1. EXECUTIVE SUMMARY

CROP IMPROVEMENT

Genetic Resources

- A total base collection of 11648 accessions of cotton germplasm that includes *G. hirsutum* (8505), *G. barbadense* (312), *G. arboreum* (1936) and *G. herbaceum* (565) are maintained in the National Cotton Gene Bank at ICAR-CICR, Nagpur.
- Seeds of 1602 accessions of *G. hirsutum* and 3 registered genetic stocks of *desi* cotton (Brown linted) were deposited at ICAR–NBPGR, New Delhi for long term storage.
- National Cotton Gene Bank at ICAR-CICR, Nagpur was enriched with 56 accessions of *G. hirsutum* and 2 of *G. barbadense* procured from USA.
- Three GMS lines and 18 newly identified GMS lines were maintained through sibmating. A pigmented thermo-insensitive GMS line CISG 20 was identified for registration with ICAR-NBPGR, New Delhi.

Germplasm Evaluation

- A set of 34 Coker variants, 2 accessions resistant to CLCuD and 58 exotic accessions were characterized for economic and fibre quality traits.
- A set of 1000 *G. arboreum* accessions were evaluated for fibre quality traits and promising germplasm accessions were identified for future breeding programme.
- In *G. barbadense*, five accessions possessing hairiness *viz.*, ICB-85, ICB-124, ICB-264, ICB-284 and HAG-02 were identified as promising for sucking pest tolerance.

Wild Species

- Wild genetic resources including 24 wild species, 12 races, 40 interspecific derivatives, 254 perennials and land races of *Gossypium* species were maintained in wild species garden of the Institute. Herbarium of the available species, races of cultivated species and registered unique genetic stocks was made to showcase uniqueness and diversity of *Gossypium* species.
- F_4 population of four crosses *viz.*, *Jawahar Tapti* × *G. longicalyx*, *G. arboreum* × *G. thurberi*, *G. arboreum* race indicum × *G. davidsonii* and *G. arboreum* Cv. AK 8401 × *G. davidsonii* were evaluated for economic traits and promising single plants were selected.

Population Improvement

- Intermating between progenies of three-way and multiple crosses involving *G. hirsutum* and *G. barbadense* was attempted and promising single plant progenies based on specific trait performance and combination of introgressed characteristics such as sub-okra leaf shape, cleistogamous flowers, stay green plants, high fibre quality and yield potential were selected for generation advancement.
- To develop compact plant type with early maturity and good fibre quality, intermating was carried out between 15 inbred lines. Eight and ten parental crosses were advanced from F_2 to F_3 generation for development of MAGIC RILs.
- Based on the performance, uniformity and fibre quality, 16 progenies of *G. arboreum* and 32 of *G. hirsutum* were identified from random mating populations for evaluation in replicated trial.

Molecular markers

- A set of 227 RILs developed from interspecific cross of *G. arboreum* (KWAN-3) x *G. herbaceum* (Jayadhar) to be used for development of consensus map using SNP genotyping were evaluated for economic and fibre quality traits.
- A total of 86 distinctly polymorphic SSR markers were identified and utilized for molecular diversity analysis among cotton varieties. A selected set of 20 SSR markers with high PIC were identified and utilized in development of robust DNA fingerprint of cotton varieties.
- Microsatellite marker based molecular characterization of 114 accessions of perennials and landraces of *desi* cotton was completed.

Interspecific hybridization

- Three interspecific F_1 plants from the interspecific cross (*G. hirsutum* × *G. arboreum*) were established through embryo rescue/immature embryo culture. Sterility of these interspecific F_1 plants was confirmed through pollen studies.
- Study of heterosis among the intra- and inter-specific crosses revealed that *G. herbaceum* x *G. arboreum*

hybrids produced more heterosis than the intra-*herbaceum* hybrids.

Early maturity

- Two early maturing breeding lines namely, CNH 09-7 and CNH 09-9 with seed cotton yield of 1165 and 1192 kg/ha respectively and having Bartlett's earliness index of 0.9 were identified.
- Most promising plants were selected for earliness (120-130 days), jassid tolerance (grade 1), compact plant type, boll weight, yield and fibre quality characters from the segregating populations (F_2, F_3, F_5 and F_6). Potential of selected promising entries was assessed under HDPS. A total of 72 selected progenies possessing earliness, jassid tolerance and compact plant architecture were tested for Bt gene through ELISA and for homozygosity through gene-specific PCR. Of which 13, 48 and 11 progenies were identified as homozygous, hemizygous and azygous respectively for *cry1Ac* gene (Mon 531 event).

