2. EXECUTIVE SUMMARY

2.1 Crop Improvement

Nagpur

- One thousand thirty eight exotic germplasm accessions of *Gossypium hirsutum* and nine wild species were procured from USA under enrichment programme of Cotton gene bank.
- Seeds of 692 accessions of *G. hirsutum*, 267 accessions of *G. arboreum* and two wild species namely *G. raimondii* and *G. anomalum* cotton were deposited for long term cold storage at NBPGR, New Delhi.
- Plants of two wild tetraploid species *i.e. G. darwinii* and *G. tomentosum* were introduced and established in the wild species garden.
- The genotypes with special morphological characters *viz*. zero monopodia, cleistogamy and protruding stigma were confirmed.
- The culture CNHO 12 (yield 14-15 q/ha, Fibre length 25mm , Fibre strength 20.2 g/tex and oil 19 %) has been recommended by AICCIP Group Meeting for Pre-release Agronomy Trial for Central Zone under irrigated conditions for the year 2008-09, while long linted *G. arboreum* strain CINA 347 was retained for further evaluation in central zone rainfed trial of AICCIP 2008-09.
- Improved strains of *G. hirsutum* CNH 1104 (fibre length 34 mm) and of *G. arboreum* CAN 1005, CAN 1006 were sponsored in AICCIP trial.
- Enhancement of boll wt. upto 3.8 g with staple of 28 mm in PKV 081 through backcross (PKV 081 x PIL 8) x PKV 081. Culture CIHS 97-10 had ranked top in station trial 2007-08.
- Improvement of diploid and tetraploid cotton through population improvement approaches is under progress. Fourth cycle of random mating through conventional crossing has been completed while first and second cycle of GMS based random mating has been completed in tetraploid and diploid cotton respectively. Single plants *viz*. 485 *G. arboreum* and 479 *G. hirsutum* were selected from the random mating populations.
- Promotion of *arboreum* varieties PA 255, PA 402 and CINA 316 amongst 33 tribal farmers in the Melghat region of Vidarbha was accomplished.
- Primary putative transformants of CLCUV trangenics were confirmed for the presence of Anti-sense Coat Protein(ACP), Sense Coat Protein(SCP) and Anti- sense Rep (A-Rep) genes.
- T_1 generation of Bt varieties LRA5166 and LRK516 were taken to RCGM strip trial.
- Transformation of *cry* 1 F, *cry*1 Ac (enhancer), *cry*1 Aa3 and Chitinase was done and 12 plants (T_0) of PA 255 and PA 402 have been established.
- Fifty six race 18 isolates of *Xanthomonas axonopodis pv. malvacearum* were characterized using six molecular markers.
- A 3.1 kb plasmid pKSB-Int was constructed for generating double stranded RNA (dsRNA) to affect post-transcriptional silencing of gene for functional analysis and also for developing resistance against plant viruses. Two dsRNA interference constructs for coat protein and C4 gene of CLCuV were developed for transformation of cotton.
- Hardseedness (physical dormancy) was found just after picking but the germination was improved after 20 days of storage by 2-40% in parents whereas in F_1 crosses the germination improved by 4-40%.
- Seed quality was better in seed samples procured from companies from Akola, Parbhani, Jalgaon, and Rahuri. Samples from Srivilliputtur, Rahuri, Dharwad, Bharuch and Kanpur carried lesser load of fungi.
- Seed hardening agents such as di-sodium hydrogen phosphate , mannitol and KCl all @ 2% resulted in increased rate of germination as well as germination percentage under normal germina-tion and osmotic stress germination tested with 10% PEG solution.

- Fifteen hybrids and their parents in *G. hirsutum* have been characterized for 37 morphological characters.

