

2. Executive Summary

2.1 Crop Improvement

Nagpur

- ~ Four thousand five hundred and twenty accessions of *G. hirsutum* and 500 accessions of *G. arboreum* were grown for rejuvenation and seed multiplication. Three hundred and sixty eight exotic genoplasm lines of *G. hirsutum* were acquired from countries like USA, China, Pakistan and Iran. Four hundred accessions of *G. hirsutum*, 119 accessions of *G. arboreum* and 43 accessions of *G. herbaceum* were distributed.
- ~ Twenty-four wild species, 20 perennials, 6 races of *G. arboreum*, 7 races of *G. hirsutum*, one race each of *G. barbadense* and *G. herbaceum* and 32 interspecific hybrids were maintained in the species garden.
- ~ TGMS lines suitable for cost effective hybrid seed production programme in diploid cotton have been identified.
- ~ The strain CNH 1102 had good combination of high fibre length (30 mm), superior ginning outturn (42.0%) and better yield potential (1476 kg/ha) compared to check LRK 516 (1027 kg/ha) and has been sponsored in AICCIP trial.
- ~ Two RCGM trials with transgenic cotton were conducted. Hybrid NHH 44 Bt recorded highest yield with 25% higher yield than the check RCH 2 and 26.56% over its non-Bt counterpart.
- ~ In an effort to develop transgenic *G. arboreum* varieties RG 8, PA 255 and PA 402 through Agrobacterium mediated gene transfer, 119 plants of Bt RG 8, 32 plants of Bt PA 255 (both with *cry* 1Ac) and 17 plants of Bt PA 402 (with *cry* 1Aa3) were tested by dipstick method. It was observed that 70% plants of Bt RG 8, 81% of Bt PA 255 and 90% plants of Bt PA 402 tested positive.
- ~ Indigenously synthesized genes, *cry* 1F and *cry* 1Aa3 have been successfully transferred to diploid cultivars, viz. PA 402, PA 405, PA 183, AKA 5, AKLA 7 and *hirsutum* genotypes, viz. LRA 5166 and LRK 516 (Anjali).
- ~ In an effort to develop diagnostic tools for differentiation and detection of biotypes / races of pathogens of cotton, PCR based method has been developed for precise detection and differentiation of four major economically important fungal pathogens of cotton, viz. *R. areola*, *R. bataticola*, *R. solani* and *A. macrospora*.

- ~ The germination and seed reserve quantity increased significantly for seeds with high seed index, whereas seed reserve utilization was unaffected by the size of seed. There was a significant increase in emergence, cotyledonary leaf area, seedling dry weight (at 15 days), sympodial number and seed cotton yield per plant for bigger seeds with larger seed index.
- ~ Eighty genotypes belonging to all the four cultivated species of cotton were characterized based on 41 morphological characteristics as per National DUS Test Guidelines.
- ~ With low input management, the *G. arboreum* varieties gave higher yield than *G. hirsutum* varieties in shallow soils.

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- ~ Two hundred germplasm accessions in each of *G. hirsutum* and *G. arboreum* species were evaluated for morphological and agronomic characters.
- ~ Characterization of 320 germplasm accessions of *G. barbadense* indicated wide variability for plant type, flowering and fruiting behaviour.
- ~ The long staple hybrids viz., LK 1 x TK 2 and LK 1 x TK 6 were superior than the check hybrids in terms of both seed cotton yield and fibre quality.
- ~ The GMS based interspecific hybrid CHB 727 has been sponsored for agronomic trials in south zones based on its consistent performance over the years.
- ~ Two new conventional interspecific hybrids viz., LS 25 x P 28 and LS 26 x P 28 have been identified based on station trial.
- ~ The medium staple culture CCH 510-4 has been sponsored for agronomic evaluation in both central and south zone locations of AICCIP.
- ~ High strength cultures viz., CCHE 4-3-13 and CCH E 5-25 have been identified to combine both yield and fibre quality vis-a-vis the check variety Surabhi.
- ~ Some superior single plants were selected from introgressed segregating population which were found to have 2.5% span length of 24.1 mm and fiber strength of 24.3 g/tex and are being further evaluated.
- ~ Single plant selections containing as high as 24-26 % seed oil have been identified from the segregating population.
- ~ Applications of mixture of DAP @ 2 %, Boron @ 0.6 kg/ha, Zinc @ 0.5% improved seed quality.