Varieties identified for release

- The high yielding variety Central Cotton CCH 12-2 (Suchitra) has been identified by CVIC for Central Zone under irrigated conditions. The variety recorded a mean seed cotton yield of 1767 kg/ha possessing an upper half mean length (28.0 mm), micronaire (4.2) and tenacity (29.0 g/tex).
- Central Cotton CCH 12-3, a *G. hirsutum* variety identified by CVIC for release in Central Zone under rainfed conditions recorded a mean seed cotton yield of 1060 kg/ha.
- Proposal for identification of high yielding good quality Central Cotton CCH 14-1 has been submitted to CVIC for release in irrigated condition in South Zone.

Bt varieties of ICAR-CICR

- Six Bt varieties *viz.*, ICAR-CICR Bt 14 (CPT2), ICAR-CICR Bt 9 (SRI1), ICAR-CICR GJHV 374 Bt, ICAR-CICR PKV 081 Bt, ICAR-CICR Rajat Bt and ICAR-CICR Suraj Bt carrying *cry1Ac* (Mon 531) gene were approved for commercial cultivation under rainfed conditions of Maharashtra.
- Bt variety CICR-Bt6 developed from ICAR-CICR, Regional Station, Sirsa was approved for commercial cultivation in Haryana state. It recorded the seed potential of 3046 kg/ha under HDPS and was found to be significantly superior than local check hybrid RCH 773 BGII in Haryana.
- Eleven new Bt genotypes (*cry1Ac*) were sponsored for testing in AICRP trial (2018-19) and the same number of entries tested in AICRP (2017-18) have been promoted for second year testing.

Stress tolerance

- One hundred and sixty six (166) cotton germplasm lines were evaluated in rainfed and irrigated regimes and seventeen (17) promising lines were identified as drought tolerant based on physiological parameters *viz.*, relative water content and mid-day leaf water potential. Lines DTS-405, DTS-413, Nagpur-9, N-2924, CNH-09-4 and 2853 were identified as promising for yield, drought tolerance and compact plant architecture.
- Crossing between five identified waterlogging tolerant (IC 359979, IC 359245, IC 357235, INGR 08092 & INGR 08093) and susceptible (IC 356708, IC 357607, IC 357558, IC 359242, IC 359915) accessions was attempted for development of water logging tolerant varieties.
- Sixteen crosses were attempted among CLCuV tolerant germplasm lines of *G. hirsutum* in a Line x Tester fashion. Thirteen F_6 progenies having high yield potential and tolerance against CLCuV were selected for advancement to station trial.

Transgene introgression

- Three BC_1F_1 populations of Tg2E13 event and three F_1 populations of CH12 event were evaluated for transgene expression. Event positive and high toxin expressing plants were utilized in backcrossing with their respective recipient cotton varieties in contained facility at ICAR-CICR, Nagpur. Embryo culture protocol was successfully explored for accelerated generation advancement.

Seed storability

- Different packaging materials were evaluated for better storability for varying period. Vacuum packing followed by orange paper envelop packing showed better storage results and maintained higher seed germination as compared to brown paper, polylined aluminium and polythene heat sealed packets.

Seed production

- A total of 1.73 q. nucleus seed of 3 Bt cotton varieties, 3.36 q. breeder seed of different cotton varieties and parents of the hybrid, 6.68 q. truthfully labeled seeds of different cotton varieties, 265 q. of certified seed of wheat Cv. WH 1142, 0.5 q. of certified seed of gram

Cv. Vijay, and 4.7 q. of certified seed and 5.14 q. truthfully labelled seeds of Red gram Cv. BSMR-736 was produced.

DUS characterization

- DUS characterization of 4 entries (first year trial), 4 entries (second year trial), 2 entries (Varieties of Common Knowledge trial), 2 entries (Essentially Derived Variety and Initial variety trial) and 12 entries (Reference trial) was conducted.