Coimbatore

- Among the 250 germplasm lines assessed, wide variability was noticed for agronomic characters with ICGH 404-1 recording 4044 kg/ha of seed cotton yield (13% yield increase over Sumangala (3568 kg/ha) several lines possessing boll weight of over 5.0 g with highest boll weight of 7.2 g /boll being in ICGH-755-1.
- Male sterile based interspecific hybrid 70 G X SR was the best with 2950 kg/ha of significantly higher seed cotton yield over the best check hybrid DHB 105 with 2348 kg/ha of yield. Conventional interspecific hybrids CCHB-51 (2324 kg/ha), CCHB-56 (2263 kg/ha) and CCHB-7 (2251 kg/ha) were significantly superior in seed cotton yield to the best check hybrid DCH-32 (1670 kg/ha).
- Intra *hirsutum* Bt cotton hybrid MRC 7351 BG II recorded 3887 kg/ha which was significantly higher than the Bt cotton check hybrid RCH 2 Bt (3272 kg/ha). Seven other Bt cotton hybrids also recorded significantly higher yield over RCH 2 Bt. Interspecific Bt cotton hybrid MRC 6918 was noticed to be best for both yield and fibre quality recording a seed cotton yield 3725 kg/ha, fibre length of 35.4 mm and a bundle strength of 24.3 g/tex.
- Among the introgressed lines tested, MM-02-11-7 was the best with a seed cotton yield of 2873 kg/ha with medium staple fibre quality. Culture MM-03-39-4-1was found best with 34.4 mm and the culture MM-03-39-4-1was the best for bundle strength with 24.9 g/tex.
- Variety CCH 510-4 tested in the AICCIP irrigated trials in South Zone during 2003 to 2007 proved its superiority in yield and quality over the check variety and has since been identified for release in South Zone under irrigated conditions.
- Medium staple genotype L (L x IBM) 2629 recorded the highest yield of 4966 kg/ha with a seed cotton yield increase of 48 per cent over the check variety and had high ginning out turn of 38 per cent.
- Pelleting and coating of cotton seeds with polymers resulted in improving viability by 3 to 4 per cent and substantial improvement in field emergence and better protection against pathogenic infection.
- Breeder seed production was taken up for cv. Surabhi, LRA 5166, MCU 5 VT and Suvin varieties and 7.75 q of breeder seeds were produced.

Sirsa

- The intra-*hirsutum* hybrid CSHH 243 was identified for release in North zone and the proposal for notification has been submitted to CVRC, New Delhi.
- The Cotton germplasm, CIR-8,CIR-12,CIR-23,CIR-26,CIR-32,CIR-38 and CIR-47 as CMS restorer lines were registered with National Identities, IC553921, IC553923, IC553924, IC553925 IC553926, IC553927, and IC553928, and Registration numbers, INGR No. 08031, 08032, 08033, 08034, 08035 08036 and 08037, respectively.
- The variety CISA 614 based on five years testing in AICCIP trials (2003-04 to 2007-08) ranked first and was recommended for Agronomy trial in north zone.
- The GMS based hybrid CSHG 1862 recorded the seed cotton yield of 1964 kg/ha and 34.2 % ginning outturn and ranked 4th position in Br 05a1 in north zone.

2.2 Crop Production

Nagpur

- Under long term fertilizer trial the organic carbon content of surface soil was enhanced from 0.41 % to 0. 51 % in both INM and organically treated plots.
- On medium black soils, application of 10 kg each of $ZnSO_4$ and $MnSO_4$ alongwith 3 kg borax / ha improved seed cotton yield by 203 kg / ha (16 % higher than control).
- There were no significant differences between Bt

and Non Bt cotton with regard to soil microbial population, but cotton grown organically recorded higher microbial population.

