markers for breeding programme.	S. K. Verma (PL), S. L. Ahuja (PA)	2008-2012
13.	Development of varieties and hybrids resistant to CLCuV.	O.P. Tuteja (PL), D. Monga (PA), Rishi Kumar (PA)	2008-2013
14.	Development of transgenic diploid cotton for insect resistance.	S. B. Nandeshwar (PI), S. B. Singh (PA) P. K. Chakrabarty (PA), V. S. Nagrare (PA)	2008-2011
15.	Development of efficient agro-techniques for enhancing the productivity and seed quality of cotton varieties.	R. K. Deshmukh (PL), K. Rathinavel (PA)	2008-2011
16.	Assessment of working seed sample size for Bt seed testing based on estimation of *cry1Ac* protein.	P. R. Vijayakumari (PL), K. R. Kranthi (PA)	2008-2011
17.	Technology to enhance the better crop establishment and yield in cotton.	R. A. Meena (PL), D. Monga (PA)	2007-2012.
18.	Breeding new *G. hirsutum* varieties with new plant type - Development of medium staple varieties.	K. N. Gururajan (PL), S. Manickam (PA)	1989-2011
19.	Development of long staple *G. hirsutum* with improved fibre strength.	S. Manickam (PL), V. N. Waghmare (PA) S. L. Ahuja (PA)	2008-2014
20.	Development of extra-long staple high spinning hybrids with wider adaptability.	KPM Dhamayanthi (PL), S. Manickam (PA)	1986-2011

	Crop Production		
21.	Development of high density planting systems (HDPS) for maximizing productivity of rainfed cotton.	M. V. Venugopalan (PL), P. R. Bharambe(PA) Jagvir Singh (PA), Punit Mohan (PA), Vinita Gotmare (PA), S.M. Palve (PA), A. H. Prakash (PA), S. Kranthi (PA), Chinna Babu Naik (PA), A. K. Mukherjee(PA) G. Majumdar (PA), A. R. Reddy (PA), S. L. Ahuja (PA), D. Monga (PA), Rishi Kumar (PA)	2010-2014
22.	Developing efficient carrier based microbial delivery system for cotton nutrition and soil health.	K. Velmourougane (PL), Jagvir Singh (PA), A. R. Raju (PA)	2008-2011
23.	Amelioration of leaf reddening and parawilt in cotton.	A. H. Prakash (PI), Jagvir Singh (PA), V. S. Nagrare(PA)	2010-2014
24.	Effect of different levels of fertilizers on Cry protein expression of Bt hybrids and effect of Bt gene on soil health, oil and gossypol content of Bt hybrids compared to their non Bt counterparts.	M. Chakrabarty (PL), Jagvir Singh (PA) K. Velmourougane (PA)	2007-2011
25.	Economic Impact of Bt Cotton Cultivation in India.	A. R. Reddy (PL), Isabella Agarwal (PA), Rishi kumar (PA)	2008-2011
26.	Assessment of cotton based intercropping system and its popularization through farmer to farmer participatory learning approach.	S. M. Wasnik (PL), S. Usha Rani (PA), A. R. Raju (PA)	2008-2012
27.	Performance of white leghorn layers under feeding of Bt and Non-Bt cotton seed.	S. N. Rokde (PL)	2010-2011
28.	Herbigating herbicide/ herbicide mixture/ herbicide rotation for efficient and environmentally safe weed control and its effects on succeeding pulses.	P.Nalayini (PL), K.Sankaranarayanan (PA), K.Velmourougane (PA)	2008-2012
29.	Evaluation of cotton base cropping system for higher economic returns	K. Sankaranarayanan (PL), P. Nalayini (PA), K. K. Bandyopadhya (PA)	2005-2011
30.	Studies on Soil Aggregation and Aggregate Associated Carbon in Cotton Based Cropping System	K.K. Bandhyopadhya (PL) and K. Velmourougane (PA)	2008-2011
31.	Simulation of effect of N management strategies on nitrogen dynamics in soil plant system and nitrogen use efficiency of ELS bt cotton in a climate change scenario	K.K.Bandyopadhya (PL), A. H. Prakash (PA), B. Dhara Jothi (PA)	2009-2012
32.	Identification and utilization of adaptive responses to abiotic stresses in cotton.	SESA Khader (PL), N. Gopalakrishnan (PA), K.N.Gururajan (PA),	1995-2011
33.	Studies on the mechanism of cuticular absorption of nutrients and hormones in Bt cotton	S.E.S.A.Khader (PL)	2008-2012
34.	Economic impact of trade liberalization in cotton economy of India	Isabella Agarwal (PL)	2010-2012
35.	Comparative analysis of conventional, biotech and organic cotton production systems in India	S. Usha Rani (PL), S. M.Wasnik (PA), K. Sankaranarayanan (PA)	2008-2011
36.	Gender and labour issues in Cotton hybrid seed production sector in India	S. Usha Rani (PL), M. Sabesh (PA) S.M. Wasnik (PA)	2010-2012
37.	MCDA based Decision Support System for Selecting Cotton Cultivars for Different Agro Climatic Conditions	M. Sabesh (PL)	2010-2013
	Crop Protection		
38.	Isolation and characterization of native Bt strains using conventional and molecular methods, for cotton pest management.	S. Kranthi (PL), K. R. Kranthi (PA)	2008-2011
39.	Bt resistance in pink bollworm *Pectinophora gossypiella* (Saunders) - monitoring mechanism and management.	Chinna Babu Naik (PL), S. Kranthi (PA)	2010-2012

40.	Screening and Identification of effective bio-control agents for the management of foliar cotton diseases.	M. K. Meshram (PL), A. K. Mukherjee (PA)	2008-2011
41.	Identification of bacterial blight and grey mildew disease resistant genotypes in upland cotton.	M. K. Meshram (PL), A. K. Mukherjee (PA)	2008-2011
42.	Identification of sources of resistance and phylloplane microflora against Rhizoctonia root rot in tetraploid and fusarium wilt in diploid cotton and their utilization for management.	R. C. Ukey (PL), V. N. Waghmare (PA)	2006-2011
43.	Studies on inoculum source and economic thresholds of cotton leaf curl and virus disease.	D. Monga (PL), Rishi Kumar (PA)	2008-2011
44.	Identification and characterization of viral diseases of cotton in India.	A. K. Mukherjee (PL), M. K. Meshram (PA)	2010-2012
45.	Studies on the role and effect of insecticides in cotton ecosystem	T. Surulivelu (PL)	1989-2011
46.	Standardization of bioassays techniques for resistance monitoring in *Pectinophora gossypiella* Saunders to transgenic cotton and development of management strategies.	B. Dhara Jothi (PL)	2007 2012
47.	Studies on epizootiology, pathogenicity and pathogenic mechanism of Entomopathogenic fungal pathogens against cotton mealybug.	M. Amutha (PL)	2008-2011
48.	Establishment of *Beauveria bassiana* as an symbiotic insecticide against major insect pests and diseases of cotton.	M. Amutha (PL), M. Gunasekaran (PA)	2010-2013
49.	Identification of hot spots for plant parasitic nematodes in cotton growing zones of India.	J. Gulsar Banu (PL), N. G. Narkhedkar (PA)	2006-2011
50.	Isolation of novel insecticidal proteins from bacterial symbionts of native entomo-pathogenic nematodes	J.Gulsar Banu (PL), N. G. Narkhedkar (PA) B. Dhara Jothi (PA)	2006-2011
	EXTERNALLY FUNDED PROJECTS		
	NAIP		
1.	Research into development of decision support systems for management of insect pests of major rice and cotton based cropping systems.	V. S. Nagrare (CCPI), G. Majumdar (CoPI), Rishi Kumar (CoPI), B. Dharajothi (CoPI), M. Sabesh (CoPI), M. Amutha (CoPI)	2008-2012
2.	A Value Chain for Cotton Fibre, Seed and Stalks: an innovation for higher economic return to farmers allied stakeholders.	N. Gopalakrishnan (CoPI), Sankaranarayanan (CoPI), P. R. Bharambe (CCPI), D. Monga (CCPI) , Rishi Kumar (CoCCPI)	2009-2012
3.	Georeferenced soil information system (Geosis) for land use planning and monitoring soil and land quality for agriculture.	M. V. Venugopalan (CCPI), K. Velmourougane (CoCCPI)	2009-2013
	DBT/DST		
4.	Enhancing sustainability of transgenic crops through gene stacking" Funded by the DBT under 'Indo-Australian –International Science Linkages' programme.	K. R. Kranthi (PI)	2008-2012
5.	Cloning and characterization of potent toxin gene from heat tolerant isolate of *Heterrorhabdus Indica*, an Entomopathogenic nematode.(DBT)	N. G. Narkhedkar (PI), P. K. Charkrabarty (PA)	2009-2012
6.	Engineering virus resistant cotton through dsRNAi-mediated targeting of cotton leaf curl virus. (DBT)	P. K. Chakrabarty (PI), S. B. Nandeshwa(PA) D. Monga (PA), B. M. Khadi (PA)	2007-2010
7.	Identification of Molecular markers and tagging genes for Bacterial blight resistance. (DBT)	P. K. Chakrabarty (PI), Punit Mohan (PA), V. N. Waghmare (PA), B. M. Khadi (PA)	2008-2011