Somatic embryogenesis

- Protocol for transient gene expression through somatic embryogenesis in Coker genotypes (312 and 310) has been standardized. Indole-3-butyric acid (1mg/L) in woody planting medium was found to be effective for improving the rooting efficiency of germinated somatic embryos in Coker 310 genotypes.

Cotton genomics

- Genome wide *in-silico* analysis of *G. arboreum* led to identification of 16 *GaLIM* members similar to animal cysteine rich proteins and 4 belong to plant specific *LIM* family *viz., GaDA1-1, GaDA1-2, GaDA1-3* and *GaDAR1*. Gene expression patterns of plant specific LIM family in response to biotic and abiotic signals were found to be significant.
- Significant down regulation in the expression of zinc finger protein encoding genes *viz., Ghzfp5* and *Ghzfp8* at 0 and 1 days post anthesis in *G. hirsutum* Cv. MCU5 mutant compared to its wild type was recorded, suggesting possible involvement of GHZFP5 and GHZFP8 transcription factors in the gene regulatory pathway of cotton fiber initiation.

Gossypol detoxification

- Gossypol detoxification assay of deoiled cotton seed cake using CYP6AE14 protein from *H. armigera* and newly isolated microorganisms from cotton soil rhizosphere showed total gossypol reduction efficacy from 8.19 to 73% over control. Seven microbial isolates showed gossypol reduction of more than 40 per cent.

Herbicide Tolerant (HT) cotton

- ICAR-CICR, Nagpur conducted field surveys and collected 379 leaf samples from different cotton fields suspected to be growing HT cotton from Wardha, Chandrapur, Yavatmal and Nagpur districts of Vidarbha, Maharashtra. Out of 379 leaf samples tested, 171 samples were positive for Roundup Ready Flex (RRF) harbouring CP4-EPSPS gene confirming illegal cultivation of HT cotton.

Entries sponsored in AICRP (2017-18)

- Cultures CSH 3419 & CSH 1604 in Br 02(a), CNH 1126, CNH 25-09, CNH 11-11, CNH 12-4-2, CNH 2050, CNH 09-70 in Br 02 (b), CSH 3824 & CSH 1613 in Br 06(a), CNH 1127, CNH 1128, CNH 136, CNH 09-9, CNH 09-98, CNH 2048 in Br 06 (b), CCB 64, CCB 129, CCB 143, CCB 102 in Br 12 (a); CCHB 32, CCHB 14 in Br 15 (a); CNA 1033, CNA 1034, CNA 2016, CNA 2031, CISA 7, CISA 33-5 in Br 22 (a/b); CNA 1058, CNA 1067, CNA1037, CISA 33-7, CISA 33-8 in Br 22 (a/b) LL; CISAA 17-1, CISAA 17-2 in Br 25 (a/b) were sponsored in respective trials of AICRP on Cotton during 2017-18.

Entries promoted in AICRP (2018-19)

- **NORTH ZONE TRIAL :** CISAA 17-1 & CISAA 17-2 in Br 25 (a/b) and Culture CSH 3129-2 were promoted to Br 06(a) (North and south zone) & CSH 5640 to north zone only. CISA 33-3 was promoted to Br 24(a) zonal trial of AICRP on Cotton during 2017-18. The culture CISA 6-2 retained in Br 24(a) zonal trial (4th year) of AICRP on Cotton during 2017-18.
- **CENTRAL ZONE TRIAL** : CNH 11-11, CNH09-70 to Br 03 (b), CNH09-9 to Br 06 (b), CCB 64, CCB 129, CCB 143-(b) to Br 13 (a) PVT *G. barbadense,* CNA 2031, CNA 1054 to Br-24 (b) CVT – *G. arboreum,* CNA1037 to Br-24 (b) CVT -LL– *G. arboreum,* CISAA 17-2 to Br25 (b)
- **SOUTH ZONE TRIAL :** CSH 1613 to Br-06(a), CCB 143 (b), CCB 64, CCB 129 to Br 13 (a), CNH09-70 to Br-03(b), CNH 1128 to Br06 (b), CNA 1054 to Br-24 (b): CVT – *G. arboreum,* CNA1037 to Br-24 (b) LL: CVT – *G. arboreum,* 16315 LB, 16301 DB, 16337 LB to Coloured Cotton Trial *G. hirsutum,* CNA407 SLP, 16378 LB-1, CNA405, CNA407 and 16377 LB-A to Coloured Cotton Trial *G. arboreum.*