- On shallow soil, fertigation in hybrid cotton (NHH-44) recorded significantly higher seed cotton yield (17.3 q/ha) with the application of 50 % RDF (120 kg N, 60 kg P_2O_5 and 60 kg K_2O / ha) through drip irrigation coupled with the addition of zinc and biofertilizers over the soil application of RDF alone.
- Higher seed cotton yield, water use efficiency and water productivity was obtained with the *in-situ* moisture conservation through intercropping with greengram followed by bio-mulching with sunhemp. Application of N and NK in 3 splits (10, 30 and 60 DAS) produced significantly higher seed cotton yields. Irrigation through drip at 0.6 Etc with 75 % RDF as fertigation to Bt cotton hybrid (Bunny) recorded optimum seed cotton yield, water use efficiency and water productivity.
- The most profitable cropping system was Bt hybrid cotton intercropped with radish followed by cowpea and cluster-bean.
- Cotton+pigeon-pea planted in 6 : 2 and 12 : 2 proportion was economical and profitable for American hybrid cotton and *desi* cotton, respectively.
- Application of Ethrel @ 30 ppm at square formation stage recorded significant increase in yield and harvest index.
- Twenty four genotypes belonging to *arboreum* races have been evaluated by using three PCR based DNA markers.
- Three defoliants namely Dropp (1 %), ethrel (1 %) and Round up (1.2 %) were tested for defoliation of cotton crop to make it enable for mechanical picking. Ethrel showed maximum percentage defoliation (73 %) but it was statistically at par with drop (71 %) and round up (60 %)
- Trials were conducted with the knapsack type power sprayer engine operated aspiration type cotton picker. Initial evaluation indicated that a team of two persons can use the suction type cotton picker which picks 6 kg cotton / hour.
- Small farm equipments for cotton farmers for increased efficiency such as (i) adjustable hoe, (ii) adjustable ridger and (iii) bund former were developed.
- Total factor productivity of cotton in Maharashtra ranged from 0.7748 to 1.3337 during the period 1995-04, while in Madhya Pradesh it ranged from 0.8264 to 1.6857 during 1996-04.
- Studies on social dynamics of cotton production in distressed areas of Vidarbha region indicated that very high percentage of respondents fall under the score medium to high degree in respect of powerlessness, meaningless and isolation.

Coimbatore

- Cotton in Cotton-Sorghum (1427 kg/ha) system was found significantly superior over cotton-fallow (1160 kg/ha) due to higher efficiencies in terms of nutrient use, water use and moderation of saline water effect (>3.5 EC).
- The highest seed cotton equivalent yield (SCEY) (53.2 q/ha) and gross return (Rs 1,06,435 /ha) and net return (Rs 69,386/ha) were noticed with the multi-tier intercropping of cotton with radish, beet root and coriander with the application of 100 per cent of recommended level of fertilizers to intercrops.
- High density planting maintained through narrow row spacing of 90 x 10 cm in cotton variety (Surabhi with 2241 kg/ha) resulted in seed cotton yield on par with Bt cotton hybrid (RCH-2 with 2554 kg/ha) at optimum spacing of 90 x 45 cm.
- Bt hybrids performed better under low scantyed rainfall situation in comparison to isogenic non Bt hybrids and variety (LRA 5166). Premature senescence in RCH 20 Bt can be managed by balanced fertilization and split application of N and K.
- Around 1464 litres of water was used per kg of seed cotton under 0.8 ETc drip in comparison to 2004 liters/kg of seed cotton in surface furrow irrigation through IW/CPE of 0.6. Thus, for economic water use and without sacrificing on yield, drip irrigation scheduling at 0.8 ETc was optimum.