8.	"Gene stacking in Bt Cotton". (DBT)	G. Balasubramani (PI), S. B. Nandeshwar (PA), S. B. Singh (PA)	2008-2011.
9.	Isolation and identification of seed specific promoter and gossypol synthesis genes for silencing through RNA interference. (DBT)	K. P. Raghavendra (PI), J. Amudha (PA)	2010-2013
10.	Molecular mapping of fibre quality and lint yield traits: construction of a framework linkage map in *desi* cotton (*Gossypium* sp.) (DBT)	V. N. Waghmare (PI), A. B. Dongre (PA), Vinita Gotmare (PA), S.B. Jadhav (PA)	2006-2011
11.	Molecular mapping of fibre quality traits QTLs and marker assisted selection (MAS) in upland cotton (*Gossypium hirsutum* L.) (DST)	V. N. Waghmare (PI)	2007-2010
12.	Fine mapping and advance backcross QTL analysis of fiber quality and economic traits in diploid cotton.	V. N. Waghmare (PI), T. R. Loknathan (PA)	2010-2012
	Indo -US-AKI		
13.	Development of drought resistant transgenic cotton and identification of new genes for high water use efficiency	J. Amudha (PI), A. H. Prakash (PA), G. Balasubramani (PA)	2008-2011
	GEAC		
14.	Event based approval mechanism (GEAC)	S. Kranthi (PI)	2009-2011
	CSIR : NMITLI		
15.	Novel approaches for production of hybrid seeds with characteristics of improved insect resistance and higher yield.	K. R. Kranthi (PI)	2008-2012
	ICAR Network Project		
16.	Impact, adaptation and vulnerability of Indian agriculture to climate change. Sub project- changes in soil carbon reserves as influenced by different ecosystems and land uses in India.	M. V. Venugopalan (CCPI)	2009- 2012
17.	Transgenics in Crops (NPTC): Development of bollworm resistance transgenic cotton.	G. Balasubramani (PI), S. B. Singh (CoPI), J. Amudha (CoPI), S. B. Nandeshwar (CoPI) A. B. Dongre (CoPI), K. R. Kranthi (CoPI) P. K. Chakrabarty (CoPI)	2006-2012
18.	Contractual research project on DNA bar coding of cotton insect pests.	S. Kranthi (PI), K. R. Kranthi	2010-2012
19.	Mega Seed Project - Seed production in Agriculture crops.	P. K. Chakrabarty (Nodal Officer), P.R. Vijayakumari (PI), R. K. Deshmukh (PA), V. Santhy (PA), K. Rathinavel (CCPI), R. A. Meena (CCPI)	2007-2012
20.	National Seed Project (crops).	K. Rathinavel (PI), P. R. Vijayakumari (PA), R. A. Meena (PA)	1999-2012
	PRIVATE SEED COMPANIES		
21.	Monitoring changes in baseline susceptibility of cotton bollworm to transgenes deployed in pest resistant transgenic cotton	S. Kranthi (PI), B. Dhara Jothi Rishikumar, C.B. Naik	2009- 2012
	DUS		
22.	Testing & Documentation of Extant Varieties, hybrids and their Parents for Distinctness, Uniformity & Stability (PVP & FR ACT, 2001).	N. Gopalakrishnan (PI), K. Rathinavel (CCPI) V. Santhy (CCPI), P. R. Vijayakumari (CCPI) R. K. Deshmukh (CCPI)	2003-2012
	Govt. of Maharashtra		
23.	Crop pest surveillance and advisory project (CROPSAP)	V. S. Nagrare (PI)	2010-2011

TECHNOLOGY MISSION COTTON (TMC) : Mini Mission I - 2007-2012		
Project code	**Project Title**	**Name of PI/CCPI**
MM 1.1	Development and promotion of medium and long linted diploid cottons (*G.arboreum* and *G.herbaceum*)	S. K. Verma - PI, T. R. Loknathan - CCPI Punit Mohan - CCPI
MM 1.2	Development of extra long staple G.barbadense cotton with improved fibre qualities to meet the requirements of textile industry	K. N. Gururajan - PI
MM 1.3	Identification of G. hirsutum genotypes suitable for machine picking and development of agronomic package	V. Gotmare - CCPI
MM 1.4	Development and promotion of Bt transgenic cotton for bollworm resistance	S. Manickam – CCPI, Suman Bala Singh - CCPI, S. B. Nandeshwar – CCPI S. M. Palve - CCPI, O. P. Tuteja - CCPI
MM 1.5	Molecular characterization of cotton germplasm using DNA markers	A. B. Dongre – PI, V. N. Waghmare - CoPI, R. K. Deshmukh - CoPI, Vijaya Kumari - CoPI, V. Santhy - CoPI, K. Rathinavel - CCPI, R. A. Meena - CCPI
MM 1.6	Exploitation of apomixis and TGMS system in hybrid cotton seed production	S. M. Palve – PI, V. Gotmare - CoPI V. Santhy - CoPI
MM 2.1	Development of production technologies for Bt cotton and improvement of water and nutrient use efficiency with precision farming techniques	J. V. Singh - PI, P. R. Bharambe - CoPI, M. V. Venugoplan CoPI, S. Sankaranarayanan - CCPI
MM 2.2	Identification of innovative Bt cotton based cropping systems.	P. Nalayini - PI, K. K. Bandopadhyay - CoPI, A. R. Raju - CCPI, P. R. Bharambe - CCPI, G. Majumdar - CCPI, R. A. Meena - CCPI
MM 2.3	Mechanization of cotton production	G. Majumdar - PI, A. R. Raju - CoPI
MM 2.4	Physiological manipulation of Bt plant morphoframe for enhanced productivity under varied agro-climatic conditions	A. H. Prakash - PI, R. K. Deshmukh - CoPI
MM 3.1	Emerging and key pests: - their characterization, taxonomy, genetic diversity and control	S. Kranthi - PI, K. R .Kranthi - CoPI, M. K. Meshram - CoPI, V. S. Nagrare - CoPI, A. K. Mukherjee - CoPI, V. Chinna Babu Naik - CoPI, T. Surulivelu - CCPI, B. Dharajothi - CCPI, D. Monga - CCPI, Rishi Kumar - CCPI, J. Gulsar Banu - CCPI
MM 3.2	Development and validation of IPM / IRM strategies for Bt and conventional cotton under different eco-systems.	S. Kranthi - CCPI , V. S. Nagrare - CoPI, V. Chinna Babu Naik - CoPI Rishi Kumar - CCPI
MM 3.3	Development, validation, utilization and / or commercialization of bio-pesticides and bio inoculants	P. K. Chakrabarty - PI, T. Surulivelu - CCPI, J. Gulsar Banu - CCPI, N. Narkhedkar - CCPI, D. Monga - CCPI
MM 3.4	Development of farmer friendly diagnostic kits for transgenic event seed purity.	K. R. Kranthi - PI
MM 4.1	Quality evaluation of cotton fibres	M . Chakrabarty - CCPI
MM 5.1	Total factor productivity of cotton in India	Isabella Agarwal - PI, A. R. Reddy - CCPI S. M. Wasnik - CCPI
MM 5.3	Indian cotton portal	M. Sabesh - PI, N. Gopalakrishnan-CoPI, G. Majumdar - CCPI, A. R. Reddy - PI, M. V. Venugopalan - CoPI,
MM 5.4	TMC MMI Co-ordination and Monitoring Cell	V. Santhy - CoPI
TECHNOLOGY MISSION COTTON (TMC) : Mini Mission II - 2007-2012		
	Dissemination of IRM strategies in India.	K. R. Kranthi (PI), B. Dharajyoti - CCPI , D. Monga - CCPI, Rishi Kumar - CCPI

11.3 : Consultancy, Patents, Commercialization of Technology

Patents granted

S. No.	Title	Patent granted no.	Name of Inventor
1.	Rapid detection of Bt Cry toxin	No. PA/A2004/01179	Dr. K. R. Kranthi

Patents filed

Complete Applications submitted for Patent of Technologies

S. No.	Title	Provisional Application No. allotted by the Patent Office	Complete application submitted and No. allotted by the Patent Office	Name of Inventor
1.	Propagation of diploid cotton *Gossypium arboreum* by multiple shoot induction	1557/MUM/2009	E - 2/508/2010-MUM Pages:-5, Claims:- 8	Dr. S. B. Nandeshwar, Principal Scientist, CICR, Nagpur
2.	PCR detection Kit for *Xanthomonas axonopodis* pv. *Malvecearum*	1558/MUM/2009	E - 2/509/2010-MUM Pages:-6, Claims:- 5	Dr. P. K. Chakrabarty, Principal Scientist & Head CICR, Nagpur
3.	Bacterial biopesticidal formulation derived from Entopathogenic nematodes for management of sucking pests of crops	1854/ MUM/2010	--	Dr. Nandini Gokte - Narkhedkar, Principal Scientist, CICR, Nagpur

11.4 : Significant Decisions of RAC, IRC, IMC and other Important Meetings

1. Research Advisory Committee Meeting

The second meeting of Research Advisory Committee of the institute was held at CICR, Nagpur on May 19-20, 2010. Dr. S. S. Baghel, Ex.Vice Chancellor, Assam Agricultural University, Jorhat & Central Agricultural University, Imphal, Chairman of RAC presided over the meeting. Dr. K.C. Jain, ADG (CC), ICAR, Dr. S.K. Sharma, Ex. Project Director, Project Directorate of Cropping Systems Research, Modipuram, Dr. G.T. Gujar, Head, Division of Entomology, IARI, New Delhi and Dr. J. Kumar, Professor & Head, Deptt. of Plant Pathology, GB Pant University of Agriculture & Technology, Pantnagar, Members of RAC; Dr. K.R. Kranthi, Director, CICR, Nagpur, Dr. P.R. Bharambe, Head, Crop Improvement Division, Dr. P.K. Chakrabarty, Head, Crop Improvement Division, Dr. M.K. Meshram, Member Secretary RAC & I/c Head Crop Protection Division, CICR, Nagpur, Dr. N. Gopalakrishnan, Project Coordinator (AICCIP) and Head, CICR RS Coimbatore and Dr. D. Monga, Head, CICR Regional Station Sirsa (Haryana) attended the meeting.

Dr. K.R. Kranthi, Director, CICR, Nagpur welcomed the chairman and members of RAC. In his introductory remarks, Dr. Baghel, Chairman, RAC advised that CICR should undertake commercialization of genetic stock with specific traits. Dr. K.C. Jain, ADG (CC) emphasized that cotton Scientist must carry out focused research on specific objectives. Dr. S.K. Sharma advised that the technologies developed should have end use and stressed the need for development of good Bt varieties from the public sector. Dr. G.T.Gujar remarked that commercialization of technologies is easy and quick in the private companies as compared to public sector. Dr. J. Kumar informed the house that lately pesticide consumption in Bt cotton has again been showing upward trend and stressed the importance of studies on insecticide resistance development. The Member Secretary presented Action Taken Repot on the recommendations of the previous RAC meeting. Heads of Crop Improvement, Crop Protection and Crop Production Divisions, CICR, Nagpur, Project Coordinator (AICCIP) & Head CICR Regional Station Coimbatore and Head CICR Regional Sirsa also presented salient achievements of the respective Divisions/ Regional Stations. The presentations were followed by lively discussions. The meeting ended with a Vote of Thanks proposed by the Member Secretary.