Entries proposed for agronomy trial

- **Central zone:** CCH 15-1, *G. hirsutum,* Variety (Irrigated), CSA 102, G. *arboreum* Variety, (Rainfed); **South zone:** CCH 15-1 *G. hirsutum,* Variety (Irrigated)

Crop Production

Weed management

- Sunnhemp, sorghum and sesame were the most effective in smothering weed growth. The major compounds identified in the cover crops were, phytol and pentadecanoic acid,1,4-methylene methyl ester in sorghum; squalene & linolenic acid in sunnhemp and 9,12-octadecadienoic acid, 9,12-octadecatrienoic

acid (Z,Z) & their methyl esters in sesame.

Long linted Desi cottons

- Among, seven *G. arboreum* genotypes (6 long linted - DLSA 17, PA 528, PA 402, PA 812, PA 760, CNA 1037 and short stapled Phule Dhanwantary evaluated under rainfed conditions at 2 spacings (60x10-HDPS and 60x 30 cm-normal) on a shallow Inceptisol (Typic Haplustept) and a deep Vertisol (Typic Haplustert) on two sowing dates - June 22 and July 7, 2017 at Nagpur, highest yield of 2522 kg/ha was realized with CNA 1037 planted at 60x10 cm on June 22, 2017 on an Inceptisol.
- Test of Homogeneity in yield for soil types and dates of sowing indicated that genotypes DLSA 17, PA 812 and Phule Dhawantary shows homogeneity for different soil types and dates of sowing for the spacing 60x10 cm. Similarly, under 60x30 cm spacing, the genotypes PA 402 and PA 760 shows homogeneity for different soil types and dates of sowing
- At Coimbatore, among seven long linted *G. arboreum* genotypes (DLSA 17, PA 760, PA 812, PA 402, PA 528, K12 and Phule Dhanwantery) planted in two dates of sowing dates (4th August and 4th September 2017). ,K-12 registered the highest seed cotton yield.
- De-topping + side shoot removal and application of Mepiquat chloride @ 50 g ai/ha in 2 sprays were effective in reducing plant height and improving the yield of *G arboreum* variety PA 255.
- Estimation of ethylene level in young cotton bolls was done in six long linted desi cotton genotypes (& check). There were significant differences among the genotypes. Expression analysis of two major enzymes of ethylene biosynthesis Aminocyclopropane (ACCS and ACCO) was performed using qRT-PCR, to correlate their expression with ethylene level. The expression of ACCS was more or less same as of ethylene level in respective varieties.

Nutrient management in calcareous soil

- Results of on farm field experiments in calcareous soil clearly indicated that moisture stress can be overcome by opening ridges and furrows with first hoeing operation. Further, multiple nutrient stress in calcareous soil can be managed by use of biofertilizer (*Azotobacter*+PSB+*Trichoderma*) treated seeds along with 125% RDF and application of micronutrients based on soil test.

Stress and cotton biochemistry

- Cotton leaves showed Oxalate oxidase (OxO) activity, but it was less as compared to sorghum a C-4 plant. Compared to other tissues (leaves, fiber), cotton seeds had maximum OxO activity. Drought stressed leaves had greater OxO activity than un-stressed leaf samples.

Brush type cotton harvester

- Under the development, refining and up-scaling of Brush type cotton harvester, quality of pre-cleaned cotton in a boll crusher did not significantly differ from that of brush type harvested cotton. Total picking cost for manual picking, Brush type Stripper cotton cleaned in pre-cleaner factory set up and Brush type Stripper cotton cleaned in a low cost boll crusher was found to be Rs. 6, Rs. 4.1 and Rs. 2.6/kg, respectively.

Nanofertilizers

- Commercially available nanofertilizers (Nualgi and Nanomol) were evaluated. Nualgi nanofertilizer without surfactant and Nanomol with surfactant showed significant effects on increasing Nitrogen concentration in the cotton plants. However, nanofertilizers did not influence fibre quality parameters.

