1. EXECUTIVE SUMMARY

Crop Improvement Division

- A total of 24 wild species, 15 races of cultivated species and more than 45 synthetic polyploids are conserved in the 'wild species garden' at ICAR-CICR, Nagpur.
- The Gossypium species *G.anomalum*, *G. triphyllum*, *G. capitis viridis*, *G. thuberi*, *G. armourianum*, *G. davidsonii, G. raimondii, G. trilobum, G. stocksii, G. somalense, G. longicalyx*, *G.nelsonii*, *G. barbasonum* received from other sources were confirmed through morphological characterization.
- More than 1000 new crosses were attempted exploring the wild species namely *G. longicalyx, G. somalense*, *G. anomalum, G. capitis viridis, G. australe, G. thurberi, G. raimondii, G. barbosanum, G. triphyllum, G. klotzchianum,* and *G. mexicanum.*
- More than 12,335 accessions of *Gossypium* (*G. hirsutum – 8851, G. barbadense – 536, G. arboreum – 2053, G. herbaceum – 565, Wild Species – 24, interspecific derivatives – 40, Perennials and land races – 254, Races and derivatives of cultivated species – 12*) *are being maintained at ICAR-CICR Cotton Gene Bank.*
- Sixty nine (69) germplasm of *desi* cotton collected from different states of North Eastern Hill Region (NEH Region) were characterized and evaluated. Forty Eight (48) germplasm consisting of G. *hirsutum*, *G. arboreum* and wild species were distributed to breeders/ scientists of CICR, State Agricultural Universities and Private Seed Companies for utilization in their cotton improvement programme.
- One *G. barbadense* line CCB-12 was identified for registration with ICAR-NBPGR, New Delhi for its cleistogamous nature of flower as unique trait.
- One inter-specific hybrid (*G. hirsutum* × *G. arboreum*) plant was established at ICAR-CICR, Nagpur through embryo rescue technique.
- CNA 1032, a *G. arboreum* genotype tested in Agronomy trial in Central Zone during 2019-20 was identified for commercial cultivation by Varietal Identification Committee.
- An ELS cotton genotype CCB-51 was released for irrigated conditions of South Zone (Andhra Pradesh, Telangana, Karnataka and Tamil Nadu). It has an yield potential of 1464kg/ha with duration of 165-170 days. It has a fibre length of 37.4 mm, micronaire of 3.3 and tenacity of 38g/tex.
- CICR-H Cotton 36 (Suraksha), an extra long staple variety was identified for release for both Central and South Zone States in irrigated condition with an yield potential of 4019 kg/ha and average values of Upper Half Mean Length (UHML) of 32.4 mm, micronaire of 3.7 and tenacity of 34.3 g/tex in HVI mode in South Zone and UHML of 31.9 mm, micronaire of 4.4 and tenacity of 33.5 g/tex in HVI mode in Central Zone.
- Four GMS based *G. arboreum* hybrids were evaluated for seed cotton yield with two check hybrids. One GMS based hybrid CISAA 19-5 (2802 kg/ha) recorded significantly higher seed cotton yield than both the check hybrids, CICR 2 (2466 kg/ha) and CISAA 19-4 (2659 kg/ha).
- GMS lines (DS5, CISA 2, GAK 413A, CISG-20) and 18 newly identified GMS lines [CISG-1, CISG-2, CISG-4, CISG-8, CISG-9, CISG-10, CISG-11, CISG-13, CISG-14, CISG-15, CISG-16, CISG-17, CISG-18 (narrow leaf), CISG-18 (broad leaf), CISG-19, CISG-21, CISG-22 (narrow leaf) and CISG-22 (broad leaf)] were maintained through sibmating.