2. Institute Research Council (IRC) Meeting

IRC meeting of CICR, Nagpur and CICR RS Sirsa was held on April 28-30, and May 21, 2010 at CICR Nagpur under the Chairmanship of Dr. K.R. Kranthi, Director, CICR Nagpur. The Chairman in his opening remarks requested the scientists to focus on the flagship programmes on discovery of new genes, gene constructs, gene markers, alleles, RNAi and GM crops and enhanced yields through 'high density planting system' (HDPS), etc. The Chairman desired that the number of projects should be trimmed based on priority. He further requested each scientist to come out with new original ideas to mitigate the present and emerging problems in cotton production.

All the Heads of the divisions/research station-Shri M.K. Meshram, Dr. P.R. Bharambe, Dr. P.K. Chakrabarty and Dr. D. Monga presented the significant research achievements of their respective division/Station. They also presented decision taken in the divisional/Station IRC meeting in relation to the project continuation/ merger/ closure etc. based on the priority.

Dr. V. S. Nagrare, Secretary IRC presented action taken report of the last IRC-2009 meeting. Dr. N. Gopalakrishnan, PC and Head RS, Coimbatore discussed the recommendations and action taken report of last RAC 2009. Shri M. K. Meshram presented the salient recommendations of Research Advisory Committee (RAC) meeting held on 19-20 May 2010. Each

research project was discussed thoroughly and decisions on project continuation, merger, termination and extending duration of existing project and approval of new projects were taken by IRC. The meeting was attended by all the Scientists of Nagpur and Sirsa. Dr. A.K. Mukherjee, Mr K. Velmourougane and Dr. V. N. Waghmare acted as Rapporteurs of the meeting.

Prior to the main IRC, each project was discussed at length in divisional pre-IRC meeting held in respective division viz., Crop Protection on April 19, 2010, Crop Production on April 23, 2010, Crop Improvement on April 24, 2010 and RS Sirsa on March 26-27,2010. Dr. V. S. Nagrare, Secretary IRC and Shri K. Velmourougane, Jt. Secretary coordinated the IRC meeting.

The Institute Research Committee (IRC) meeting of CICR, Regional Station, Coimbatore was held on july 7-9, 2010 at CICR, Regional Station (RS), Coimbatore under the Chairmanship of Dr. K.R. Kranthi, Director, CICR Nagpur. Dr. V.S. Nagrare, Secretary IRC welcomed Dr. K.R. Kranthi, Director, CICR Nagpur and Chairman IRC and all the Scientists.

Dr. N. Gopalakrishnan, PC and Head RS, Coimbatore presented the overall progress of the Regional Station and plan of action for the ensuing crop season 2010-11. Action taken report of the last IRC meeting held on February 10-11, 2010 in respect of CICR, RS, Coimbatore was presented by Dr. V.S. Nagrare. The IRC confirmed the minutes of last IRC meeting held on 10-11 February 2010. The institutes as well as externally funded projects presented by each scientist were critically reviewed by the IRC. The meeting was attended by Dr P. R. Bharambe, Head Division of Crop Production, Dr P. K. Chakrabarty, Head Division of Crop Improvement, Dr D. Monga, Head CICR RS Sirsa, Dr N. Gopalakrishnan, PC & Head CICR RS Coimbatore, Dr M. V. Venugopalan, Principal Scientist & In charge RCM Unit, CICR Nagpur and all the Scientists of Regional Station, Coimbatore.

3. Institute Management Committee Meeting

The 48th Meeting of Institute Management Committee of CICR, Nagpur was held on 27 April, 2010 at CICR, Nagpur under the Chairmanship of Dr. K. R. Kranthi, Director, CICR, Nagpur. The following Committee Members were present during the meeting:

1. Dr. O.P. Tuteja, Principal Scientist, CICR-RS, Sirsa - Member
2. Dr. K.N. Gururajan, Principal Scientist, CICR-RS, Coimbatore -Member
3. Dr. (Mrs.) Sandhya Kranthi, Senior Scientist, CICR, Nagpur -Member
4. Dr. (Mrs.) Vinita Gotmare, Senior Scientist, CICR, Nagpur -Member
5. Dr. N. Gopalakrishnan,PC & Head, CICR-RS, Coimbatore - Spl. Invitee
6. Dr. D. Monga, Head, CICR-RS, Sirsa - Spl. Invitee
7. Dr. P.R. Bharambe, Head, Division of Crop Production, CICR, Nagpur - Spl. Invitee
8. Dr. P.K. Chakrabarty, Head, Division of Crop Improvement, CICR, Nagpur - Spl. Invitee
9. Dr. M. K. Meshram, I/c Head, Division of Crop Protection, CICR, Nagpur - Spl. Invitee
10. Smt. Banu Narayanan, I/c F & AO, CICR, Nagpur - Spl. Invitee
11. Shri. M.S. Murthy, Administrative Officer, CICR, Nagpur - Member Secretary

The following are the major recommendations of the committee:

1. Taking into consideration of the fact that the availability of fibre quality evaluation unit in the premises of CICR-RS, Coimbatore will help the station in timely evaluation of the fibre samples of the experiments conducted at the regional station and AICRP on Cotton Centers. The committee recommended for accommodating "CIRCOT Fiber Evaluation Unit" in the un-occupied one Type-IV quarter at CICR-RS, Coimbatore.
2. The Committee strongly recommended to replace the old and rusted barbed wire fencing in the CICR, Nagpur farm boundary about 5,000 running meters length to protect the experimental fields and also to guard the property from encroachment.
3. The Committee recommends to renovate the Director's Chamber/Committee Room/Reception at CICR, Nagpur on priority basis during the financial year 2010-11, by meeting the expenditure from the funds available under the Head Furniture & Fixtures in XIth Plan EFC Document.
4. Taking into consideration of the fact that the institute is in the dire necessity of the Training Hall to cater to the needs and its activities, the Committee strongly recommends to provide additional funds amounting to Rs. 25.00 lakhs by (a) surrendering the civil work first floor construction for laboratory on the existing main building at CICR-RS, Coimbatore amounting Rs. 10 lakhs and (b) utilization of additional amount of Rs. 15 lakhs revenue generated under the AICCIP Bt Testing Fee. The Committee also advised the Institute to make all out efforts to take up construction of the Training Hall at the Institute at the earliest.

The meeting ended with thanks to Chair and the Members by the Member Secretary.

4. 21st Meeting of ICAR Regional Committee No. VII

The 21st ICAR Regional Committee Meeting for the Region-VII was inaugurated on December 2, 2010 at Central Institute of Agricultural Engineering, Bhopal by the Minister of Farmer Welfare and Agriculture Development, Govt. of Madhya Pradesh, Hon'ble Dr Ramkrishna Kusmariya. Vice Chancellors of State Agricultural Universities located in Region VII i.e. Madhya Pradesh, Chhattisgarh, Maharashtra and Goa, DDGs of ICAR, higher officials of the State Agricultural Universities were present on this occasion. The inaugural function was presided over by Dr S. Ayyappan, Secretary, DARE & Director-General, ICAR.

Dr Pitam Chandra, Director, Central Institute of Agricultural Engineering welcomed the Chief Guest and all the distinguished guests present on the occasion and informed that the growth in agricultural sector has increased to more than 6% and agricultural machines have played an important role in this rise. At the outset, DDG (Engg), ICAR Dr M.M. Pandey gave a brief outline of the proceedings of the meetings of the Regional Committee No. VII held earlier. He requested the representatives of the MP Government to actively participate in the present meeting and put forth their various problems related to agriculture.

Addressing the gathering on this occasion, Secretary, DARE & Director-General, ICAR, Dr S Ayyappan underlined the need of enhancing organic farming in the Region. He told that in the four states of the Region, the cultivated area is about 25% of the total area available for agriculture, whereas the agriculture

production is just approximately 15% of the national output. There are good opportunities for enhancing the production of sorghum, soybean and other coarse cereals in the region. He told that by controlling weed infestation, the agricultural production can be enhanced by 15 to 30%. He also stressed the need for efficient agricultural input utilization with special emphasis on processing equipment.

While addressing the gathering, the Chief Guest of the function, Dr Ramkrishna Kusmaria exhorted to reestablish the old practices of agriculture and disseminating the results on their research and importance to the farmers. He mainly spoke on land security, organic farming and food security. He requested the Indian Council of Agricultural Research to act as a guide to the State Governments of Region-VII in the respective disciplines of agriculture. He further requested the agricultural scientists to make available an agricultural model so as to make the marginal farmer fully independent. He suggested to promote the organic farming mission and publicizing the education of organic farming at the national level by forming a curriculum in this regard. In his opinion – processing of soybean at village level, evolving an alternative to chemical fertilizer and resolving the unemployment at rural level are the priority areas, which should be addressed during the three day meeting.

Dr K.R. Kranthi, Director, CICR Nagpur and Member-Secretary for Region-VII proposed vote of thanks.

The KVK Regional Interface was also held on 3-4th Dec. 2010. The interface started with the welcome address by Dr. K. D. Kokate, DDG (AE). He briefed about various activities performed and salient achievements made by KVKs in the region.

Dr. S. Ayyappan, Secretary DARE & Director General, ICAR said that main motto behind conducting KVK Interface during Regional Committee meeting is for confidence building and cross learning to the Programme Coordinators. He desired to see KVK as Knowledge Management Centre in place of Knowledge Resource Centre.

The Zonal Project Directors of Zone –V, VII, VIII presented the salient achievements of KVKs of their Zone. Vice Chancellors, DDGs, GB Members, ADGs and Directors of ICAR institutes also expressed their views on various aspects of KVKs of the region. Ninety eight Programme Coordinators of various KVKs of this region attended the meeting and expressed their views on various issues related to KVKs.