Cotton epigenetics

- Epigenetic regulating chemicals (ERC) did not cause phytotoxicity or adverse effect to cotton plants. Among the different treatments, seed treatment with Nicotinamide @ 35 µM increased the plant height, number of leaves and number of bolls in case of Suraj and seed treatment with epigallocatechin @ 100 µM increased the number of bolls in LRA 5166.

Conservation agriculture

- Seed cotton yield was significantly influenced by the land shaping treatments, namely, ridge and furrow (1875 kg ha^{-1}), and bed and furrow (2157 kg ha^{-1}). In terms of cropping systems, highest seed cotton yield was recorded in cotton – black gram – maize (for grain purpose) system followed by cotton – maize (for green cobs) + pigeon pea (strip cropping 4:2 ratio) plots and conventional cotton – fallow system. Conservation agriculture found decreased soil penetration resistance.

Cotton economics

- Eighteen cotton growing districts of Maharashtra

were surveyed for changes in cotton area and cropping pattern for the period 2000-01 to 2014-15. Preliminary analysis indicated that in 13 districts, cotton area increased during the study period. Acreage increase ranged from <0.5 lakh to > 1.0 lakh ha. Highest increase in cotton area was observed in Aurangabad district followed by Beed and Jalna districts. Highest decrease in cotton area was observed in Amravati, followed by Akola, and Washim.

e-Kapas and Advisories

- Weekly/fortnightly cotton production advisories in Marathi language were prepared and published regularly in news papers Agrowan-Sakal, Deshonnati-Krushokonnati for wider dissemination among the growers. More than 6.11 lakh recorded voice messages were uploaded in the form of automatic phone calls to 87,132 registered farmers' mobile numbers of Nagpur district alone.

Decision support systems

- Grow Good Cotton- a mobile app for cotton pest management was developed. The Mobile application included interactive Decision Support system where user can interact and choose the option for pest management based on Economic Threshold Levels (ETLs). The application also incorporated voice module and pictorial representation to select the correct symptoms of damages on cotton plant and also to break the language and literacy barriers

Yield gap analysis

- Yield gap between potential and realized yield on farmers field is more than 30%. Analysis on yield enhancement due to Front Line Demonstrations (FLD) revealed that an average of 18.70 per cent increase over the normal farmers' practices was obtained in various locations. Possibilities exist to bridge the gap in cotton yield by proper diagnosis of the gap, devising appropriate management options to close the gap and fitting TOT innovations to disseminate the gap reducing technologies.

Crop Protection

Population dynamics of pests

- Seasonal pest population dynamics data on DCH 32 at Nagpur under pesticide free conditions recorded that Jassid were above ETL starting from third week of August till second week of September with a peak population at 36 SW (Standard Week). The highest number of aphids (146/3 leaves) were recorded during 33 SW. Whitefly and thrips were below ETL throughout the season. Negligible population of American bollworm, spotted bollworm, mirid bug and spider populations were recorded.
- Pest population dynamics in five genotypes (DCH32, RCH2, Phule Dhanwantary, Suraj and Suvin) were compared at Nagpur over the season. Population of Jassid and aphid was significantly higher at 6.51 jassid and 11.46 aphids/ 3 leaves on DCH 32. Thrips, mirids, American bollworm, spotted bollworm, mirid and spider populations were negligible in all the genotypes
- Pink bollworm infestation at Nagpur was recorded on cv Suraj from September end till first week of January. During first fortnight of October 68% boll infestation was recorded. Infestation reduced in first week of November and again steadily increased to reach up to 84% boll infestation.
- During 2017-18, highest pheromone trap moth catches of American bollworm (5.80 moths/ trap/ week), spotted bollworm (5.33 moths/trap/week), pink bollworm (99 moths/ trap/ week) and tobacco caterpillar (26.6moths/ trap/ week) were recorded at 50SW (23-29 Dec), 50SW (23-29 Dec), 47 SW(26 Nov. - 1 Dec) and 45SW (12-18 Nov), respectively .
- In yellow sticky trap catches, the highest whitefly population at 322 whitefly/ trap/week and jassid population at 435 jassid/ trap/week was recorded during 37SW (15-21 Sept) at Nagpur.
- The analysis of historical data from Hisar was carried out for population dynamics of whitefly for the period from 2004-05 to 2016-17. The analysis indicated that peak occurrences of white fly infestation has advanced. Between 2004-05 and 2009-10 peak occurrence of white fly was recorded in 40th and 41st standard weeks, whereas it was 31st and 32nd standard week during 2010-11 to 2016-17.
- Seasonal dynamics of pests at CICR RS Sirsa was studied on RCH-650 BGII hybrid, HS-6, Ganganagar Ageti and RS-2013. Peak activity of leafhopper was observed in 30th-31st SMW (Standard Meteorological Week). Peak in population of whitefly and thrips recorded in 30th SMW (40-45 whitefly/3 leaves). Bollworm infestation was not observed on RCH-650 BG II. In Non Bt varieties HS-6, GA & RS-2013 first incidence of bollworm was observed in the 37th SMW which ranged from 0.1 to 0.5, 0.30 to 0.90 & 0.23 to 1.20% fruiting bodies damage respectively.

