2 Executive Summary

2.1 Crop Improvement

Nagpur

- During the year 101 accessions of *G. hirsutum* and 100 accessions of *G. arboreum* were evaluated in multilocation trials.
- Three thousand base, 300 working and 400 new collections of *G. hirsutum*, 700 *G. arboreum* and 160 *G. herbaceum* accessions were grown for rejuvenation and seed increase. Six hundred and ninety accessions of *G. arboreum* and 550 of *G. herbaceum* were evaluated for fibre properties.
- 1870 accessions of *G. arboreum* were allotted IC/EC numbers by NBPGR, New Delhi.
- Five hundred accessions were stored in medium term storage in the Institute and 300 in long term cold storage at NBPGR, New Delhi.
- A *G. hirsutum* culture CNHO 12 was tested in AICCIP Br 02 (a) trial and was promoted to Br 03 (a) trial in all the three zones based on its superiority for seed cotton yield. This culture is also tolerant to jassid and resistant to cotton leaf curl virus. Another culture CNHO 3 has also been promoted to Br 03 (b) trial in south zone.
- Rai 11-3 possessed high yield (>96 g/plant) potential coupled with early flowering and synchronous maturity (135-145 days) which in turn facilitating escape from bollworm.
- Another line MSH 345, a multispecies hybrid derivative bearing cleistogamous flowers is characterized by big, round bolls with 4-5 locules and boll weight ranging between 3.5 and 4.9 g.
- Two genotypes viz. Khandwa 2 and Laxmi were converted in GMS background and five genotypes viz. IC 321 (EL 958), Acala Glandless, LH 900, Sharda and Reba B 50 were converted in CMS background. Five hybrids viz. NGMSH 106-05, NGMSH 89-05, NGMSH 103-05, NGMSH 109-05 and NGMSH 94-05 were found promising by recording more than 20 % heterosis over the check NHH 44. One GMS based hybrid CINGH 2006 was promoted for testing in south zone centres.
- An unique culture CINA 316 of *G. arboreum* possessing high locule retentivity (17-13 days) and low short fibre content (11.75 %) was registered with NBPGR, New Delhi with INGR No. 04079 and IC No. 296596.
- Two cultures viz. CINA 333 and CINA 334 have been identified for high seed cotton yield (1800-1900 kg/ha), boll weight (3.2 g to 3.5 g), fibre length (26.2 to 29.2 mm) and fibre strength 18.7 to 20.4 g/tex, SFC 3.6 to 5.45 %.
- Highest seed cotton yield of 1187 kg/ha was recorded by culture DTS 23 followed by CNHO 23 (1129 kg/ha) as compared to the check LRA 5166 (562 kg/ha) in Institute trial.
- Two salt tolerant callus lines growing on 25 nM and 75 nM NaCl have been isolated and are being utilised for somatic embryogenesis.
- Elite cotton cultivar Anjali (LRK516) was transformed with Bt Cry 1 A(c). T_1 seeds collected and T_2 generation raised in contained open field trial.
- Large number of putative transformed plants of LRA 5166 and LRK 516 with Bt *cry I Ac*, Bt *cry I Aa3*, Bt *cry I A5* and Bt *cry I F* were developed.

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- The medium staple hybrid LK 1 x TK 43 was found promising among 130 conventional intra-*hirsutum* hybrids evaluated over the past two years.
- Four long staple conventional intra-*hirsutum* hybrids have been identified with superior yield and fibre quality.
- Alternaria leaf spot resistant culture CCH 4 performed better than the check varieties for yield and GOT in central zone.
- The culture CCH 510-4 was found superior in terms of yield and GOT and was on par with check variety in terms of fibre quality.