5. Meeting of the ICAR Standing Committee for TMC MM-1

The Ninth Meeting of ICAR Standing Committee for TMC MM-I was held on 22.01.2011 at Central Institute for Cotton Research, Nagpur under the Chairmanship of Dr. S. Ayyappan, Secretary, DARE and DG, ICAR to review the Annual Progress of TMC MM-I programme. Other prominent members participated in the meeting includes Dr. C. D. Mayee Chairman, ASRB, Dr. Swapan K. Dutta, DDG (CS), Dr. A. K. Singh, DDG (NRM), Shri Suresh Kotak, Chairman, Kotak & Co Ltd., Dr. Sudhir Bhargava, GB Member, ICAR etc.

The Committee critically reviewed the research work done under different projects of TMC MMI and approved the work plan of 2011-12.

6. Brain Storming Session on 'Indian Cotton- What next?'

A brainstorming session on 'Indian Cotton- What next?' was conducted on 22nd January 2011 by the Central Institute for Cotton Research Nagpur. The meeting was chaired by Honorable Chairman, Agricultural Scientist Recruitment Board, New Delhi, Dr. C.D. Mayee and co- chaired by Dr. Swapan Kumar Dutta, Deputy Director General, Crop Science. Dr. Sudhir Bhargava Member, ICAR General Body and Shri Suresh Kotak, Textile Industrialist were special invitees to the brainstorming session.

The session began with welcome address by Dr. N. Gopalakrishnan Project Coordinator, All India Cotton Improvement project and Head CICR, Regional station, Coimbatore. He highlighted the roles played by the All India Coordinated Cotton Improvement Project and CICR in ensuring the sustainability of cotton cultivation across the country.

Dr. K. R. Kranthi, Director CICR, Nagpur spelt out the position India holds in terms of cotton area, production and productivity. Apart from differences in production practices he said that a turn around could be achieved through the adoption of high density planting systems, cultivation of varieties and the exploitation of the native '*desi*' cotton namely the *G. arboreum*. He put forth evidences to suggest that high density planting with the use of varieties and the use of varieties itself were prime factors responsible for increase in productivity in both Brazil and China. Dr. Kranthi enumerated crop production factors, the biotic and abiotic factors limiting yield in the country and set the ground for the ensuing brain storming session.

Dr. Swapan Dutta Co-Chairman complimented Dr. Kranthi on his presentation that was described as scientific, exhaustive and informative. He informed the house that ICAR seeks to have an active trustworthy public private partnership with prospects of sub-licensing of genes and technologies which would help give a fillip to the public sector research on cotton.

Dr. C. D. Mayee felt that while it was necessary to shift to varieties he exhorted CICR to ensure the maintenance of varieties. He further emphasized to the need to have strong research projects for the development of good diploids. He also felt the imminent need to identify genotypes best suited for the high density planting systems.

Dr. Sudhir Bhargava suggested that cotton researchers take up high density planting with genotypes having an appropriate architecture. Technologies that make cotton cultivation economically viable need to be promoted for adoption by farmers. The public sector organizations working on cotton were asked to ensure a mechanism in place for the production of quality seed

Shri Suresh Kotak advised the development of both, short term and long term programs for achieving an increase in the productivity. He unequivocally supported the necessity of public private partnership and for the exchange of genes with the private sector for the welfare of farmers.

Dr. Monga, Dr. Barik, Dr. Sarode, Dr. Pundir, Dr. Kumar, Dr. Siwach, also put forth their experiences with farmers highlighting the requirements of cotton farmers of their respective region. The program concluded with the vote of thanks proposed by Dr. D.Monga, Head CICR Regional station, Sirsa.

7. Meeting on "Bt cotton – Refugia consideration"

A meeting on "Bt cotton – Refugia consideration" was held on 31/03/2011 under the chairmanship of Dr. Swapan Kumar Dutta, Deputy Director General (Crop Science), IACR, New Delhi. Dr. C D Mayee, Chairman, ASRB, New Delhi was the Co-

Chairman. Dr. P.R. Bharambe, Head Crop Production Division welcomed the delegates. In his introductory remarks, Dr. K.R. Kranthi, Director CICR exhorted that the purpose of the meeting was to discuss sustainable technological options to sustain the benefits of Bt cotton technology for a long time and to recommended implementable (farmers' acceptable) resistance management strategies. In his opening remarks, the Chairman explained that the issue of resistance management and refugia options are not restricted to cotton alone and would be applicable to all the Bt crops. Models followed in other countries growing Bt crops may not hold good under Indian agro ecological and socio economic set up and an implementable Indian model/strategy was needed. The current refugia strategy was not being followed since, it compromises the yield realized by the farmer.

Dr. K.S. Mohan (Monsanto) made a presentation on "Sustaining Bt cotton Technology through adoption of refugia". He explained the three resistance management options-gene pyramiding, refugia strategy and in-planta effective dose. He also urged the need for a science based refugia programme that is implementable under Indian conditions.

Dr. K.R. Kranthi, Director CICR demonstrated the latest version of Bt Adapt model in his presentation. The model could predict the likely time frame for resistance breakdown under various resistance management strategies-two gene (*cry1Ac+cry2Ab*), refugia ratios, fitness costs etc. He also recommended the spray of spinosad to kill survivors as a complementary to refugia management strategy.

Initiating the discussions Dr. C.D. Mayee emphasized that sustaining cotton productivity is more important than sustaining 'Bt' gene and other management strategies including crop diversification, IPM etc. should be comprehensively viewed. He mooted the option of seed mixture (Bt + non-Bt) for North Indian conditions, where the cropping system is not diverse. Representatives from different seed companies and other delegates also expressed their views.

The meeting ended with a vote of thanks proposed by Dr. M.V. Venugopalan, Principal Scientist (Agronomy), CICR, Nagpur.

8. All India Coordinated Cotton Improvement Project

The Annual Group meeting of All India Coordinated Cotton Improvement Project (AICCIP) was organised at MPUAT, Udaipur (Rajasthan) during April, 8-10, 2010. The dignitaries Dr. S S Chahal, Hon'ble Vice Chancellor, MPUAT, Udaipur, Dr K C Jain ADG (Commercial crops), ICAR, Dr K R Kranthi, Director, CICR, Nagpur, Dr S Sreenivasan, Director, CIRCOT, Mumbai, Dr N Gopalakrishnan, PC and Head, Dr Kolhatkar, Jt Director, DOCD, Mumbai and heads of different institutions besides 300 delegates from the state SAUs and private sector and other stake holders attended the meeting. Various Issues pertaining to Cotton R&D were discussed and technical programme for the year 2010-11 was also finalised. Besides, the cotton varietal Identification Committee meeting was held during the Annual Group meeting of AICCIP under the Chairmanship of Dr. K C Jain, ADG (CC), ICAR, New Delhi.

11.5 : Workshops/Farmer's Day Organized

Nagpur

Annual Review Workshop of TMC MM-1

The Annual Review Workshop (2009-10) of Technology Mission on Cotton, Mini Mission- I was held at CICR, Nagpur on April 26, 2010. Dr. Kranthi welcomed the participants and gave a brief introduction about the recommendations made in the eighth meeting of ICAR Standing Committee for TMC MM 1, held on March 3, 2010, under the chairmanship of Dr. Ayyappan, DG, ICAR at ICAR, New Delhi. He also presented in brief the significant achievements of TMC MM 1 projects during this year. Results of the research work done in each project during the year were critically reviewed and the technical programme for the year 2010-11 was discussed and finalized in the meeting.

Organic Cotton Stakeholders' Workshop

An interactive workshop was convened on August 31 and September 1, 2010 at the Central Institute for Cotton Research, Nagpur in collaboration with Organic Exchange. Mrs. Prabha Nagarajan represented the Organic Exchange, the promoters of organic cotton movement. Representatives from the prominent organic certifying organizations including Ecocert, Control Union, IMO, Onecert and NOCA participated. The leading organic cotton producer groups from India- Bio Re, Chetna, Samrudhi, Pratibha Sintex, Mahima, Zameen Organic, Cotton Connect, Arvind Mills, Agrocel, Sunstar Super Spinning Mills and Ecofarms actively participated in the deliberations.

This workshop addressed several contemporary issues- the availability of non GM varieties/ hybrids in public sector and their suitability to different organic cotton growing areas, participatory seed Production programmes, GM and insecticide residue testing procedures, diagnostic kits and their training needs, organic production technologies and quality input delivery systems and avenues for non-spinnable organic cotton. Several areas for cooperation in R and D between CICR, different certifying agencies and producer groups were also identified. A special interactive session was also held under the Chairmanship of Dr. C. D. Mayee, Chairman, Agricultural Scientist Recruitment Board and former Agricultural Commissioner, Govt. of India. The workshop enabled the participants to learn from each others' expertise and capabilities and initiate an action plan to put in place a strong and sustainable organic cotton production system in India in wake of the challenges facing this segment of industry.

Workshop for IRM Field Workers

A day long workshop on February 8, 2011 was organized under IRM monitoring & review programme for field workers, students and teachers from Ramkrishna Bajaj Krishi Mahavidhyalaya, Pipri-Wardha at CICR Nagpur. The programme was chaired by Dr. K R Kranthi, Director; CICR and coordinated by Dr. S. M. Wasnik, Principal Scientist (Extension), which was attended by around 60 participants.

Workshops on Monitoring of Insect Resistance

1. Data generated by Monsanto Mahyco Biotech (MMB) in the 2009 Cotton season had indicated the development of resistance to *cry1Ac* in populations of the Pink bollworm (PBW) collected from Bt cotton fields of Gujarat. Dr. K.R. Kranthi, Director, CICR, Nagpur put forth his reservations on the research methodology and the data in a GEAC meeting that was called to resolve this issue of Pink Bollworm resistance and CICR was advised to take a lead in this area of work. Hence, as an initiative, Public Private Partnership (PPP) was established with MMB agreeing to join hands with CICR, Nagpur to work together on PBW resistance. CICR would be addressing the problem of pink bollworm resistance to the *cry1Ac* in the year 2010 under TMC MM 3.2 and GEAC project (ICAR 0430) with logistic

support from Monsanto Research Centre, India. In connection with this, a workshop on monitoring of cry1Ac resistance to cry toxins in the pink bollworm was held at CICR, Nagpur on August 17-18, 2010 in which Entomologists drawn from the SAUs collaborating with CICR under TMC MM3.1 and TMC MM3.2 and senior staff of Monsanto Research Centre, India, Mahyco, Jalna and Dow, India participated. A total of 28 persons attended the event. The program was chaired by the Director, CICR Nagpur. Laboratory exercises were demonstrated for mass rearing protocols, including, preparation of diet, release of neonates, maintenance of adult cages, use of special rearing trays, preparation of toxin dilutions, sex differentiation in larval stage etc.