- Average infestation of white fly per three leaves at CICR RS Sirsa was 3.98 between 2004-05 and 2009-10, whereas it was 13.70 during 2010-11 to 2016-17.
- Whitefly prefers to feed on lower canopy of the plant as compared to middle and upper canopy. Mean whitefly adults population/leaf recorded during the entire season of 2017-18 on upper, middle and lower strata was 4.77 (2.99-6.63), 12.07 (7.63-21.79) and 15.15 (7.50-33.06), respectively during different time of the day in RCH 650BG-II.

Pink bollworm infestation

- Infestation in BG II cotton fields of Gujarat was in the range of 20 to 90 per cent. The highest infestation was observed in Amreli (90%) while in Bharuch infestation at 25% was recorded lowest.
- The per cent infestation of pink bollworm in green bolls of BG-II at 140-180 days after sowing was observed in all cotton growing districts of Maharashtra *Viz.*, Yavatmal (56.63%), Akola (80%), Amaravathi (70.67%), Nandurbar (86.7%), Dhule (99%), Jalgaon (92%), Aurangabad (91%), Jalna (79%), Nanded (81%), Parbhani (82%), Hingoli (80%) and Buldhana (99%). Infestation of BG II cotton in Madhya Pradesh was recorded 68 per cent.
- Infestation of pink bollworm in South India was similar to that of central India. In Andhra Pradesh the infestation ranged from 72 to 84 per cent and in Telangana 69 to 91.2 per cent with highest population observed in Adilabad (91.2%).
- In North India Pink bollworm infestation on Bollgard-II was negligible. Pink bollworm damage in the range of 7-42% was recorded on non-Bt cotton in Punjab, Haryana and Rajasthan after the third picking.

Resistance monitoring

- The resistance development of pink bollworm on BG-II and non Bt cotton fields was monitored in 46 districts across India. Thirty one populations of Pink bollworm were subjected to Cry1Ac and twenty seven population were subjected to Cry2Ab log dose probit assays. Pink bollworm populations from Prakasam, Bharuch, Rajkot, Kurnool and Surendrangar recorded 172, 278, 372, 391 and 674 fold increase in resistance to Cry1Ac over susceptible check. Surendranagar, Guntur, Warngal, Yavatmal, Jalna, Buldhana, Jalgaon, Anand, Vadodara, Bharuch, Aurangabad, Dhule, Rajkot and Khammam populations recorded 141, 182, 182, 220, 287, 315, 436, 436, 444, 518, 671, 671, 4214 and 5947 fold increase in resistance over the susceptible check to Cry2Ab.
- Resistance monitoring was carried out with four population of Leafhopper from Nagpur, Wardha, Amravati and Yavatmal against nine insecticides. Nagpur populations were more susceptible to Flonicamid while susceptibility of populations from Amravati were more to Clothianidin and Dinotefuran as compared to other populations.
- Resistance monitoring for cotton whitefly (*Bemisai tabaci*) was initiated from 2015-16 for Nagpur population. Twenty one insecticides from 10 groups (Biorationals, Neonicotinoid, Phenylpyrazole, Carbamates, Pyridinecarboxamide, Insect Growth Regulators, Organophosphate, Pyridine, Tetronic acids, Synthetic pyrethroid) were taken for resistance monitoring during 2015-16, 2016-17 and 2017-18. In the current year, resistance was negligible in all the insecticides indicating intact susceptibility of whitefly.
- Whitefly resistance to insecticides in India with special reference to North zone was studied at CICR, RS Sirsa with organophosphate, neonicotinoid, synthetic pyrethoids and insect growth regulator. Resistance ratios for various organophospahtes ranged between 1.84 to 54.6 fold in 2017-18 and could be correlated with the insecticide use patten not only of cotton but also other crops. High resistance was recorded for Thiamethoxam but not with other neonicotinoids (acetamiprid, imidacloprid, dinotefuran, thiacloprid, and clothianidin). Among the synthetic pyrethoids very low or minimal resistance in Fenpropathrin was recorded. Among the newer insecticides, insect growth regulator Difenthiauron recorded 70.67-163.30 & 33.33-128 fold increase in resistance ratio during 2016-17 & 2017-18.
- Abundance and diversity of natural enemies was studied in cotton cvs. Phule Dhanwantary, Suraj, Suvin, RCH-2 and DCH-32. It was observed that species richness and abundance was highest in Phule Dhanwantari (H=1.94, S=20) followed by Suvin (H=2.09, S=15) and Suraj (S=15) as compared to the RCH-2 and DCH-32. Unprotected cotton varieties carry more species richness than protected ones.