- Breaking of sub soil compaction by chisel ploughing and adoption of drip system for irrigation and fertigation (low cost drip system) combined with foliar application of poly feed (19:19:19) @ 1 % at 75 and 105 DAS and multi K (13:0:46) at 90 DAS registered higher seed cotton yield (2,732 kg/ha) in the yield maximization trial with ELS Bt hybrid.
- The poly mulch + drip system resulted in higher seed cotton yield ranging from 37.6 to 59.1 per cent over the conventional method.
- The generic simulation model INFOCROP showed that the difference between the observed and simulated yield was of the order of 12.4%. However, the model under-predicted seed cotton yield at higher N levels, which calls for its further fine tuning.
- Simultaneous planting of sunhemp at the seed rate of 15 kg/ha and cotton at the normal seed rate in ridge-furrow planting, followed by burying of green manure *in situ* at 40-45 DAS (but before flowering) with 50% RD-N (30 kg) and earthing up is recommended under medium land and irrigated condition.
- Application of ethylene in the form of ethrel was found to be suitable to bring about a change in crop ideotype that will help in enhancing the yield by 30-40% over the control.
- Regression results on the impact of Bt cotton showed a significant impact on yield, value of output and pesticide cost. Bt cotton farmers attributed more profit (72.14 per cent), less pesticide (52.31 per cent) and comparatively more bolls (49.15 per cent) for the choice of Bt cotton.
- Cost of cultivation was higher with non-contract farming when compared to contract farming by Rs.2500/- which was due to higher labour use in the former case. B:C ratio over total cost and cost of production per quintal was remunerative under contract farming (1.64; Rs.1581.60/q) compared to non-contract farming (1.08; Rs.1911.19/q) in cotton. The returns to scale was more than unity in case of contract farming depicting increasing returns to scale.
- Newer version of contents of CICR website was uploaded at the new web location with new domain name www.cicr.org.in
- A high share of waged work was provided by women at peak times namely at weeding and harvesting. The major farm activities which cause health hazards are also done by women.

Sirsa

- To find out the profitable crop rotation system with Bt cotton hybrids (RCH 134 and MRC 6301) under north zone with normal sowing as well as transplanting of seedling system, six crop combinations (cotton normal, cotton transplanted followed by wheat, barley and mustard) were evaluated. The highest net income/ha Rs 46935 and 51315 was observed in cotton followed by wheat with normal as well as transplanted cotton sown field, respectively whereas minimum net income was observed in cotton-mustard cropping system.
- The contribution of transplanting of raised seedling for improvement in plant stand in field was assessed against normal sowing. The per cent plant stand was significantly higher in both the hybrids (RCH-134 and MRC 6301) when seedlings were raised in medium type container and transplanted at seedling age of 15 days (92.9 %) and 20 days (98.8 %).

2.3 Crop Protection

Nagpur

- Incidence of various diseases was noted at seedling and boll development stage. Analysis of healthy-looking and diseased seed lots of the previous crop season (2006-07) revealed pathogenic infection due to seven cotton pathogens. In the evaluation of storage fungi, nine species of *Aspergillus* were recorded which includes mycotoxin (Aflatoxin) producing *Aspergillus flavus and Aspergillus parasiticus*.
- Bacterial blight X. *a.* pv. *malvacearum*, Race 18 is predominant in Maharashtra and Karnataka.
- Two lines viz. ORS 75 - 75 and Rowden 41 B Watson of *G. hirsutum* were observed to be resistant against race 18 of *Xam*.