2. A one day workshop on resistance monitoring for insecticides used against sucking insect pests with special emphasis on jassids was held at CICR, Nagpur on August 19, 2010 in the public private partnership mode. It was attended by entomologists from the SAUs collaborating with CICR under TMC MM3.1 and TMC MM3.2 . Resistance monitoring data generated at six centers, using a common protocol, namely Sirsa (for North India; Dr. Rishi Kumar), Gujarat (Dr. H. Desai), Nagpur (Central India including Maharashtra and Madhya Pradesh; Dr. S. Kranthi), Guntur (Dr. G.M.V. Prasad Rao), Dharwad (Dr. Udikeri) and Coimbatore (Dr. Dharajothi) was presented. Refinements were made in the technical program for monitoring resistance in sucking pests. Dr. Ranga Rao and his staff from Bayer, India attended the workshop. The program was chaired by the Director, CICR Nagpur.

Farmers meet and strengthening of farmer's linkages

With a view to strengthen linkages with the farmers extension scientist participated in number of farmers meet organized by different organizations and provided scientific information from time to time. Dr. S. M. Wasnik, Principal Scientist (Extension) attended '*Charcha Satra*' on Cotton and Tur on 30th May 2010 at Pusad, Yeotmal district organized by Vasantrao Naik Smruti Pratisthan, on 'Natural Farming' on 20 October 2010 organized by Marathi daily Newspaper "Agro-One" at Girad, '*Shetkari Charcha Satra*' on 'Organic Farming' on 30 November 2010 at Bamhani, Nagpur tahsil organized by 'Eumenical Sangam', 'Farmers Meet' on 21st December, 2010 at Ballarpur organized by Guru Nanak College of Science, Ballarpur in Chandrapur district, '*Kisan Mela*' on 31 December 2010 at Nagziri in Warud tahsil of Amaravati organized by Krishi Padvidharanchi Krishi Bahauudheshiya Seva Sahkari Sanstha Maryadit, Amaravati., "Farmers Workshop" on 'Water Conservation and Natural Farming' on 17 February 2011 at village Vijay Gopal in Deoli tahsil of Wardha district organized by Govt. of India, Central Water Commission . The programmes were attended by prominent personalities like Sh. Manohar Naik, Min. of Food and Administration, Govt of Maharashtra, by Sh. Harshavardhan Deshmukh, Director, National Horticulture Board, Sh. Subhash Sharma of Natural Farming, Sh. A. M. Patil, Chief Engineer, Water Commission, GOI, Ex-Commissioner & President, Zilla Parishad, Amavati, Zuari Pvt. Ltd, Agril Depts. The entire programmes were well attended by large numbers of farmers, farm women and rural youths. Distributed extension folders to farmers on various topics during the programmes. Farmers were very keen to visit CICR & learn latest technological development in cotton.

Coimbatore

Workshop on Integrated Cotton Production

Two days workshop on "Integrated Cotton Production" had been organized on 7-8th Oct. 2010 at Central Institute for Cotton Research, Regional Station, Coimbatore. Feed back on field problems were collected and discussed. The training was provided to production of hybrid seed , market facilities and price forecast, development programmes, stem weevil and mealy bug control, nematode management, growth hormones use, sucking pests management options, IPM , cotton pest expert system and its use, disease management. The demonstration of poly mulch techniques, multi tier system and low cost drip system were explained to trainees.

11.6. Participation of Scientists in Seminars/ Symposia/ Workshops

Sr. No.	Seminars/Conferences /Symposia/ Workshops/Training	Place and Date	Participants
1.	Annual Group Meeting of AICCIP	MPUAT, Udaipur 8-10 Apr., 2010	K.R. Kranthi, N. Gopalakrishnan, D.Monga, S.L.Ahuja, O.P. Tuteja, R A Meena, S.K.Verma,Rishi Kumar, S Manickam, T Surulivelu, M Sabesh, S.UshaRani, M.V.Venugopalan, S.M. Wasnik
2.	Monitoring workshop of CeRA	Coimbatore 16 Apr., 2010	S. Usha Rani
3.	Open Forum discussion on Organic Cotton-on the Recent Problems confronting Organic cotton	Mumbai 17 Apr., 2010	K.R. Kranthi
4.	National Workshop on Global Plan of Action (GPA) for Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture (PGRFA)	New Delhi 17 Apr., 2010	S Manickam
5.	Workshop on 'Rural Development and Appropriate Technology'	Nagpur 22 Apr., 2010	S.M. Wasnik
6.	Annual breeder Seed review meeting of breeder seed produced during 2008-09	New Delhi 24 Apr., 2010	K Rathinavel
7.	XXX Annual Group Meeting, AICRP- National Seed Project (Crops)	Barrackpore 4-6 May, 2010	K Rathinavel
8.	Interface Meeting of Directors/ PCs of Crop Science and Horticulture Divisions of ICAR	Jabalpur 17-18 May,2010	K. R. Kranthi
9.	Review and planning meeting of TMC- MM II	Mumbai 20 May, 2010	S. Usha Rani
10.	Fifth Meeting of Standing Committee to review applications for commercial release of Bt Cotton hybrids	New Delhi 29 Jun.,2010	K. R. Kranthi
11.	Protection of Plant varieties and Farmers rights Act Task Force meeting	Mumbai 30 Jun., 2010	K. R. Kranthi
12.	National conference on current scenario on global challenges in germplasm conservation and biodiversity	Nagpur 7-8 Jul., 2010	A.B.Dongre
13.	3rd National Congress on Plant Breeding and Genomics	Coimbatore 7-9 Jul., 2010	K. R. Kranthi S Manickam KPM Dhamayanthi
14.	16th meeting of the Technical committee of Central Seed Certification Board	New Delhi 15 Jul., 2010	K Rathinavel
15.	Director's Conference	New Delhi 15-16 Jul., 2010	K. R. Kranthi
16.	Interaction Meeting on Mechanization in Agriculture	Bhopal 23-24 Jul., 2010	K. R. Kranthi
17.	14th ICAR Industry Meet 2010	New Delhi 28-29 Jul., 2010	K. R. Kranthi
18.	Cotton Advisory Board Meeting	Mumbai 30 Jul., 2010	K. R. Kranthi
19.	Training on identification of mealybug species	New Delhi 2-6 Aug,2010	Rishi Kumar
20.	Brain Storming Discussion on Strategies for increasing production of oilseeds / vegetable oils	Hyderabad 7-8 Aug., 2010	S Manickam

21.	Workshop to review the conduct of DUS test for the period 2007-2010	Hyderabad 11-12 Aug., 2010	K Rathinavel
22.	Meeting on Revising the Methodology of estimating Cotton production and also working out advance estimates for 2010-11	New Delhi 12 Aug., 2010	K. R. Kranthi
23.	QRT meeting of Directorate of Seed Research, MAU	Hyderabad 12-13 Aug., 2010	K Rathinavel
24.	Workshop on PBW resistance monitoring	Nagpur 17-18 Aug., 2010	Rishi Kumar, Chinnababu Naik
25.	Workshop on jassid resistance monitoring	Nagpur 19 Aug., 2010	Rishi Kumar Chinnababu Naik B Dhara Jothi
26.	Conference on whitefly and thrips transmitted diseases.	New Delhi, 27-28 Aug., 2010	D .Monga
27.	Workshop on Organic Cotton Stakeholders	Nagpur 31Aug. & 1 Sep., 2010	S.K.Verma S Manickam M.V.Venugopalan M. Chakrabarty All CICR scientists
28.	AICOSCA Annual General Body Meeting	Mumbai 3 Sep., 2010	K. R. Kranthi
29.	ICGI Research Conference 2010	Canberra, Australia 20-23 Sep, 2010	P.K. Chakrabarty S.K.Verma
30.	Workshop on Paradigm Shift in Cotton Research and Cultivation	Mumbai 18-19 Oct., 2010	K. Sankaranarayanan
31.	National Conference on Cotton	Surat 19-20 Oct., 2010	K. R. Kranthi
32.	Three days Indo-UK workshop on Bridging Urban – Rural divide	Wardha 19 – 21 Oct., 2010	V. Santhy
33.	Conference on Biopesticides Emerging Trend (BET 2010)	Hisar 20-22 Oct, 2010	Rishi Kumar
34.	National Conference on " Paradigm Shift in Cotton Research and Cultivation"	Surat 20 -22Oct., 2010	D Monga., P. K Chakrabarty, S. Usha Rani
35.	2nd National workshop on Marker assisted selection for crop improvement	Hybderabad 27-29 Oct., 2010	V.N Waghmare
36.	Sensitization cum training Workshop on 'Project Information & Management System of ICAR (PIMS-ICAR)'	Bhopal 11 Nov., 2010	M.V.Venugopalan
37.	Recent advances in soil science 2010	Bhopal 14-17 Nov., 2010	Jagvir Singh Singh, K. Velmourougane, P.R. Bharambe
38.	Meeting on India-Africa Cooperation along the Cotton Value Chain	Mumbai 16-Nov-10	K. R. Kranthi
39.	Workshop on Towards A Knowledge Economy	New Delhi 18-20 Nov. 2011	S. Usha Rani
40.	National Conference on Challenges in weed management in Agro-ecosystems Present status and Future strategies	Coimbatore 30 Nov.–1 Dec., 2010	P. Nalayini Dr. K. Sankaranarayanan
41.	XIX National Symposium on Resource Management Approaches Towards Livelihood security	Bengaluru 2-4 Dec., 2010	P. Nalayini
42.	21st Meeting of ICAR Regional Committee No. VII	Bhopal 2-4 Dec., 2010	K. R. Kranthi
43.	National Workshop on Innovations and Better Management Practices for Climate Resilient and Sustainable Cotton Production	Hyderabad 15-16 Dec., 2010	B Dhara Jothi M.V.Venugopalan