- ~ Pelleting cotton seeds with Thiram @ 2 g kg⁻¹ + Gypsum @ 60 g kg⁻¹ + Micronutrient @ 20 g kg⁻¹ + Imidacloprid @ 7 g kg⁻¹ + DAP @ 20 g kg⁻¹ in five layers sequentially significantly enhanced the seed viability.
- ~ RAPD markers OPJ 10 and OPA 4 expressed similar DN A sequences in male parent and hybrid of Savita.
- ~ Draft National Test Guidelines for tetraploid and diploid cotton was developed and published.
- ~ Morphological characterization of 131 extant cotton genotypes was completed and digitized.
- ~ Cotton seeds of 85 varieties including parental lines and hybrids were collected and kept under reference collection.

Sirsa

- ~ The *intra-hirsutum* hybrid CSHH 238 and *G. arboreum* variety CISA 310 were notified by the Ministry of Agriculture, Government of India for commercial cultivation under irrigated conditions of North Zone. The *intra-hirsutum* hybrid CSHH 243 was identified for release under irrigated conditions of North Zone during the Annual Group Meeting of All India Coordinated Cotton Improvement Project on 11-13 April, 2007 at Navsari, Surat.
- ~ CPF -1, a spontaneous *G. hirsutum* mutant with pink anther filament was registered with NBPGR (No. INGR07036).
- ~ CSPF-1, a spontaneous *G. hirsutum* mutant with pink petals has been registered with NBPGR (No. INGR07035).
- ~ Two bollworm tolerant lines viz., BN-Okra and BN-Red were registered as INGR 07050 and INGR 07049 with NBPGR.
- ~ Boll setting was high upto 5th October in the hybrid seed production plots.
- ~ Foliar spray of boron (0.1 %) at 60, 75 and 90 DAS enhanced boll setting during the entire crossing period.
- ~ Significant increase in boll number and boll weight was observed when DAP (2%) at 45 DAS + MgSO₄ (1%) at 50 DAS + Boron (0.1 %) at 60 DAS + ZnSO₄ at 75 DAS were applied.
- ~ Topping at 60 DAS increased boll weight, seeds/boll, yield/plant, germination percentage and vigour index.

2.2 Crop Production

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- ~ Integrated nutrient management significantly increased seed cotton yield. Application of FYM and enriched compost were found equally effective. Fibre quality remained unaffected with nutrient management.
- ~ Application of RDF in combination with 20 kg ZnSO₄ /ha and Boron @ 0.5% resulted in significantly higher seed cotton yield.
- ~ Application of N in 3 splits with foliar N supplementation improved the Cry toxin expression in Bt cotton. It was significantly higher in deep soil than in shallow soil.
- ~ Application of 50% RDF in soil + 50% through fertigation with the soil application 10 kg ZnSO₄ /ha significantly increased the seed cotton yield. It also improved the nutrient use efficiency.
- ~ Intercropping in cotton and *in-situ* moisture conservation with opening furrows in alternate rows significantly increased the cotton yield. One protective irrigation at boll development stage recorded the highest yield.
- ~ Tillage effects were significant with regard to weed density and weed dry matter accumulation only. Green manuring with 80 kg N /ha yielded at par with 100kgN /ha.
- ~ American cotton + Pigeonpea strip cropping (6: 2) and *desi* cotton + Pigeonpea (12 : 2) were economical and profitable.
- ~ Urea and single superphosphate 1 % foliar spray during flowering increased seed cotton yield.
- ~ Foliar application of 0.01 % spray of ethrel showed a marginal increase in yield of LRA 5166.
- ~ Plant water status was found higher in *G. hirsutum* as compared to *G. arboreum* and *G. herbaceum* at a given moisture stress.
- ~ The drought tolerance studies indicated that development of water stress at elevated temperature and low humidity led to marked increase in stomatal resistance and decreased transpiration rate. The relatively tolerant lines identified are CAT 3640, CAT 3874, CAT-1058, AC-7602, AC-7185. Nitrate Reductase Activity showed a decreasing trend while peroxidase activity was increased under stress condition.