- Two new wild species *viz.*, *G. nelsonii and G. gossypioides* were established and added to species garden.
- The conventional interspecific hybrid LS 25 x P 28 recorded the highest yield of 2950 kg/ha combining superior fibre quality and was superior than the best check hybrid TCHB 213 (1900 kg/ha).
- The GMS hybrid J 34 x TK 15 recorded the highest seed cotton yield of 1760 kg/ha as against the best check hybrid with 1290 recording 37 % yield increase.
- Among the CMS based intra-*hirsutum* hybrids, RKR 4145 x A was the best with 2270 kg/ha followed by LRA 5166 x AK 2 with 2140 kg/ha of seed cotton yield.
- Of the 22 CMS based interspecific hybrids evaluated in a station trial, the highest seed cotton yield was recorded in the test hybrid 70 G x PR with 1520 kg/ha as against the best check hybrid TCHB 213 with 1400 kg/ha.
- The GMS based interspecific hybrid CCHB 125 has been promoted to coordinated hybrid trial in Central Zone.
- The high strength culture 72 (M5 x Z2) 7132 recorded high seed cotton yield and fibre strength of 25.1 g/tex.
- Under multilocation testing of promising cultures, the genotype CCH 226 recorded the highest yield of 1904 kg/ha, ginning out turn of 36.8 % and fibre strength of 23.3 g/tex.
- Single plant selected from segregating populations *viz.*, TMSGH 20 – (2), TMSGH 20 – (7), TMSGH 18 – (5), TMSGH 18 – (7) possessed around 27% seed oil content.
- In a common trial under NATP-HCP with 12 interspecific hybrids, the hybrid CCCHB 04-2 had superior fibre quality and high yield.
- Delinted seeds of cultivar LRA 5166 treated with bioinoculants *Pseudomonas fluorescens* and *Trichoderma viride* were as effective as fungicides in protecting the seeds from deterioration.
- Supplementary foliar nutrition as DAP @ 2 % + Boron @ 0.6 kg/ha + Zinc @ 0.5% significantly improved the seed quality.
- Polymer coating of cotton seed @ 5 ml kg^{-1} were equally effective in maintaining the seed viability, vigour and seed health.

Sirsa

- Two mutants with pink petal colour and pink filaments in *G. hirsutum* were identified. One new cytoplasmic male sterile line with red-pigmented plant body and petal spot in American cotton and a GMS line CISA 2 with yellow flower in *Desi* cotton were identified.
- In *G. hirsutum*, the new restorer lines namely CIR97P1, CIR97P3, CIR119P1, CIR119P3, CIR126P1, CIR526P1, CIR526P3, CIR 920 P1, CIR 926 P2, CIR 926 P3, CIR 1169 P1 and CIR 1169 P2 have been identified. An intra-*hirsutum* hybrid CSHH 238 and *G. arboreum* culture CISA 310 ranked first over the three years and were recommended for agronomic trials for their identification. The cultures CSH 7106 of *G. hirsutum* and CISA 614 of *G. arboreum* ranked first under zonal trials. An intra-*arboreum* hybrid CISAA 6 and intra-*hirsutum* hybrid CSHH 243 were at 3rd and 5th position, respectively under zonal trials.
- The highest cross boll setting percentage for hybrid seed production was noticed during crossing period from August. 18th to September 7th. Seed soaking in succinic acid for six hours before sowing and foliar spray of 0.1% boron at 60, 75, 90 DAS increased the seed yield in all the hybrids. In varieties the significant and maximum increase in boll number and boll weight was observed when boron was sprayed @ 0.1% at 60 DAS. The topping at 60 DAS and defoliant sprayed at 140 DAS increased seed cotton yield

in *G. hirsutum* and *G. arboreum* varieties. Seed obtained from second picking was found better in quality.