44.	98th Indian Science Congress	Chennai 3-7 January, 2011	P Nalayini, M Amutha, S. Usha Rani, A.H. Prakash
45.	Advance training on molecular basis of Host Plant Resistance at Centre of Advance Faculty Training.	11-31 January 2011, Department of Entomology, CCS HAU, Hisar	Rishi Kumar
46.	National Training "Molecular Characterization of GMO's and its purity testing"	Nagpur 18Jan. - 7 Feb., 2011.	A.K. Mukherjee, C.B.Naik A.Sampath kumar
47.	Brain Storming session on Cotton Breeding	Nagpur 22 Jan., 2011	All scientists of Breeding & Genetics. D.Monga, S. L Ahuja & S. K. Verma
48.	Annual Review Workshop of TMC- MM II	Mumbai 25 Jan., 2011	S. Usha Rani
49.	National Seed Congress on Quality Seeds for Prosperity	Pune 29-31 January, 2011.	R. K. Deshmukh , R. A. Meena, A.H. Prakash
50.	International Conference on preparing for climate change	Ludhiana 6-8 Feb., 2011	T. R. Loknathan
51.	International Conference on Chemistry for mankind : Innovative ideas in Life Sciences ICCM – 2011	Nagpur 9-11 Feb., 2011	A.B. Dongre
52.	10th Agriculture Science Congress Meet	Lucknow 10 Feb., 2011	K. R. Kranthi
53.	Annual breeder Seed review meeting of breeder seed produced during 2009-10	New Delhi 14 Feb., 2011	K Rathinavel
54.	Awareness workshop on Intellectual Property Right	Valparai, (T.N.) 23 Feb., 2011.	Gulsar Banu
55.	Interface meeting of Directors and Vice Chancellor of Agriculture University	New Delhi 23-24 Feb., 2011	K. R. Kranthi
56.	5th Meeting of Asian Cotton Research and Development Network	Lahore , Pakistan 23- 25 Feb.,2011	K. R. Kranthi, D. Monga, P.K.Chakrabarty
57.	Annual Progress Review meeting of the project Implementation of PVP legislation, 2001	New Delhi 25 Feb.,2011	K. Rathinavel
58.	National Seminar on Improving Water Productivity: Limits and Opportunities	Gwalior 25-26 Feb., 2011	M.V. Venugopalan
59.	Meeting of Directors of Crop Science division along with respective chair person of RAC of Institute	New Delhi 1 Mar.,2011	K. R. Kranthi
60.	Microbial diversity and its applications in health, agriculture and industry	Goa 4-5 Mar., 2011	Jagvir Singh, K. Velmourougane, P.R. Bharambe
61.	Zonal Technology Management & Business Planning and Development	Mumbai 11-12th March, 2011	Dr. G. Balasubramani
62.	Meeting of Directors of Crop Science division along with respective chair person of RAC of Institute	New Delhi 17 Mar.,2011	K. R. Kranthi
63.	Seminar on Soil health improvement for enhancing crop productivity	Coimbatore 17-18 Mar., 2011	K. Sankaranarayanan
64.	World Congress on Biotechnology-2011	Hyderabad 21-23 Mar., 2011	A.B.Dongre
65.	Workshop on "Present status of Cotton Leaf Curl Virus Disease" and its management	Sirsa 30 Mar., 2011,	D.Monga, S.L. Ahuja, O.P. Tuteja, R.A. Meena, S.K.Verma, Rishi Kumar

11.7. Distinguished Visitors

Name & Designation	Organisation	Date
Nagpur		
Dr. S. S. Baghel, Ex. Vice Chancellor and Chairman RAC, CICR	Central Agricultural University, Imphal	19 May, 2010
Dr. C. D. Mayee, Chairman	ASRB, New Delhi	31 August, 2010
Dr. Gurbachan Singh, Agricultural Commissioner	Ministry of Agriculture, GOI, New Delhi	12 July, 2010
Shri. P.K. Basu, Secretary, Agriculture Shri. Mukesh Khullar, Joint Secretary, Agriculture	Ministry of Agriculture, GOI, New Delhi	11 October, 2010 11 October, 2010
Dr. M.M. Pandey, DDG(Agril. Engg.)	ICAR, New Delhi	18 January, 2011
Dr. S. Ayyappan, Secretary DARE & Director General, ICAR	DARE, Ministry of Agriculture, GOI, New Delhi	22 January, 2011
Dr. Swapan Kumar Dutta, DDG (CS)	ICAR, New Delhi	22 January, 2011
Dr. A. K. Singh, DDG (NRM)	ICAR, New Delhi	22 January, 2011
Dr. C. D. Mayee, Chairman	ASRB, New Delhi	22 January, 2011
Dr. Sudhir Bhargava, Member ICAR General Body	ICAR, New Delhi	22 January, 2011
Shri. Suresh Kotak, Chiarman	Kotak & Co. Ltd., Mumbai	22 January, 2011
Dr. V. K. Yadava, Additional Plant Protection Adviser	GOI, Faridabad	22 January, 2011
Dr. Swapan Kumar Dutta, DDG (CS)	ICAR, New Delhi	31 March, 2011
Dr. C. D. Mayee, Chairman	ASRB, New Delhi	31 March, 2011
Coimbatore		
Dr C D Mayee, Chairman	ASRB, New Delhi	8 July, 2010
Sirsa		
Shri. Ashok Yadav, IAS, Director Agriculture	Govt. of Haryana	9 October, 2010
Shri. Rajnikanthan, IAS, Deputy Commissioner		

11.8 : Personnel

Name of the Officers/Scientists	Designation
K R Kranthi	Director
PROJECT COORDINATOR (Cotton)	
Coimbatore	
N Gopalakrishnan (up to 27.01.2011)	P.C. (Cotton) & Head
BIOTECHNOLOGY	
Nagpur	
G Balasubramani	Senior Scientist
Smt. J Amudha	Senior Scientist
K P Raghavendra	Scientist
Smt Pratiksha Mayee (joined on 17.08.10)	Scientist
PLANT BREEDING	
Nagpur	
P.K. Chakrabarty	HOD, Crop Improvement
Smt. S B Singh	Principal Scientist
T R Loknathan	Principal Scientist
S M Palve	Principal Scientist
V N Waghmare	Senior Scientist
M Saravanan (joined on 27.08.2010)	Scientist
Coimbatore	
K N Gururajan	Principal Scientist
S Manickam (joined on 20.11.2010)	Principal Scientist
Sirsa	
S L Ahuja	Principal Scientist
O P Tuteja	Principal Scientist
S K Verma	Senior Scientist
GENETICS & CYTOGENETICS	
Nagpur	
S B Nandeshwar	Principal Scientist
Smt. Vinita Gotmare	Senior Scientist
Coimbatore	
Smt. K P M Damayanthi	Senior Scientist
SEED TECHNOLOGY	
Nagpur	
R K Deshmukh	Principal Scientist
Smt. P R Vijayakumari	Principal Scientist
Smt. V Santhy	Scientist (SS)
Coimbatore	
K Rathnivel	Principal Scientist
Sirsa	
R A Meena	Principal Scientist
ECONOMIC BOTANY	
Nagpur	
Punit Mohan	Principal Scientist
AGRONOMY	
Nagpur	
PR Bharambe	HOD, Crop Production
MV Venugopalan	Principal Scientist
R B Singhandhupe (joined on 14.10.2010)	Principal Scientist
A R Raju	Senior Scientist
Coimbatore	
K Shankaranarayanan	Senior Scientist
Smt P Nalayani	Senior Scientist
SOIL SCIENCE	
Nagpur	
Jagvir Singh	Principal Scientist
Coimbatore	
Smt D Kanjana (joined on 03.09.2010)	Scientist
AGRICULTURAL ENGINEERING	
G Majumdar	Scientist (SG)

Name of the Officers/Scientists	Designation
PLANT PATHOLOGY	
Nagpur	
M K Meshram	Principal Scientist
R C Ukey	Principal Scientist
A K Mukherjee	Senior Scientist
A Sampath Kumar (joined on 04.05.10)	Scientist
Coimbatore	
M Gunasekharan	Senior Scientist
Sirsa	
Dilip Monga	Head of Station
ENTOMOLOGY	
Nagpur	
Smt. Sandhya Kranthi	Principal Scientist
V S Nagrare	Scientist (SS)
Chinna Babu Naik V	Scientist
Coimbatore	
T Surulivelu	Principal Scientist
Smt. B Dhara Jothi	Senior Scientist
Smt M Amutha	Scientist
Sirsa	
Rishi Kumar	Senior Scientist
NEMATOLOGY	
Nagpur	
Smt. Nandini Narkhedkar	Principal Scientist
Coimbatore	
Smt. J Gulsar Banu	Senior Scientist
PLANT PHYSIOLOGY	
Nagpur	
A H Prakash	Principal Scientist
Smt Annie Sheeba (joined on 27.04.10)	Scientist
Coimbatore	
S E S A Khader	Principal Scientist
BIOCHEMISTRY (PS)	
Nagpur	
A B Dongre	Principal Scientist
Smt. M Chakrabarty	Scientist (SG)
MICROBIOLOGY (PS)	
Nagpur	
K Velmourougane	Scientist
AGRICULTURE EXTENSION	
Nagpur	
S M Wasnik	Principal Scientist
Coimbatore	
Usha Rani	Scientist (SS)
AGRICULTURAL ECONOMICS	
Nagpur	
A R Reddy	Senior Scientist
Smt Anuradha Narala	Scientist
Coimbatore	
Smt. Isabella Agarwal	Senior Scientist
COMPUTER APPLICATION	
Coimbatore	
M Sabesh	Scientist (SS)
KVK	
Nagpur	
S N Rokde	Principal Scientist
Susanta Saha (joined on 07.10.2010)	Sr. Admn. Officer
N V R N Murty (joined on 07.03.2011)	F & A Officer