- ~ The seed germination was adversely affected with soil salinity. Genotypes with shallow root system are more prone to wilting. Cotton area in select locations and the prediction model developed with integrated approach incorporating remote sensed data on crop acreage, GIS and weather maps was found satisfactory with 85 % success.
- ~ Battery operated knapsack sprayer has been developed and it is found to perform satisfactorily under field conditions.

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- ~ Studies revealed that introduction of grainjowar as a sequential crop in cotton fallows enhanced seed cotton yield by 22% and with an additional sorghum grain yield of 6160 kg/ha.
- ~ A field trial indicated that application of FYM @ 5 t/ha and *in-situ* green manure of sunhemp @ 15 kg/ha produced highest seed cotton yield (1739 kg/ha) and fibre production efficiency over control.
- ~ Shading of top soil surface under the semi-arid condition with mulch had an advantage in terms of moisture conservation, weed suppression and nutrient availability besides improving field performance of cotton crop.
- ~ The partial factor productivity of N (PFPN) decreased with the increase in the N levels and the maximum PFPN was recorded under protective irrigation treatment.
- ~ Application of protective irrigation (three times) to protect the crop from continuous dry spell which occurred during the crop growth period gave the highest seed cotton yield (1530 kg/ha).
- ~ The highest net return (Rs. 24,404/ha) and benefit cost ratio (1.9) were arrived with low cost poly-tube (using 300 gauge thickness) drip system with an average increase of 13 per cent in seed cotton yield.
- ~ For maximizing the yield in ELS cotton, chisel ploughing + drip fertigation + foliar spraying of speciality fertilizer (19:19:19 @ 1% at 75 and 105 DAS and 13:0:46 @ 1% at 90 DAS) was found suitable.
- ~ Cotton intercropped with radish + beetroot + coriander system recorded the highest net return of Rs. 85,644/ha and benefit cost ratio 2.9 because of higher performance of all three intercrops.
- ~ Bt cotton hybrids under rainfed condition with sub optimum rainfall produced significantly higher mean yield of 1250 kg/ha, which was 105 per cent higher than their non Bt counterparts (610 kg/ha).
- ~ Poly mulch + Drip at 0.4 Etc recorded the highest seed cotton yield of 5494 kg/ha, lesser water requirement of 44.5 ha cm and the highest water use efficiency of 123.5 kglha cm. The conventionally irrigated cotton recorded the highest water requirement of 95.8 ha cm with the lowest water use efficiency of 36.0 k glha cm.
- ~ The enhancement in seed cotton yield was 22.8 % due to drip and 46.7 % due to Drip + poly mulching.
- ~ Application of 75 % recommended Nand P with Azospirillum + PSB + PPFM as seed and soil treatment with two foliar spraying of PPFM at flowering to boll development was comparable with 100 % recommended Nand P without bio-inoculants.
- ~ Foliar application of ethrel @ 45 ppm at 40 DAS increased NR activity, enhanced accumulation of reducing sugars, proline and protein. There was a synchronous flowering and boll development with ethrel application leading to uniform boll bursting leading to enhanced yield to an extent of 26-46%.
- ~ With specific RAPD marker, the MCU 5 showed two extra bands of size 2767 bp and 503 bp as compared to lint less mutant of MCU 5.
- ~ Morphological attributes like plant height, sympodial length, leaf size, boll weight and yield were significantly reduced when water logging was imposed beyond five days irrespective of the Bt cotton genotype.
- ~ Among the variables, price of the seed and distance traveled to procure the seeds were found to have significant influence in the choice of varieties / hybrids.
- ~ Lack of labour and low price were the major constraints for seed growers and varietal unawareness for cotton seed buyers.
- ~ Eighty five per cent of the Bt farmers opined for higher yield for adopting Bt cotton coupled with less cost of cultivation, marketing facilities and early maturity.
- ~ The major reasons for poor area of cotton in Tamil Nadu were improper management, un-irrigated areas, absence of integrated pest management, vagaries of monsoon, labour shortage etc.
- ~ The total cost of cultivation was higher in case of non

contract farming due to higher labour use when compared to contract farming. The difference was Rs.2200/- per hectare.