- Two F_5 generations of eight and ten parental crosses were raised for developing MAGIC RILs. 1000 lines were evaluated for leaf temperature and chlorophyll content which ranged from 24.1 to 29.5°C and 18.8 to 65.9 µmol/m² respectively while, 250 lines were evaluated for proline content that ranged from 1.4 to 2.18 µmol g^{-1} FW.
- Promising introgression lines were developed through interspecific (*G. hirsutum* × *G.barbadense*) hybridization for specific traits like high ginning outturn percentage (CNH 20378, CNH 20387, CNH 204710, CNH 204910) and cluster boll bearing (CNH 2020-7, CNH 2020-15, CNH 2020-16, CNH 2020-17, CNH 20 SP 2).
- In order to develop mapping population for waterlogging tolerance, four accessions each of tolerant (IC359979, IC359245, IC563998 (INGR 08093), LRA5166) and susceptible (IC357558, IC359242, IC357607, IC356708) group were characterized and molecular diversity was analyzed using SSR markers.
- Twelve F_4 populations of interspecific crosses of *G. herbaceum* × *G. arboreum* were evaluated. The population of cross IC371362 × PA785 had maximum UHML (30.1mm), UI (83%), MIC (3.3µg/inch), bundle tenacity (31.3g/tex) along with good yield potential.
- In order to develop compact desi cotton (*G. arboreum*) genotypes, BC_3F_1, BC_2F_2 and F_4 population of long linted genotypes *viz.,* PA255, PA812, PA740, PA783 and KWAN3crossed with Phule Dhanwantari were evaluated and selections were carried to combine plant architecture and fibre quality.
- A total of 165 single plant selections and 85 progenies were evaluated for earliness, jassid tolerance, compact plant architecture, good boll weight and yield. Eighty one single plant selections and 53 progenies were categorized as tolerant (grade 1) for jassid tolerance. Based on the molecular divergence revealed by 50 polymorphic markers, the jassid tolerant and susceptible upland cotton genotypes were grouped into 3 major clusters.
- Seven male parents (*G. barbadense*) *viz.,* ICB 161 (compact type), CCB 11A (early maturing), CCB 29 (Advance culture for yield), Suvin (fibre quality), ICB 124 (High leaf trichome), CCB 25 (Epicuticular wax content), ICB 46 (High gossypol glands) were selected to develop interspecific hybrids by crossing them with four female parents namely Suraj, Surabhi, MCU5 VT, CCH 15-1. The 50 *G. barbadense* accessions were grouped into seven clusters.
- A total of 24 samples representing 12 male sterile and 12 male fertile plants submitted for SNP genotyping. The seed of 12 CMS and its maintainer lines, 28 GMS and 25 Restorer lines were submitted for medium term storage (MTS).
- Resistance to CLCuD was studied using GVS-8 (EC881780) and GVS-9 (EC881781) and it was confirmed to be governed by a single dominant gene. Selfed and backcrossed populations are being derived to develop upland cotton varieties with better fibre traits and tolerance to CLCuD.
- Under Mega Seed Project, 5.87 q TFL seeds of 4 ICAR-CICR Bt varieties, 7.45 q breeder seeds and 7.16 q TFL seeds of popular non Bt varieties was produced.
- Foliar supplementation of micronutrient mix and neem kernel extract significanlty enhanced the quality seed yield in Non Bt Cv.Suraj. Application of Mepiquat Chloride (Chamatkar) significantly increased the boll weight but did not affect the seed index.
- Maintenance breeding and characterization for 186 extant cotton varieties which includes 141 *G. hirsutum*,

35 *G. arboreum,* 3 *G.herbaceum* and 7 *G.barbadense* varieties has been performed.