Bollworm management

- The lowest per cent of locule damage by PBW at Nagpur was observed in Deck (Cypermethrin+ Profenophos) (8.62%) followed by cypermethrin 25

EC (13.60 %).

- *Trichogramma bactrae* treatment recorded significantly lower per cent locule damage due to pink bollworm and it was at par with chemical treatment (profenophos 50 EC, thiodicarb 7 WP, Cypermethrin 25 EC).
- Fatty acids like Palmitic acid, Linoleic acid, Oleic acid, Steric acid and their methyl esters were identified from eggs and faecal pellets of pink bollworm in studies done on Push Pull strategy for PBW management at Nagpur.
- Eight new dispensers and ten pheromone trap designs were evaluated against the cotton pink boll worm. The dispenser made of polypropylene (11.28 adult/trap/week) and silicone (10.93 adult/trap/week) were significantly superior to the standard rubber dispenser (7.36 adult/trap/week) in attracting the pink bollworm moth
- A combo trap for pink bollworm targeting both chemo and visual stimuli was developed at CICR RS Coimbatore by combining pheromone compound gossyplure (chemical stimulus) and LED light source (visual stimulus). The trap with blue colour light provided significantly more traps catches.
- Compounds *viz.*, hexadecanoic acid octadecanoic acid dotriacontane, dodecanoic acid and tetradecanoic acid were identified as potential oviposition deterrant for *H.armigera* at Nagpur.