- ~ User-friendly information retrieval system has been developed.
- ~ Second version of cotton cultivars CD has been developed.
- ~ CICR web site (www.cicr.gov.in) has been updated with Indigenous Technical Knowledge on cotton production and protection; IPM package and IRM package for Cotton; Bt Cotton Reports; Details of Bt cotton detection Kits etc.
- ~ Seven technological interventions were assessed through seventy on farm trials and were found to give better yield and enhanced the B:C ratio for adopted technologies.
- ~ Farm women played significant role in decision making and the major activities performed by the farm women in cotton are stubble removal, sowing, gap filling, intercropping, thinning, weeding, fetching water for pesticide application, de-topping, labour supervision, harvesting of crop and intercrop and cotton grading.
- ~ Front line demonstrations were conducted on production technologies, implement demonstration and demonstration of IPM in cotton in Annur block.

2.3 Crop Protection

Nagpur

- ~ Incidences of various diseases were recorded at seedling and boll development stage. Analysis of diseased and healthy-looking seed lots revealed pathogenic infections due to 6 cotton pathogens, 5 other crop (wheat, soyabean, sorghum) pathogens and that of storage fungi comprising the species of *Aspergillus*, *Penicillium* and *Rhizopus*.
- ~ Five races viz. 3, 7, 10, 15 and 18 of *X. a. pv. malvacearum* were identified among 150 isolates of which race 18 was predominant. Two lines viz., CTI42545-R and EL 395A of *G. hirsutum* exhibited resistant reaction against virulent race 18 of *Xam* under pot culture test. Two hundred and sixty nine single plant selections with resistance to bacterial blight were identified from different crosses involving resistant donor parents.
- ~ Morphological, cultural and pathogenic variation in the isolates of *R. areola* indicated the existence of races/ biotypes.
- ~ Variability in growth pattern, influence of salt concentration on growth, pigmentation, pathogenic virulence and RAPD - PCR pattern were observed in eleven isolates of *Fusarium oxysporum* f. sp. *vasinfectum*. Four rhizobacteria belonging to *Pseudomonas* sp. and *Bacillus* sp. were effective in inhibiting the growth of *Fusarium oxysporum* f. sp. *vas infectum* and *Macrophomina phaseolina* thereby improving the seedling vigour.
- ~ Out of 73 lines screened, 7 lines of *G. hirsutum* and 6 lines of *G. arboreum* were found to be resistant/tolerant against *Rhizoctonia* root rot and *Fusarium* wilt.
- ~ Jasmine perfume is an induced volatile chemical triggered by injury in plants. A synthetic analogue of Jasmine perfume was found to induce early maturity in the two hybrids tested (RASI-2 and NHH-44) by almost 20-25 days as compared to the untreated plots while conferring jassid tolerance.
- ~ A molecular tool based on PCR-RFLP with Bst 2 UI was developed to identify and map the distribution of a founder haplotype of *Helicoverpa armigera* (haplotype 17) across diverse agro-ecological regions of India.
- ~ Studies were carried out to monitor *Helicoverpa armigera* resistance to *cryIAC*, *cry2Ab2* and *cryIAC-JK* deployed in three independent events that were released for commercial cultivation in India. The data showed a decrease in variability between *H. armigera* populations in their response to *cryIAC*.
- ~ Seven additional Hemipteran species- 1. *Geocoris ochropterus* (Fieber), Lygaeidae; 2. *Badozorus* sp. Miridae; 3. *Zanichius* sp. Miridae; 4. *Nezara viridula* (Linnaeus) var. *torquata* (Fabricius), Pentatomidae; 5. *Nezara viridula* (Linnaeus) var. *smargdula* (Fabricius), Pentatomidae; 6. *Plautia frimbriata* (Fabricius), Pentatomidae and 7. *Piezodorus rubrofasciatus* (Fabricius), Pentatomidae, were recorded thereby indicating an increase in the taxonomic biodiversity within the cotton ecosystem.
- ~ Seasonal dynamics data showed enhancement in bollworm control by parasitoids and a significant role of spiders in regulating jassids and mirids.
- ~ Calendar based accumulated degree days of 2424 was used to predict the onset of *H. armigera* oviposition on cotton for the season and the seasonal predictions of less severe infestation of *H. armigera* and *P. gossypiella* was validated.