- Seeds stored along with Zeolite beads and kept in a refrigerator as well as seeds stored in polylined aluminium packets with modified atmosphere viz., Nitrogen and CO2 revealed higher germiantion than those stored with out zeolite beads and those stored in normal polylined aluminimum foil packets kept in cold as well as ambience.
- More than 100 genotypes are under Bt conversion and evaluation at all three stations of ICAR-CICR. The promising Bt lines are being evaluated in Institute common trial and the promising one are sponsored for AICRP trials. Promising released varieties like LRA 5166, Anjali, MCU 5-VT, Suraj, Surabhi, Supriya, Sumangala, CCH 2623, Subiksha, Sunantha, Suraksha, CCH 19-2, CCH 19-4 etc. are being converted to Bt. Nucleus seed of four Bt varieties *viz.,* 115kg of ICAR-CICR Suraj Bt, 153kg of ICAR-CICR GJHV374 Bt, 187kg of ICAR-CICR Rajat Bt and 156kg of ICAR-CICR PKV081 Bt was producedSeven Bt varieties *viz.,* ICAR-CICR Bt 6, ICAR-CICR PKV Bt, ICAR-CICR Suraj Bt, ICAR-CICR Rajat Bt, ICAR-CICR GJHV Bt, ICAR-CICR Bt 16 and ICAR-CICR Bt 23 were notified in the Gazette *vide* S.O. 3482(E) dated Oct. 7, 2020.
- Introgression of Tg2E13 event (*cry1Ac* gene) and CH12 event (*cry2Ax1* gene) into Suraj, NH615 and CISH3178 is in BC4F2 and BC3F1 stage. Non-deregulated transgenic events viz., Tg2E13 (*cry1Ac*) and CH12 (*cry2Ax1*) were assessed for their bio-efficacy against pink bollworm and American bollworm along with checks [BG II hybrid check (*cry1Ac+cry2Ab*); Suraj Bt variety (Mon531) and non-transgenic (Coker 310)]. For pink bollworm, Tg2E13 was found comparable to single and dual gene Bt checks. The event has also showed good bio-efficacy against American bollworm.
- *Agrobacterium*-mediated genetic transformation of *G.hirsutum* Coker 312 with *CICR- cry2Ab1Ac::chitinase* gene constructs and regeneration through somatic embryogenesis found four putative transgenic plants positive for *npt*-II and *chitinase* gene with PCR analysis using gene specific primers.
- Putative transgenic callus cultures derived from transformation of *wnt 3A* gene cassette in *G hirsutum* cv. Suraj were confirmed through PCR analysis using combination of gene and vector backbone primers.
- Callus cultures derived from Agrobacterium mediated transformation of Coker 312 hypocotyls with four gene targeting vectors *viz.,CRISPR/Cas9::GhPHYA1sgRNA1,CRISPR/Cas9::GhPHYA1sgRNA2, CRISPR/Cas9::GhPHYA1sgRNA3 and CRISPR/Cas9::GhPHYA1sgRNA4* are being maintained through sub culturing for regeneration of putative genome edited plants through somatic embryogenesis.

Crop Protection Division

- Thirty-six and forty-two geographical populations of pink bollworm were monitored for resistance against baseline susceptibility to cry toxins Cry1Ac and Cry2Ab, respectively. Among the populations tested, highest resistance ratios were recorded in population from Kurnool (Andhra Pradesh) to both Cry1Ac (423 fold) and Cry2Ab (3737 fold) compared to susceptible check (1.00 fold).The pink bollworm larvae from the infested green boll samples collected from

various locations of India were found parasitized by *Apanteles angaleti* under field conditions.