2.2 Crop Production

Nagpur

- Significant mean maximum (23.30 q ha^{-1}) seed cotton yield was recorded with two irrigations @ 4 ha cm of water, first at flowering and second at boll development stage closely followed by (22.64 q ha^{-1}) three irrigations at flowering, early boll development and peak boll development stages.
- Seed cotton yield due to moisture conservation practices was found to increase from 0.61 – 2.4 q ha^{-1} over control. Ridge and furrow system was evaluated as the best over other moisture conservation practices adopted in different toposequence.
- Maximum WUE (2.46 kg $ha^{-1}mm^{-1}$) was recorded in the treatments where greengram was intercropped with cotton closely followed by (2.40 kg ha^{-1} mm^{-1}) cotton intercropped with blackgram and the minimum (2.01 kg $ha^{-1}mm^{-1}$) under control.
- Among the various moisture conservation practices tested over the years in 40 farmers' fields on upper, middle, lower and bottom toposequences, ridge and furrow system across the slope at the end of August was evaluated as the best system and effective in reducing maximum runoff, increasing percolation, conserving maximum rainwater and improving the recharge capacity of irrigation wells.
- A significant effect of nutrient management practices was observed in a field experiment conducted for the second consecutive year. Response to Zn and B was not observed. Yield in the plots with partial supplementation through organics (25 % and 50 %) was at par with the NPK plots. On the other hand, site specific nutrient management for a targetted yield was found to be the best treatment. None of the treatments affected the fibre quality parameters.
- Response of both *G. arboreum* (cv. AKA 8401) and *G. hirsutum* (cv. Rajat) was noticed to foliar application of potassium at early and peak boll formation stages compared to K applied basally as soil application. Furthermore, soil applied K resulted in significant yield increase over the NP plots. However, K application did not impact any of the fibre quality traits.
- Application of micronutrients with supplemental irrigations such as B 3 kg ha^{-1} and Mn 10kg ha^{-1} singly or together soil +foliar application in 3:1 together Zn, Mn and Boron @ 10, 10 and 3 kg ha^{-1} every year significantly improved the seed cotton yield by 25, 20 and 18% or 372, 335 and 332 kg ha^{-1} over rainfed conditions.
- Effects of tillage management practices on *G. arboreum* and *G. hirsutum* were assessed for the third year. Tillage x genotype interaction was significant. Yield of the *G. arboreum* did not differ significantly between tillage systems. On the other hand, yield of the *G. hirsutum* was significantly better in the reduced tillage systems compared to the conventional tillage system.
- In NHH 44 hybrid strip cropping with pigeon pea in 8:2 ratio, biofertilisers in hybrid cotton improved seed cotton yields by 153 (10%) and 93 kg ha^{-1} (7%) at 50% and 100 % recommended fertilizers respectively in 2/3 years. The pigeon pea grain yields were improved by 157 kg ha^{-1} at 50% recommended fertilizers with hybrid cotton strip cropping. The B:C ratio were improved from 2.78 to 3.66 by biofertilisers followed by RDF + biofertilisers 3.47 and biofertilisers with 2% urea as foliar spray by 3.18 in hybrid cotton + pigeon pea strip cropping.
- One year study with extra long staple genotypes found Bunny, Abadhita, Sahana and Swati to be superior to NHH 44 under organic management. N fixing, P solubilising bacteria, *Trichoderma*

viride and *Pseudomonas* application as seed treatment improved seed cotton yield by 21% over farmers' organic practice in long staple Surabhi cotton . Vermi compost improved seed cotton yield by 11%, Neem Seed Kernel Powder (after spray) @ 2 kg ha^{-1} improved by 28% and EM application by 12% over farmers' organic practice.