- ~ The yield potential of genotypes was found to be a function of differential phenology and response to loss in fruiting parts. The genotypes' response was passive and instantaneous to *Earias vittella* damage during mid and late season.
- ~ It was possible to devise indices to measure 'explicit tolerance trait of compensation' (excluding yield criteria) only when early season damage occurred with or without moisture limitations.
- ~ On farm trials indicated that the plant protection cost in BtIPM was 53% less compared to BtNIPM, and 32% less than NBtIPM. The plant protection cost in CIPM was 35% less than CNIPM, whereas the costs in Bt NIPM were only 7% less than the CNIPM thereby implying the imminent need for IPM on Bt cotton.
- ~ Based on selection and crossing, a heat and moisture stress tolerant isolate of entomopathogenic nematode (EPN), *Heterorhabditis indica* was developed.
- ~ Extracts of a bacterial symbiont of an isolate of *Heterorhabditis indica* was identified as a potent bioagent for management of sucking pests.
- ~ Two sprays of EPN @ one billion nematodes per ha at an interval of 4-5 days sprayed in the evening with addition of 1 % sticker and phagostimulant, glycerine resulted in reduction of bollworm population by 58%.
- ~ Two discriminating doses for *cryIAc* resistance were validated on progeny of specific backcrosses made using homozygous parents. A dose of 5 Ilg/gm diet was able to discriminate RR from RS and SS, whereas a dose of 1.0 Ilg/gm was able to discriminate RS from SS. Inheritance of *Helicoverpa armigera* (Hubner) resistance to *ChyIAc* toxin from *Bacillus thuringiensis* was determined through genetic crosses.
- ~ A SCAR marker was developed from a unique RAPD-amplicon (1.18 Kb) associated with *cryIAc* resistant strains. The amplicon was cloned and sequenced. Based on the sequences obtained a set of three primers was designed to specifically amplify two different amplicons from the resistant (1.18 Kb) and susceptible (1.06 Kb). The primer set enables the characterization of unknown samples with respect to their susceptible / resistant properties towards *cryIAc*.
- ~ The *cryIAc* resistance allele frequency was estimated using 198,330 and 165 isofemale lines of

H. armigera collected from north, central and southern parts of the country. Based on the F_2 progeny tested, only one *cryIAc* resistance conferring allele in the central Indian population was detected. A Bayesian analysis of the data indicated that the frequency of resistance alleles was 0.00125, 0.0015 and 0.00149 in south, central and north India, respectively, with 95% probability, and a detection probability of >85%.

- ~ Field experiments showed that Marigold and sunflower attracted significantly more eggs and sustained more larvae as compared to non-Bt cotton. Pigeonpea was also found to be attractive at the later part of the cotton fruiting phase. Hence it would be possible to devise a strategy with a combination of crops along the border that can serve as an effective refuge instead of the conventional recommendation of 5-border non-Bt cotton rows.
- ~ During the 2006-07 cropping season, IRM (Insecticide Resistance Management) strategies were disseminated to 72,783 farmers in 1.38 lakh hectares in a total of 1062 villages in 33 districts across India. Implementation of the programme resulted in yield increases estimated at a net additional benefit of Rs 48.4 crores and a saving on reduction in insecticide use accounting for Rs 27.4 crores, thus adding up to a total additional benefit of Rs 75.8 crores due to the project.

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- ~ Population of aphids was negligible through out the cropping period.
- ~ Mirid bug incidence was recorded during the first week of January in both Bt and Non Bt cotton.
- ~ Higher incidence of up to 80-90 % plants was observed to have mealy bug incidence both in Bt and Non Bt cotton.
- ~ Percentage of incidence of Pink bollworm was significantly lower on Bt hybrid than on the non Bt hybrids.
- ~ During the winter cotton season of 2006 -07, grey mildew was noticed in severe form throughout Tamil Nadu and all four cultivated *Gossypium* spp. were affected. Sporadic incidences of alternaria leaf spot were noticed.
- ~ In the IRM project villages of Salem District, Bt hybrids were superior than the NBt counterparts by recording minimum percentage of boll damage. Sucking pests viz., jassid, aphids, thrips and

whiteflies population were below threshold level and the low population of the bollworms resulted in lower damage.