- Endosymbiotic gut bacteria belonging to five genera viz., Burkholderia, Pluralibacter, Gergoviae, Enterobacter and Citrobacter were identified as a core microbial community associated with pink bollworm larvae. Twenty-nine haplotypes (from Pb_H1 to Pb_H29) were identified from 38 sequences of pink bollworm larvae collected from 21 different cotton growing locations across India. The most common haplotype was Pb_H1 which was shared by nine populations and Pb_H3 shared with two populations whereas, other 27 haplotypes were found as unique.
- Using marker assisted selection using CIR-246 marker and artificial inoculation of BLB resistant plants, 56 BC4-F2 and 38 BC5-F1 BLB resistant plants were selected, screened and grouped.
- Nine potential endophytes were screened in vivo against cotton diseases using pot culture. The endophytes viz., *Diaporthe longicolla* (CEL 41, CEL 48), *Daldiniae schscholtzii* (M1-4) did not prove pathogenic to cotton cultivars Suraj and Phule dhanwantary. Cross pathogenicity of endophyte *Daldiniae schscholtzii* (M1-4) against wheat, sorghum, red gram, soybean, cowpea and brinjal did not reveal symptoms of pathogenicity or abnormality.
- Symptomatological studies were carried out on boll rot samples collected from cotton fields of Maharashtra, Telangana and Madhya Pradesh states. Twenty-eight bacterial and nine fungal isolates causing inner and external boll rots, respectively in cotton were identified.
- Target leaf spot samples from 35 different cotton growing locations of Maharashtra, Gujrat, Telangana, Andhra Pradesh, Rajasthan and Haryana states were collected and the pathogens were isolated on PDA medium.Pathogenicity of these isolates was tested on susceptible cotton cultivar PKV-081 (*G. hirsutum*).
- Grey mildew disease samples were collected from cotton growing districts of Maharashtra and Telangana states. Different agar media like Richard's, Kirchoff's, leaf decoction and Coon'swere used for isolation of the pathogen, *Ramularia areola*. In all the tested media, pathogen growth was slow with no sporulation even after 30 days of incubation.
- Cotton intercropping systems significantly reduced the thrips population compared to sole cotton crop. Cotton intercropped with marigold had the lowest thrips population. Bt cotton + onion followed by Bt cotton + vegetable cowpea were found as the most profitable cropping systems. Among 10 different insecticides evaluated against thrips under field condition, spinoteram was found the most effective and buprofezin was least effective. *Metarhizium anisopliae* was found as most effective biopesticide whereas neem oil followed by castor oil recorded higher efficacy among botanicals.
- The absorbance value was higher in leaf followed by petiole and squares among the different plant parts used for tobacco streak virus (TSV) detection. The absorbance values obtained from different plant parts were found in decreasing order for germplasm lines ICB 38, ICB 36 and ICB 37. Variation in absorbance in different plant parts revealed that DAS-ELISA can be used for the detection of TSV in cotton.
- Samples of *Alternaria* leaf spot (141) collected from the cotton growing states of India viz., Telangana, Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra and Gujarat were tested for pathogenicity and virulence on susceptible genotype LRA 5166 under glasshouse conditions. All the

141 isolates were found pathogenic to cotton and Telangana isolates were more virulent (7 to 54 PDI) followed by Karnataka (15 to 45 PDI), Andhra Pradesh (11 to 37 PDI) and Tamil Nadu (4 to 17 PDI)

- For the first time the natural infection of reniform nematode eggs by nematode antagonistic fungus, *Pochonia chlamydosporia* was reported from India. The fungus can parasitize more than 75% of eggs and cause 100% mortality of juveniles in root-knot and reniform nematodes. The mass production protocol for *P. chlamidosporia* under in vitro condition was standardised. Two new nematode antagonistic fungi were isolated from the rhizosphere of cotton. The temperatures between 25-35^{0}C were favourable for multiplication of reniform nematode.
- Bioassays conducted against whitefly red eyed nymphs indicated maximum mortality due to pyriproxyfen (64.00%) and least mortality due to diafenthiuron (48.00%) among tested insecticides. Dislodgement, predation, parasitization and non-viability were recorded as key mortality factors for eggs. Whiteflies deposited fewer eggs and had shorter developmental period (egg-adult) on CLCuV infected plants compared to healthy plants. Ninety-one exotic and indigenous germplasm lines and released cultivars of *G.hirsutum* cotton were screened against whitefly under field and laboratory conditions.Seasonal dynamics of sucking pests viz, whitefly, jassids and thrips were studied on both Bt and non-Bt cotton cultivars.
- Biopesticides viz., *Beauveria bassiana*, *Lecanicillium lecanii*, *Metarhizium anisopliae*,HaNPV, SlNPV with neem oil and chlorpyriphos 20EC as control were evaluated under field conditions. Twelve bacterial and 10 fungal isolates were obtained from infected pink bollworm larvae.
- A technical guidance on pest management was provided to Department of Agriculture based on analysis of weekly pest situation. Mass awareness was created among cotton production stakeholders through print and electronic media, invited talks, press notes, articles in newspaper and magazines, TV and Radio talks and published literature etc.
- IRM-PBW project was implemented in 105 villages of 21 districts covering 1050 acres area of 8 states. Random surveys to assess the level of field infestation of pink bollworm and various outreach activities oriented towards creating mass awareness were carried out.
- Highest whitefly adults were trapped in yellow-daffodil sticky trap followed by yellow-orange appeal sticky trap. Seven different vegetable oils viz., groundnut, sunflower, rice bran, soybean, safflower, sesame and palm oil containing compounds like linoleic acid, palmitic acid, myristic acid and stearic acid exhibiting oviposition deterrent properties were found effective against *Helicoverpa armigera* in cotton and in chickpea. All the tested oils were effective in deterring the oviposition by *H. armigera* at a concentration of 1% and above both in cotton and chickpea crops. Blends of these oils in different combinations were also effective against *H. armigera* in cotton.
- Spatial maps depicting the risk of pink bollworm establishment, number of generations and potential population abundance in different geographical locations were prepared by coupling a temperature-based phenology model with geographical information system (GIS). The indices representing the pest risks were computed using interpolated temperature data from Worldclim