11.9 : Other Information

Visits Abroad

- Dr. K.R. Kranthi, Director, CICR attended 30th International Cotton Conference held in Bremen, Germany from March 24-27, 2010. He was honoured with a special Bremen Award by President of the Bremen Bauwollborse, Wolfgamg vogt-Jordan in Germany. He delivered a special talk on "New Perspectives on Crop Production Research" in the inaugural session of the conference.
- Dr. K.R. Kranthi, Director, CICR was nominated by Govt. of India , Ministry of Commerce and Industry, Department of Commerce Trade Policy Division , New Delhi as a Member of delegation to visit C-4 countries (Chad, Burkina Faso, Benin , Mali), Nigeria, Uganda from 3-14 May, 2010.
- Dr. K.R. Kranthi, Director, CICR Nagpur and Dr. D. Monga, Head, CICR-Regional Station, Sirsa participated in the 5th Asian Cotton Research & Development Network meeting at Lahore, Pakistan from 23-26 February 2011. Dr. K.R. Kranthi presented invited paper on 'Mealybug management' during the meeting.
- Dr. P.R. Bharambe, Head, Division of Crop Production, CICR Nagpur was nominated by Ministry of External Affairs (West Africa Division) and Ministry of Agriculture, Govt. of India, New Delhi as a member of delegation to visit Benin in Western Africa from 22 Nov. - 2 Dec., 2010 for preparation of a feasibility study on enhancing the production of cotton and also the post harvest management and value addition to cotton in Benin.
- Dr. K. Rathinavel, Principal Scientist (Seed Technology), CICR Regional Station, Coimbatore was trained at the International programme on Plant Variety Protection and DUS testing for Indian Experts at the National Institute of Agricultural Botany (NIAB), Cambridge, UK from 28 June - 9 July, 2010.
- Dr. P.K. Chakrabarty, Head, Division of Crop Improvement, CICR Nagpur and Dr. S.K. Verma, Senior Scientist, CICR Regional Station, Sirsa attended the International Cotton Genome Initiative Research Conference held at CSIRO Discovery Centre, Canberra, Australia from Sept. 20-23, 2010. They presented three research papers during the meeting.
- Dr. K.P. Raghavendra, Scientist (Biotechnology), CICR Nagpur attended the Bt resistance mechanisms workshop of the Indo-Australia Bio-technology funded project 'Sustainability of Pyramided Bt genes for Insect Control in Crop Plants"(2008-11), from 19-26 June, 2010 at the Institute of Molecular Biology and Biotechnology at the University of Melbourne, Australia.

Foreign delegation visits to CICR

Heads and members of delegations from eight African countries namely Ethiopia, Kenya, Malawi, Mozambique, Uganda, Tanzania, Zambia and Zimbabwe visited CICR Nagpur in November 2010. The delegation was in India to participate in seminar on "Indian- Africa Cooperation along the Cotton Value Chain" jointly organized by Confederation of Indian Textile Industry and International Trade Centre, Geneva at Mumbai on November 14-19, 2010. During the visit to CICR Nagpur, the delegation members visited important laboratories and experimental fields.

Participation in Agricultural Fair Expo Programme – 2010

Southern Regional Agricultural Fair was organized by Tamil Nadu Agricultural University (TNAU) at Coimbatore District Small Industries Association (CODISSIA) Complex, Coimbatore, Tamil Nadu from Sept.30, 2010 to Oct.03, 2010. This programme was inaugurated by the State Rural and Development Minister Mr. Pongalur Palanisamy. As many as 250 Agricultural Research organizations of various Central/ State Agriculture Departments, Research Stations, Colleges, Farm machinery and farm input producing companies and Non-Government Organizations (NGO) participated and exhibited the new innovations, farm machineries, equipments and improved production / protection technologies in the fair. CICR, Regional Station, Coimbatore also participated in the Southern Regional Agricultural Fair (SRAF) by exhibiting a stall with display boards depicting photographs of recent cotton varieties / hybrids, live specimens of cotton pests, natural enemies, nutritional deficiency symptoms and diseases of cotton. Farmers were explained about various technologies such as multi-tier cropping system, nutritional management and IPM / IRM Strategies in cotton pest management. Different folders/ leaflets pertaining to the improved cotton production technologies and emerging pest management and value addition to Cotton were also distributed. More than 2500 farmers visited CICR Stall. This fair was a useful platform to showcase the technologies developed by CICR, RS, Coimbatore for the benefit of cotton farmers. The programme was coordinated by Dr. (Mrs.) Dhara Jothi, Senior Scientist.

Agro-vision 2011- A National Expo

CICR stall was organized during National Expo- Agro-Vision 2011-Exhibition-"Building sustainable livelihood & increasing farmers income" at Reshim Bagh Ground, Nagpur from March 4-7, 2011.The expo was organized by Vidharbha Economic Development Council and supported by Purti Power and Sugar Ltd. The exhibition was designed with the thrust areas to 'Educate, Encourage & Empower farmers and CICR, Nagpur participated in the expo and highlighted activities of institute through displaying exhibit banners such as cotton varieties/hybrids developed by CICR developed, cotton production technologies, pests management, diseases management, biotechnological tools, machineries and implements, IRM strategies, physiological disorders, organic cotton production of mileaykit/mealykil, etc. Live materials such as Bt detection kits, cotton planter, solar power sprayer, adjustable hoe, etc. were kept which was an attraction for the visiting farmers.

Library

Additions

During 2010-11, the Library purchased 163 new books and subscribed 18 foreign journals and 30 Indian journals.

Documentation Services

- Library has developed computerized bibliographic database on cotton to provide comprehensive and updated information on cotton. About 3900 bibliographic references along with abstracts have been stored in it. Based on this bibliographic database the Library publishes a current awareness bulletin namely "*COTTON RESEARCH ABSTRACTS*". The Bulletin is circulated to all the scientists of the Institute and to all AICCIP Centers in India. In the reported period, four issues of *COTTON RESEARCH*

ABSTRACTS (V24, (No. 1-4), January – December 2010) were published and circulated.

- The Library is actively participating in the CeRA, a E-Journal Consortium by responding regularly through E-mails and thus also receiving updates. More than 2000 on-line journals on agriculture and crop science are made available over the network through this consortium.
- Four User Terminals installed in the Library have facilitated the library users to access the databases uploaded in the Library Server. Users can also access the Internet on these terminals. Similarly the entire catalog of the library has been downloaded on these terminals for ease of use.
- The WebOPAC version of the Library software SLIM21 was updated and by using this Library Application Software, the entire catalogue of holdings of the Library (books and bound volumes) is available on all terminals within the Institute.

Progressive Use of Hindi

Nagpur

Hindi Day :

- CICR celebrated Hindi Day as Hindi *Chetna* fortnight during 13-28 Sep, 2010 at the Institute Headquarters, Nagpur. Various programmes and competitions like handwriting, dictation, word-meanings, *lokocti* question-answer, news-reading, word-translations, debate, song translation, hindi-poetry writing, *hasya kavi-sammelan*, publication of technical/scientific articles in Hindi, administrative work in Hindi, etc. were organized during this fortnight. The winners were awarded prizes during the valedictory function held on 28th Oct, 2010.
- In administrative work in Hindi competition Shri. Richhpal Singh (Sirsa Centre) got 1st prize, Shri. Prakash Mishra (Nagpur) got 2nd prize and Shri. Satbir Singh (Sirsa Centre) got 3rd prize. In publishing technical/scientific articles Dr. Rishikumar from Sirsa Centre got 1st prize while Dr. S. N. Rokde (Nagpur) was awarded 2nd prize. The chief guest Dr. M. S. Kairon, Ex-Director of CICR and Dr. K. R. Kranthi, Director addressed on the occasion.
- Hindi Day was also celebrated in Institute's regional stations Sirsa and Coimbatore, wherein, various programmes were organized and the winners were awarded.
- Translation work in different disciplines was done as and when required. The executive summary of research achievements during 2009-10 was translated in Hindi and published in the Institute's Annual Report for the year 2009-10.
- Popular articles and extension folders were prepared in Hindi and published for farmers and extension personnel.

Coimbatore

Official Language Implementation Activities

The Official Language Implementation is being effectively carried out at CICR, Regional Station, Coimbatore. In the month of September 2010, Hindi day was organized. Various competitions like memory contest, reading and writing in Hindi, translation, objective words usage, general knowledge and comprehension based questions were held for scientists and staff during Hindi Day celebrations and prizes were distributed on October 4, 2010.

The CICR, Coimbatore was awarded a special prize for commendable performance in Hindi Implementation for the year 2009-10 by the Town Official Language Implementation Committee, (TOLIC) Coimbatore. The Half Yearly Meetings organized by the TOLIC were regularly attended by PC and Head and Hindi Liaison Officer of this Station Ms. Subhasree.

The Official Language Implementation Committee Meeting is being regularly organized at CICR, Coimbatore to discuss various issues on Development and Proceedings sent to Head quarters. The Hindi Workshops are regularly organized as per the Official Language Policies to promote Hindi usage in official activities by the staff members and to learn official use and communicative Hindi. The Name Boards indicating the Scientists and Staff members and Name Boards of all scientists and Labs have been made both in Hindi and English. Annual Purchase for Hindi Books worth Rs.2200/- has been done. Regular Correspondence to Head quarters regarding Hindi activities, Quarterly Hindi Meeting, Scientific Articles for Institute Magazines has been carried out. The Hindi Cell and the Official Language Implementation Committee of this Institute are working towards achieving the Progressive use of Hindi at this Institute.

Sports

CICR, Nagpur participated in ICAR Zonal Tournament (Central Zone) meet at Directorate of Weed Science Research, Jabalpur during February 15-19, 2011 and won Gold medal in Javelin Throw by Smt. Sunita Chauhan, Silver medal in Chess & Carrom by Dr. Vijaya Kumari, & Smt. Shubhangi Kharche and Smt. Sunita Chauhan won Bronze medal in 100m race & Discuss throw respectively.