- ~ Yield loss of upto 26 % has been observed due to grey mildew disease in cotton.
- ~ There is specific variation among the populations of *H. armigera* collected from other crops and cotton also from different locations.
- ~ Seed treating chemicals thiomethoxam 500FS @ 5 ml and 7.5 ml/kg of seeds was effective up to 35 days in reducing jassids and aphids.
- ~ For controlling the pink bollworms, Triazophos 0.05% was found effective.
- ~ TERJ formulations could effectively bring down the population of sucking pest and bollworm with corresponding increase in predator population.
- ~ Imidacloprid and new insecticides like E 2Y45 and Spinosad were found to have moderate effect in reducing the population of mirid bug.
- ~ New insecticides E2Y45 and Flubendiamide + Thiacloprid were effective and brought down the fruiting body, locule and boll damage by bollworms.
- ~ The new fungicide Propineb was as effective as the standard Propiconazole in the control of grey mildew.
- ~ Implementation of IRM strategies in the project villages resulted in the reduction of number of sprays and plant protection cost.
- ~ The resistance levels were very high to fenvalerate (90.00%) and low for Chlorpyrifos (3.33%).
- ~ Six lines viz., GSHV-153, NH 630, CCH LS4, AKH 05-5, CNH-1101 and CNH 1102 recorded resistant reaction to jassid.
- ~ Of 88 promising advanced genotypes screened 22 cultivars showed tolerance to jassid while 12 cultivars showed tolerance to bollworm complex.
- ~ Derivatives of tolerant introgressed lines possessed higher levels of terpenoid metabolites and phenols in young squares and developing bolls.
- ~ Four disease resistant lines ALR- 20, GMR- 13, CBR -29 and MAR-8 had better seed cotton yield than LRA 5166 and Sumangala.
- ~ Among the AICCIP entries (333 nos.) screened for grey mildew disease resistance under poly house condition, eight lines were resistant and 58 were moderately resistant.
- ~ Of the 77 breeder's lines screened, eleven lines have shown moderate resistance to grey mildew.
- ~ Survey revealed the presence of entomopathogenic nematodes like *Heterorhabditis indica* and *Steinernema siamkayai* and an unidentified species of *Steinernema* in 8-10 % of the samples in cotton ecosystem.
- ~ The bacterial symbionts associated with entomopathogenic nematodes were *Photorhabdus* and *Xenorhabdus* and were isolated, cultured and characterized. They possessed antimicrobial property against wide range of bacteria and fungi.
- ~ The preliminary study of pathogenicity of two native entomopathogenic nematodes viz., *Heterorhabditis indica* and *Steinernema glaseri* indicated their usefulness against *H. armigera*.
- ~ Based on prominence value, *Rotylenchulus reniformis* was identified as Key nematode pest of cotton.

Sirsa

- ~ A plant polyclinic was established at Rangri village along with prototype IPM farm demonstrating the pheromone trap, light trap, neem products, etc.
- ~ The IRM Programme in Haryana covered 49,558 ha in 150 villages and involved 13721 farmers. IRM strategies resulted in the reduction of number of sprays (23 to 40 per cent). The average yield obtained in the IRM village was 1897 to 2185 kg/ha, as against 1804 to 1995 kg/ha in the control village. Consequently, the IRM farmers realized a net increased profit of Rs. 2435 to 5233 per hectare than the control village farmers. Implementing IPM strategies in Bt cotton hybrids also resulted in reduction in number of sprays (16 to 18.5 %), increased yields (181 to 223 kgl/ha) and increased net profit (Rs.3251 to 5595 /hectare).
- ~ The primer designed for detection of *Rhizoctonia bataticola*, the causal organism of root rot disease, was validated and it showed amplification of all *R. bataticola* isolates from cotton and other crops where as it did not amplify isolates of *R. solani* and *Fusarium* spp.
- ~ A net return of Rs. 24,535 per hectare was obtained in the seed production of conventional hybrid CSHH 198. A net return of Rs. 60,830 per hectare was obtained in the seed production of GMS based hybrid CICR2.