- NMDS nozzle was found to deliver finer spray followed by hollow cone and BCN single nozzle with minimum ground loss of pesticide and giving maximum deposition on the site of egg laying on the top.
- A generic model INFOCROP has been calibrated and validated using crop, weather and soil as basic inputs. The model has simulated the phenology more accurately and the accuracy of simulated yield and biomass were 92 % and 89 % across the centers.
- Removal of early formed squares either mechanically or using low concentration of ethrel led to more vegetative growth, sympodial node production and spurt in fruiting activity.
- Growth and development of seven *arboreum* genotypes revealed that CINA 348 had better performance in shallow soil.
- Database for gossypol content in working collections of germplasm lines has been further strengthened by estimation of gossypol in 60 additional samples and variability has been observed.
- A few *G. arboreum* germplasm lines and some single plant selections were found to possess higher seed oil content (18.5 to 22.6 % and 22 to 26%) than the average value of 14-16%.
- Foliar spray of 2,4-D (5 ppm) during flowering led to malformation of leaves and flowers. 2,4-D spray led to severe boll drying and reduction in flower size. The response was, however, found to be temperature dependent.
- Nineteen *G. hirsutum* and *G. arboreum* lines were screened for drought tolerance during flowering. Leaf relative water content and water potential are more prominent sustainable tolerance traits in *hirsutum* while solute concentration and root/shoot ratio are conspicuous in *arboreum* genotypes. Nitrate reductase activity was found to be higher during stress period in some *hirsutum* and *arboreum* lines. As a result of stress response, some lines also showed accumulation of proteins. The lines with higher leaf relative water content were identified.
- With regard to salinity, cotton genotypes showed decline in growth and yield beyond 7 EC. *G. arboreum* and *G. herbaceum* genotypes had better tolerance for salinity. Leaf area production was very sensitive to salinity compared to decline in photosynthesis. Tolerant genotypes possessed higher accumulation of proline and higher K/Na ratio. Decline of yield was more marked in *hirsutum* genotypes.
- Continuous water-logging for 15 days led to yellowing and shedding of leaves and squares. Yield reduction was higher in Asiatic genotypes as compared to American cotton. Higher transpiration loss of water in addition to restricted uptake of water due to impaired root activity promoted wilting in hybrids and early maturing genotypes.
- One hundred *G. hirsutum* and fifty *G. arboreum* lines were evaluated for physiological attributes under rain grown conditions. Considerable variability was recorded for growth, yield and process attributes.

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- Combined inoculation of *Azospirillum* + PSB + PPFM at 75 % NP level recorded 412 kg/ha additional seed cotton yield than 100 % NP alone without bio-inoculants.
- Poly mulching benefited the cotton crop to the

tune of 1.88 fold and the maize crop by 2.87 fold than conventional method and recorded higher water use efficiency of 42.7 to 53.6 kg/ha as compared to 23.1 kg /ha under non mulching.

- FYM alone @ 15 t/ha, FYM @ 5 t/ha + RD-NPK, or RD-NPK + crop residues @ 2.5 t/ha had a beneficial effect on both performance of crop and soil.
- Application of FYM @ 5 t/ha along with cotton whole residue @ 2.5 t/ha and green manure sun hemp grown *in situ* and buried at 45 DAS produced significantly higher yield over both control and RD-NPK.
- A multi-tier cropping consisting of cotton + radish + amaranthus gave the highest net return as compared to sole cotton crop.
- The poly tube laterals (600 gauge) drip system with LLDPE (Linear Low Density Poly Ethylene) has been found beneficial and gave a cost benefit ratio of 1:1.56 when compared with ridges and furrow method of irrigation.
- The peroxidase activity was slightly high in fuzzless genotype (76 - 12 units in fibres and 87 - 196 units in ovules) during progressive boll development stage as compared to fuzzy genotype (68 - 10 units in fibre and 74 - 170 units in ovules).
- Application of Ethrel at 45 ppm showed an increase in yield of 40% (2340 kg/ha in LRA 5166 and 2400 kg/ha in Sumangala) over control (1620 kg/ha).
- MS basal medium with phytohormone combination of NAA (0.5 mgL^{-1}) + Kin (0.5 mgL^{-1}) and 2,4-D (1.5 mgL^{-1}) + Kin (0.5 mgL^{-1}) and planting density of 2 x 10^4 protoplasts/ml led to first cell division after three days in culture and subsequently showed quadruplet formation.
- Foliar application of *Pseudomonas fluorescens* pf1 induced higher peroxidase activity (102 -115 units), while the control plants possessed low activity (36-51 units).
- Seed dressing insecticides triggered ATP activity and energy availability in young cotton seedlings.