- Out of 542 lines of upland cotton evaluated under natural incidence of field conditions, 15 lines exhibited disease free reaction and 32 lines were resistant.
- Isolates of *R. areola* from *G. arboreum* and *G. herbaceum* grow rapidly on new synthetic media/broth as compared to the isolates from the varieties/hybrids of *G. hirsutum*.
- Out of the 58 advance cultures of *G. hirsutum* and 6 of *G. arboreum* screened in sick field, and Agar gel test, 32 strains of *G. hirsutum* and 2 strains of *G. arboreum* were found resistant to root rot and wilt, respectively.
- A survey conducted in 47 locations in the nine cotton-growing states showed that two mealybug species, the solenopsis mealy bug, *Phenacoccus solenopsis* (Tinsley), and the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) were found to occur on cotton plants of which. *P. solenopsis* was found to be the predominant mealybug species that comprised 95 % of the samples examined.
- The cotton mealy bug was identified as *Phenacoccus solenopsis* (taxonomically) with minimum genetic diversity (molecular analysis) throughout the country.
- Biorationals Neem oil, Herbal product, *Verticillium lecani, Beauveria bassiana*, Buprofezin and Acephate (slightly hazardous WHO class: III organophosphate insecticide) can be part of *P. solenopsis* management strategy in light of their ecological safety.
- Acetamiprid 20SP, Thiomethoxam 25WG and NSKE were found most effective as foliar spray. Acetamiprid 20SP was also found effective as spot soil drenching as well as stem application that was on par with stem application of Chlorpyriphos 20EC and Triazophos 40EC against jassids.
- Taxonomic identity of the two mirids (Miridae; Hemiptera) *viz., Campylomma livida* Reuter and *Hyalopeplus lineifer* Walker was established.
- Jassids and whiteflies between mid-August and September, aphids during mid August, thrips during the second fortnight of August, and mirids between last week of August and first week of November had their peak incidence
- Numerical mean density of the native predators was in the order of spiders > predatory mirids > chrysopids >coccinellids. The 2007-08 cotton season had witnessed 22 % reduction in damage due to all the three bollworms over the 2006-07 season.
- Relying on host plant resistance for jassids, early season sucking pest control with contact insecticides (based on symptom over population counts, use of imidacloprid only for the late season management of sucking pest (jassids & mirids) and management of late season bollworms with insecticides of conventional chemistries other than pyrethroids have been drawn as the overall pest management strategies.
- Five promising cultures *viz.,* CIPT 511 (A), CIPT 50(C), MTHC 53, MTHC 5(B) and JTHC 50(B)) were identified based on their tolerance to jassids and bollworms coupled with higher yields and good fibre quality parameters.
- JTHC 1104, a jassid tolerant high compensating genetic stock possessing the phenological mechanism of compensation for bollworm damage has been developed.
- Raj 2006, a genetic stock has been registered as source of resistance to jassids with registration number INGR No. 08059 at National Bureau of Plant Genetic Resources, New Delhi.
- Yield level of Bt cultivar (Ankur 651) was high under IPM mode with an increased yield and net returns by 3.25 q/ha and Rs.8150/ha, respectively over recommended package of practices.
- Twenty cotton cultivars viz.LRA 5166, LRK516, Surabhi, Sumangala, PKV081, G Cot10, RG 8, NHH 44, Rajat, AKH 4, H 777, CINA 316, AKA 8401, AKA 5, AKA 7,Laxmi, MCU 10, MCU 5, Omshankar, RS 875 screened against root-knot nematode and reniform nematode under pot conditions were found susceptible to both.
- One isolate of Entomopathogenic nematode (EPN) *Heterorhabditis indica* could be made to tolerate high temperatures by periodic exposure to high temperatures and selection of individuals that can tolerate it.

- Five rhizobacterial isolates belonging to *Bacillis spp*. with nematode antagonistic effect were isolated.
- CINH Ti1, CINH Ti2, CINH Ti3, and CINH Ti4 homozygous for trypsin inhibitor properties with comprehensive pest tolerance have been developed in Bikaneri Nerma and G Cot respectively.
- A replicated field trial demonstrated that AR 27, ND 63, Piedmont Cleveland, JR 52 and G-21-617 can be cultivated with zero plant protection to yield a minimum of 12 q/ha under low input cotton cultivation.
- LC_{50} values derived from 17,330 larvae tested, ranged from 0.057 to 1.146 g Cry1Ac/ml of diet with 8.5-fold, 16.61-fold and 14.88 fold variability in susceptibility across the North, Central and South Indian strains of *H. armigera*. The LC_{50} values ranged from 0.009- 0.201 µg *cry* 1Ac/ml of diet with 22.33 fold variability across the country.
- Economic Threshold Levels for *Spodoptera litura* on MRC 6301 Bt and MRC 6301 non Bt was 12 larvae and 4 larvae per plant respectively under rain-fed conditions.
- The frequency of resistant alleles for *cry* 1Ac was found to increase marginally in increments over 2005-2007 in Gujarat, Maharashtra and Andhra Pradesh.
- Primer sets developed for 6 genes (*cry*1F, *cry*1C, *cry*1C, VIP3A, *cry*1Aa and Round-up Ready) amplified the target sequences unambiguously.
- The total additional economic benefit resulting from the IPRM project implementation in the country is estimated at Rs. 5161 lakhs on account of Rs. 4184 lakhs due to enhancement in yields and Rs. 977 lakhs due to savings on insecticides.
- The technology 'GUS detect' was transferred to state agricultural departments all over the country. The kit enables the detection of GUS marker that is tightly linked with *cry*2Ab and also all GM crops that have GUS as the reporter gene
- A total of 10,000 Bt-Express kits were procured by the Agriculture Department of all the nine cotton-growing states for the purposes of Bt-seed purity quality control
- A biopesticide has been developed from primary phase bacterial symbiont of EPN for use against sucking pests of cotton.