11.10: Weather

Nagpur

Month	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	No.of Rainy Days
	Max.	Min.	Max.	Min.		
June, 2010	40.1	28.2	60.2	37.9	157	6
July, 2010	31.0	24.4	90.7	73.3	385	19
August, 2010	30.6	24.0	88.4	74.4	266	18
September, 2010	31.8	23.9	88.0	65.4	214	9
October, 2010	32.1	21.8	77.2	55.2	10	1
November, 2010	30.5	19.9	83.8	56.2	17	3
December, 2010	29.3	13.2	72.2	36.6	0	0
January, 2011	28.5	11.4	61.8	29.3	0	0
February, 2011	30.8	15.2	64.2	31.7	0	0
Total					**1049**	**56**

Coimbatore

Month	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	No.of Rainy Days (>2.5mm)
	Max.	Min.	Max.	Min.		
April, 2010	36.6	25.2	85	42	15.0	2
May, 2010	34.5	25.0	89	51	99.9	4
June, 2010	32.2	24.0	84	57	40.8	4
July, 2010	31.7	23.4	82	57	8.3	1
August, 2010	30.5	22.7	88	63	69.9	3
September, 2010	31.4	22.7	88	56	25.6	2
October, 2010	31.1	22.2	91	62	156.4	9
November, 2010	28.1	21.8	95	70	311.1	15
December, 2010	28.3	19.3	93	61	35.0	2
January, 2011	30.1	19.0	89	44	0.4	0
February, 2011	31.6	18.4	89	40	125.6	3
March, 2011	33.5	20.7	88	35	23.6	1
Total					**911.6**	**46**

Sirsa

Month	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Rainy Days
	Max.	Min.	Max.	Min.		
April, 2010	40.5	23.4	50.0	24.8	0.2	2
May, 2010	42.6	27.3	42.5	18.8	16.0	2
June, 2010	40.5	27.8	51.3	31.3	43.6	3
July, 2010	35.3	27.5	82.6	60.4	161.6	15
August, 2010	35.0	27.3	85.5	61.8	149.0	8
September, 2010	32.8	24.2	86.5	63.0	157.7	9
October, 2010	32.7	19.2	80.8	37.4	0.0	0
November, 2010	27.7	12.0	76.8	30.3	0.0	0
December, 2010	31.3	5.9	82.8	43.0	4.4	1
Total					**531.5**	**40**

11.11 : Cotton Scenario

Cotton is one of the principal crops of India and plays a vital role in the country's economic growth by providing substantial employment and making significant contributions to export earnings. World cotton production is expected to be around 25.19 million tones of which India's contribution would be about 22 per cent (5.53 million tones).

Cotton Cultivation in India

India is the only country to grow all four species of cultivated cotton besides different combinations of hybrids. The majority of the cotton in India is grown in nine states which are grouped into three different zones namely, Northern zone (Punjab, Haryana and Rajasthan), Central zone (Maharashtra, Madhya Pradesh and Gujarat) and Southern zone (Andhra Pradesh, Karnataka and Tamil Nadu). Approximately 65% of India's cotton is produced under rainfed condition and 35% on irrigated conditions. Details of cotton scenario (2010-11) are given in Table 1 and 2.

Table 1: Cotton Growing Zones in India

Zones	North Zone	Central Zone	South Zone
States	Punjab, Haryana, Rajasthan	Maharashtra, Madhya Pradesh, Gujarat	Andhra Pradesh, Karnataka, Tamil Nadu
Area (Lakh ha)	13.59	72.57	24.40
Production (Lakh bales)	39.00	201.00	68.00
Productivity (kg/ha)	488	471	474
Conditions	100% irrigated	Irrigated and rainfed	Irrigated and rainfed
Soil Type	Alluvial soils	Black cotton soils	Black soils and Red soils
Nature of Genotype	Hybrids and varieties	Hybrids and varieties	Hybrids and varieties
Species Hybrids	*G.hirsutum, G. arboreum* intra *hirsutum*	*G. hirsutum, G. arboreum, G.herbaceum,* intra-*hirsutum*	*G.hirsutum, G. arboreum, G. herbaceum, G. barbadence,* Interspecific tetraploids(HB)
Insect/ Pest	Whitefly, Mealy bug	*Helicoverpa,* Whitefly, Jassids, Aphids, Pink bollworm, Mealy bug	*Heliothis,* Whitefly, Jassids, Aphids, Pink bollworm, Mealy bug
Diseases/physiological disorder	Leaf curl virus, Wilt	Wilt, leaf reddening	Wilt, Foliar disease
Sowing Method	Drill Sown	Hand dibbling	Hand dibbling
Time of Sowing	April-May	June-July	Aug-Sept

Cotton Situation after introduction of Bt hybrids

After the introduction of Bt-cotton in 2002, India's contribution to global cotton production increased from 14% in 2002 to 20.5% in 2007. The production increased from 170 lakh bales in 2002 to all time highest record of 315 lakh bales during 2007-08 and 312 lakh bales in 2010. For five consecutive years after 2005, India has harvested a record average of 300 lakh bales, leaving behind the best ever historical record of 165 lakh bales before the introduction of Bt cotton. India has been producing at least 60-90 lakh bales in excess of domestic consumption over the past few years. Domestic consumption also increased from 168 lakh bales in 2002, to 247 lakh bales in 2010. It is widely believed that the introduction of Bt cotton into India has contributed to the sudden increase of India's contribution to global cotton production. The enhancement in yields has been primarily due to several technological changes that have taken place since 2002, significantly related to the introduction of Bt-cotton, new cotton hybrids, seed treatment and process, new novel pesticides, feasible research outcome from NATP, NAIP, TMC, IRM, IPM and INM. Apart from these, the 29% increase in area under cotton from 78 lakh hectares in 2002 to 111 lakh ha in 2010, increase in hybrid cotton area from 40% in 2001 to 92% in 2010, favourable weather conditions, extremely low bollworm infestation and good market price for the cotton have contributed to the rise in area and production. India became a leading global exporter of raw cotton with exports ranging from 35 to 85 lakh bales raw cotton each year from 2005 onwards, while concomitantly, imports declined from 25 lakh bales to 5 lakh bales. The quality has improved, trash content was reduced and bollworm affected 'bad-kapas' was gone. Prior to 2002 long staple cotton production was only 38% of the total cotton, but after five years the proportion increased to 77%. Insecticide use on cotton was 46% of the total insecticides used in India in 2001 and before, but soon declined to 25% within 4 years of Bt cotton introduction.

Despite the good progress made by public and private sector research and development, it is a matter of concern that productivity started to decline from 566 kg/ha in 2007 to 522 kg/ha in 2008, 486 kg/ha in 2009 and 475 kg/ha in 2010. The factors responsible for the decline included erratic rainfall and emerging biotic and abiotic stress. The quality profile of Indian cotton has also changed. Long staple cotton which constituted 20% in 2000, increased to 74% of the total cotton produced in 2010 because of the Bt cotton hybrids, most of which are of the long staple category. The area under public research bred varieties and hybrids reduced significantly to less than 8% of the total cultivable area and is anticipated to shrink further. The area under hybrid cotton increased from 40% in 2002 to 92% in 2010. The area under *G. hirsutum* varieties was 33% in 2000 which reduced to less than 3% in 2009. The area under *G. barbadense*, *G. arboreum* and *G. herbaceum* was 6.6%, 25% and 13% during 1995, which has

declined to less than 7% in 2010 for the three species together.

Without proper refugia compliance with more than 90% area under Bt-cotton, there was high risk of bollworm resistance development (8 to 32-fold in *H. armigera*). CICR was exploring the possibilities to develop adaptable resistance management strategies. Another immediate concern was jassid resistance to Gaucho to an extent of 50 to 5450-fold resistance in 75% populations tested. Since all hybrid seeds are treated and crop is also sprayed with Imidacloprid, insecticide usage and concomitant pest resistance to imidacloprid had increased. Emerging biotic stress factors such as mealybugs, miridbugs and minor pests have started causing considerable economic damage. New abiotic stress factors such as leaf reddening and wilt emerged as major problems. At this crucial juncture, there is an imminent need to plan with a renewed vision to address all the concerns through good research and extension initiatives so as to enable India become the global leader in cotton.

Details of state-wise cotton area, production and productivity are given in Table 2.

Table 2: State-Wise Cotton Area, Production and Productivity

Zone/State	2009-2010			2010-2011		
	Area (Lakh ha)	Production (Lakh bales)	Productivity (Kg/ha)	Area (Lakh ha)	Production (Lakh bales)	Productivity (Kg/ha)
Punjab	5.11	14.25	474	5.30	16.00	513
Haryana	5.07	14.75	495	4.95	14.00	481
Rajasthan	4.44	11.00	421	3.34	9.00	458
North Zone	**14.62**	**40.00**	**465**	**13.59**	**39.00**	**488**
Gujarat	26.25	98.00	635	26.33	102.00	659
Maharashtra	35.03	63.00	306	39.73	82.00	351
Madhya Pradesh	6.11	15.00	417	6.51	17.00	444
Central Zone	**67.39**	**176.00**	**444**	**72.57**	**201.00**	**471**
Andhra Pradesh	14.75	52.00	599	17.76	53.00	507
Karnataka	4.55	9.00	336	5.34	10.00	318
Tamil Nadu	1.04	5.00	817	1.30	5.00	654
South Zone	**20.34**	**66.00**	**552**	**24.40**	**68.00**	**474**
Others	0.32	1.00	227	1.05	4.00	648
Total	**103.10**	**283.00**	**486**	**111.61**	**312.00**	**475**
Loose cotton consumed but not counted for in State-wise prod.		12.00			0.00	
Grand Total	**103.10**	**295.00**	**486**	**111.61**	**312.00**	**475**

1 bale = 170 kg.
Source : *Office of the Textile Commissioner, Mumbai*.

11.12 : Impressions of Visitors

The visit to the Institute and interactions with the colleagues were very interesting, bringing out the new lines and leads that the CICR has made. Cotton in India has received much from this Institution. The future is exciting as well as demanding for the researchers here. Compliments to the Director and Colleagues at CICR and Best wishes in all future endeavours .

Dr. S. Ayyappan,
Secretary, DARE & DG, ICAR,
New Delhi

Visit CICR in the New Year and was happy to see the progress both physical and technical made by the Institute in the last few years. I Congratulate the Director and staff for this. New Year can be devoted to take up another resolve to see cotton productivity to touch 1000 kg lint/ha. This will bring prosperity to cotton farmers of India.

Dr. C. D. Mayee,
Chairman, ASRB,
New Delhi

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