Sucking pest management

- Among the insecticides tested at Nagpur, Dinotefuran 20% SG and Flonicamid 50% WG registered lowest population of jassid. Whitefly population was lowest in Spiromesifen 22.9% SC and Flonicamid 50% WG.
- The field trial conducted at CICR RS Sirsa during 2017-18 recorded highest nymphal mortality with *Beauveria bassiana.* 4511 (83.65%) followed by *Paecilomyces javanicus* CICR RS S 0102 (81.78%) and were significantly superior to Diafenthiuron 50% WP (1. g/L), Neem oil (300 ppm) and commercial formulation of *Lecanicillium lecanii* (0.1% WP).
- Efficacy of twelve label claim insecticides and five biorational interventions (castor oil, pongamia oil, sesame oil, 2 neem based formulation) were tested under laboratory conditions against thrips at CICR RS Sirsa at three dosages during 2017-18. Among the insecticides spinosad, fipronil, spinoteram, diafenthiuron and profenphos gave highest mortality (66-78%). Among the biorational approaches, sesame oil, castor oil, pongamia oil recorded moderately good mortality (40-66%) against thrips.
- Castor oil, pongamia oil and sesame oil reduced whitefly population by 42.81, 39.20 and 36.86 percent respectively. The maximum reduction was obtained in chemical treatment with difenthiauron (55.24%) .
- Out of eight insecticides tested, clothinidin was found to be more toxic to *P. solenopsis*. The descending order of toxicity clothionidin > cypermethrin > pyriproxyfen + fenpropathrin > lambdacyhalothrin > spiromesifen > flonicamid > diafenthiuron.
- Out of thirteen different insecticides evaluated against larvae of *Chrysoperla zastrowii sillamii,* thiamethoxam (LC_{50}=7.010mg ai/ L) was found to be more harmful to the larvae of chrysoperla, whereas thiodicarb (LC_{50}= 307.75 mg ai/l) was found to be safer
- In safety evaluation study of fourteen different insecticides against the grubs of *Cryptolaemus montrouzieri*, imidacloprid (LC50= 3.70 mg ai/l) was found to be more harmful to the grubs of *Cryptolaemus*, whereas thiodicarb (LC50= 286.51 mg ai/l) was found to be safer to the grubs.
- Use of Basil oil in yellow sticky traps found to enhance efficacy against sucking pests (whitefly, jassids and aphids) of cotton.
- Intercropping of cotton with marigold was effective in reducing population of thrips at CICR, RS, Coimbatore.
- In studies on isolation and identification of Kairomone from sucking pests, three probable compounds (1-Dodecanol, Eicosane and Octadecane) have been identified in samples analysed in GC-MS.
- Bacterial endophytes *B. subtilis* and *B. cereus* strain used as seed coating, soil drenching and foliar spray reduced the population of sucking pests *viz.*, Aphid, Jassid, and Whitefly by 10-15% as compared to the control.
- A new wax degrading entomopathogenic fungus, *Aspergillus fumigatus* Fresenius 1863 (Accession No. MF421525) isolated from striped mealybug, *Ferritia virgata* Cockerell found to degrade waxy coating of mealybug under laboratory condition at CICR RS Coimbatore.
- EPF strain namely, *Paecilomyces javanicus* - 89 *Paecilomyces javanicus* 102, *Metarhizium anisopliae* - 1299, *Beauveria bassiana* - 4511 were found to be the

most compatible with full and half dose of the chemical and botanicals tested.

- CICR Whitefly adult suction trap designed under TMC 1.5 project was evaluated consecutively for two years under AICRP on cotton at multi locations. The trap was recorded to reduce whitefly population by 12.7 to 46.6% at different locations and was reported to be more efficient in situations with high adult whitefly pressure.
- Modified poly house bioassay method was standardised for screening of entompathogenic fungi against white fly nymphs at CICR RS Sirsa and was found to be most suitable.

Disease incidence

- During survey, the cotton leaf curl virus disease grading was recorded highest in Fatehabad District (Haryana) followed by Sirsa (Haryana) and Hanumangarh District (Rajasthan).
- Target leaf spot caused by *Corynospora cassicola* was recorded as emerging potential pathogen of *G. hirsutum* in central india.
- For the first time symptoms resembling Tobacco Streak Virus (TSV) on *G. hirsutum* were recorded in some fields of Fatehabad and Sirsa Districts of Haryana during survey.
- TSV infected cotton plants in the germplasm of *Gossypium barbadense* at CICR RS Coimbatore were observed at 90 DAS (Days after sowing). The per cent disease incidence ranged between 1.61% (CCB 140) to 26.60% (ICB 71). In varieties and hybrids of *Gossypium hirsutum* TSV infection was observed at 60 to 70 DAS (Days after sowing). The per cent disease incidence varied from 5.0% (Suraj) to 16.6 % (Surabhi and RCH659 BG-II).
- In soil samples collected from 9 districts of Vidarbha, the reniform nematode *Rotyelcnchulus reniformis* was most frequent and dominant species followed by *Meloidogyne incognita*

Disease Dignosis

- Standardized and validated the protocol for diagnosis of CLCV by using LAMP technique.

Disease Management

- Among PGPR strains evaluated against soil borne fungal pathogens, *Bacillus aryabhattai* CICR-D5, *Bacillus cereus* CICR-D3 and *Bacillus tequilensis* CICR-H3 were found to be most effective under *in vitro* and glass house studies at Nagpur.
- In 2017-18 on Cv PKV081 formulation with curcumin, cow urine and neem oil reduced nematode population and increased yield by 29% at Nagpur. The spray treatments were better than the corresponding treatments applied to soil in reducing nematode population and increasing seed cotton yield.