2.3 Crop Protection

Nagpur

- Out of 229 genotypes involving 131 crosses and 98 single plant selections evaluated for genotypic tolerance using phenological trait of compensation 14, 32 and 21 were susceptible, moderately tolerant and tolerant respectively to early season bollworm damage and had higher compensation.
- Two lines CTI 4-21-14-22-1 and EC 11943 x Jhiang of *G. hirsutum* have exhibited the resistant reactions against virulent race 18 of *Xam* under glass house conditions.
- Out of 3516 *G. hirsutum* germplasm lines screened against fungal foliar pathogens, two namely, RAMPBS 220 and RAMPBS 261 were resistant to Alternaria leaf spot and two viz, Coker 100 AWR cc and 65-2(S)2-3 were resistant to grey mildew and 26 lines showed resistance to Myrothecium leaf spot.
- Reproductive compatibility in interstrain crosses was studied in *H.armigera*. Maternal influences on feeding preferences of inter strain crosses was demonstrated.
- No development of resistance to Bt cotton has been observed till date with LC_{50} well within the range like that of previous years.
- Soil solarization of 15 days was found to reduce population of root-knot nematode from 300 juveniles/ 250 cc soil to 20 juveniles/ 250 cc soil.
- Sixteen isolates of Entomopathogenic nematodes (EPN) belonging to *Heterorhabditis bacteriophora*, *H. indica* and *Steinernema glaseri* isolated from cotton growing ecosystems and found effective against cotton insects particularly cotton bollworms were quantified for variation in tolerance to temperature stress and host finding ability.

- Two *Photorhabdus* isolates, the symbiont of Entomopathogenic nematode which were earlier recorded to be antagonistic towards sucking insect pests of cotton, were field tested and found effective in preliminary field trials. Protocol was developed using soaked grains of rice and jowar fortified with 1 % yeast granules for development of *N. rileyi* and *Metarhizium* mycelia and sporulation.
- Nine potential antagonists comprising eight species of fluorescent and non fluorescent *Pseudomonas* and one species of *Bacillus firmus* isolated from rhizosphere and phylloplane of cotton provided highly effective inhibition of *Xam* and possessed strong PGPR activities including production of H_2S, levan, protease, siderophore, fluorescin and pyocyanin.
- Isolates of *R. areola* made from the cultivars of *G. arboreum* and *G. herbaceum* were observed to be fast in growth as compared to the isolates of *G. hirsutum*. RAPD-PCR pattern of amplification gave indication of variation among the isolates at species level.
- Variability in growth pattern, influence of salt concentration on growth, pigmentation, pathogenicity and RAPD-PCR pattern was observed in 13 isolates of *F.o.f.* sp. *vasinfectum.*
- Based on pathological and molecular data generated on Rep-PCR genomic DNA fingerprinting, RFLP and RAPD, 10 biotypes of race 18 were documented. Specific fingerprinting pattern of each biotype is documented. rDNA genes from representative biotypes were cloned and submitted for nucleotide sequencing. RFLP of genomic and plasmid DNA of isolates belonging to six different races exhibited clear polymorphism. Race 18 isolates possessed few copies of *Xanthomonas* avr pth gene family (predominantly two) compared to less virulent races which possessed up to seven copies of avr/pth genes. Besides, the less virulent races were also differentiated from more virulent races 10, 12 and 18 with conspicuous absence of a plasmid of 31.2 kb.
- Southern hybridization of PCR fragments generated by using coat protein primers from diploid cottons did not hybridize to CP gene probe ruling out any possibility of diploid cotton serving the collateral host to the pathogen. In an effort to further improve expression of recombinant coat protein in *E. coli,* the gene was swapped from pCaln (Stratagene) expression vector into pET 27b (Novagen).
- Based on crop phenology and seasonal occurrence of insect pests in relation to pest management options tested, rainfed IPM system was evolved.
- Early season sucking pest control using systemic insecticides, either through seed treatment or foliar sprays altered the phenology of the cotton plant and predisposed to the higher attack by bollworms especially *H. armigera.*
- Larval survival of *H. armigera* was high on crop that had seed treatment and/or systemic foliar insecticidal sprays.
- Diploids had higher parasitisation levels of *H. armigera* than the *hirsutum* / hybrids
- More than two rainy days each during 35 and 41 standard weeks (SW) led to higher incidence of *H.armigera* in cotton eco system. The critical periods of weather influence were SWs 35, 41, 45 and 47 corresponding to rainy days, maximum temperature and rainfall, respectively.