Coimbatore

- Acephate, profenophos, thiamethoxam and acetamiprid were effective against aphids.
- Bio-pesticides *Verticillium lecanii*, *Metarhizium anisopliae* and *B. bassiana* and insecticides imidacloprid (Confidor), thiamethoxam, acephate and dimethoate brought down the population of jassids.
- Profenophos, thiamethoxam, chlorpyriphos and acephate were effective against mealy bug. However, acephate and *B. bassiana* reduced the activity of spiders, while thiamethoxam, imidacloprid and acephate reduced the coccinellid predator activity.
- Triazophos (0.05%), Cypermethrin (0.07%) and Thiodicarb (0.075%) were superior to other treatments in controlling pink bollworm (*P. gossypiella).*
- Based on prominence value, *R. reniformis* was identified as key nematode pest of Bt cotton in South India.
- Life cycle studies on *R. reniformis* indicated the susceptibility of Bt cotton hybrids to nematodes. Crop species Brinjal, Tomato, Cowpea, Bhendi, Pigeon pea, Black gram and Castor and weed species *Abution* sp., *Eclypta alba* and *Amaranthus* sp are very good hosts for *R. reniformis*.
- All stages of *Spodoptera litura* were found to be susceptible to EPNs viz., *H.indica , S.siamkayai and S.glaseri* nematode infection. A maximum of 100% mortality was recorded for an initial inoculum of 40 IJ / larva.
- Sixteen isolates of bacterial symbionts of entomopathogenic nematodes were isolated from cotton ecosystem. Three isolates viz., *Xeno -1, Xeno 12* (Bacterial symbionts of *Steinernema* sp.) and *Photo 3* (Bacterial symbionts of *Heterorhabditis indica*) recorded 37-62 % mortality against Mealy bug.

- Avoidable yield loss due to sucking pests damage was higher in RCH 2 Bt (15.3%), followed by Bunny Bt (12.8%) and MRC 6918 Bt (11.3%). It was low in other Bt hybrids viz., RCH 20 Bt (7.5%), RCH B 708 (7.4%), Mallika Bt (8.1%) and MECH 184 Bt (9.2%).
- Seed dressing insecticides helped in inducing ATPase activity at a higher level as compared to control in Bt cotton hybrids. Efficient metabolic status by way of acid Phosphatase and alkaline Phosphatase activity in addition to higher peroxidase activity could be maintained in young seedlings due to seed dressing chemicals.

Sirsa

- Mealy bug was the most important emerging pest of cotton and the predominant species in the region was identified as *Phenacoccus solenopsis* Tinsley. *Meconellicoccus hirsutus* Green was also noted but to a much lesser extent. A total of 36 plants were recorded as its hosts.
- The IPM Bt plots gave better performance over non-IPM plots when B: C ratio was calculated.
- A total of 9353.6 ha area covering 75 villages was covered under IPRM program in Districts of Sirsa, Hisar and Fatehabad where 19.59 to 44.65% reduction in insecticidal sprays over non-IPRM villages was recorded, reducing the expenditure to the tune of Rs 662-1502 per hectare. This led to increase in the C: B ratio which gave Rs 2354 to 4030 more net profit in IPRM villages over non IPRM villages.