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- Insecticides Spinosad 45 SC (50, 75, 100 g), NNI 0001 (48, 60 g), KN 128 (75g), RIL 038 (50, 60 g) were found effective against *H .armigera* larval incidence.
- Pink bollworm incidence was significantly low in Spinosad (100 g), Karate Zion 5 CS (20, 25 g), Karate 5 EC (25 g) and Endosulfan (700 g) treated plots as compared to control.
- Four cultures viz. (VRS x V112) 3-2-4, 5(1 x 2)

724- 2, (V22 x V112)(L x M55)-443 and LS 3 have been identified as resistant source to pink bollworm and the BRS-5 (L x BRS) 355 as a tolerant genotype to all the three bollworms.

- The location specific IPM at village level led to reduction in savings in plant protection cost by Rs. 688 / ha and increased seed cotton yield by 350 kg / ha.
- Aphid population was at its peak during December on RCH Bt cotton; leaf hopper infestation was seen throughout the season and natural enemy population of Coccinellids and spiders were more during November-December.
- The population build up of the stem weevil (*Pempherulus affinis* Faust) was maximum during May and extended upto second fortnight of July.
- Neemazal (a neem based formulation) granules @ 12.5 kg/ha, Carbofuran @ 33.33 kg a.i. /ha and Phorate (150 kg/ha) significantly reduced the stem weevil incidence.
- Application of neemcake (150 kg/ha) or Farmboon (1.2 tons/ha) have been found effective in stem weevil management.
- Spraying of talc powder formulations of *Trichoderma harzianum* and *Pseudomonas fluorescens* @ 0.2% at 10 day intervals reduced the grey mildew incidence to the extent of 13-14 %.
- Based on the disease symptoms and the morphology of the pathogen on the hosts, *R.areola* has been placed into four groups. *Euphorbia heterophylla*, a weed has been identified as a possible host for *R. areola.*

Sirsa

- IPM was demonstrated successfully in 23 acres including four acres of Bt cotton (RCH 134, RCH 317, MECH 6301, MECH 6304). In *desi,* the cost: benefit ratio was more in IPM (1: 3.61) than non IPM (1 : 2.65). The C : B ratio of 1 : 3.60 was obtained in IPM plots of American cotton followed by 1 : 3.42 in the hybrids IPM whereas in Bt cotton it ranged from 1 : 3.52 to 1:2.11 and in non Bt it was from 1 : 2.64 to 2.08.
- In epidemiological studies of cotton leaf curl virus disease, the pooled data suggested mostly clustering of infected plants showing that a part of inoculum comes from outside and then the disease spreads from plant to plant within a field. It was observed that higher maximum temperature, lower maximum and minimum relative humidity and lower rainfall up to 30th meteorological week led to lower incidence of leaf curl in 2004 crop season. Prediction equation for the disease was developed.
- The isolates of *Rhizoctonia solani* and *R. bataticola* the causal agents of root rot of cotton were grouped into four and two broad groups using OPM and OPN series primers.