database for current and future climate change scenarios. The risk maps indicated increased pest activity of pink bollworm due to climate change and intensification of yield losses in cotton.

- Based on presence of two fatty acids(oleic and linoleic) in faecal pellets of pink bollworm, six different vegetable oils were identified and evaluated as oviposition deterrents under field conditions. Similarly, based on the presence of α/β pinene, carene, γ terpinene, α copaene, caryophyllene and humulenein square extract of cotton, the cotton twig, square extract and artificial blend of identified compounds were evaluated for oviposition preference of female pink bollworm. Higher proportion of γ terpinene in *Gossypium herbaceum* might attribute to oviposition deterrent effect.Higher quantity of caryophyllene and α/β pinene with low levels (G. arboreum) or absence (*G. hirsutum* and *G. barbadense*) of γ terpinene attracts pink bollworm female for egg laying.
- The bacteria viz., *Bacillus subtilis*, *B. cereus*, *Lysinibacillus sphaericus*, *Brevibacterium epidermidis*, *Providencia vermicola* and *Ochrobactrum pseudogrignonense* induced resistance in cotton plants against reniform nematodes. Spray of formulation of curcumin + cow urine in combination with neem oil reduced nematode population and increased yield in cv PKV081(13.1 q/ha) as compared to control (11.47 q/ha). Short-ter*m* culture collection repository has been established in house at Division of Cop Protection, ICAR-CICR, Nagpur for deposition, preservation and maintenance of microbial cultures.
- Mass production unit for a talc-based formulation of *Trichoderma harzianum* was established at Bio-control laboratory of Division of Cop Protection, ICAR-CICR, Nagpur.
- The information on compatibility and field efficacy of multi lure pheromone system against major lepidopteran pests of cotton was explored. The field experiments provided insight on how different pheromone lures housed in one trap performed in combination in attracting more than one lepidopteran pests in cotton to cater the needs of pest monitoring and management. Nine different cotton genotypes (Bt and non-Bt) were evaluated for tolerance against stem weevil, wherein the infestation varied from 10 to 43%. Affected stems showed hypertrophy and hyperplasia of cells resulting in extensive stem swelling. Higher proportion of phenolic and terpenoids compounds imparted field level tolerance whereas, high soluble sugar content increased susceptibility to stem weevil.
- Entomopathogenic fungal consortia caused significantly higher mortality than any solo entomopathogenic fungus in sucking pests of cotton under in vitro condition. A primary form of bacterial symbiont of entomopathogenic nematode *Xenorhabdus nematophilus* caused significantly higher mortality than that of *X. stockiae* in jassids under in vitro condition. Entomopathogenic nematode, *Steinernema* sp isolated from *S. frugiperda* larvae caused 100% mortality of larvae and pupae. Twenty isolates of endophytic fungi from the cotton roots were isolated. A methodology for the virulent isolates of entomopathogenic nematode and fungi by modified soil baiting method has been standardized.
- About 100 fungal isolates were purified from cotton rhizosphere soil samples collected from different cotton cropping systems in North, Central and South Zones of India. Three liquid bioinsecticide formulations of most virulent Entomopathogenic fungus (EPF) strains compatible with insecticides were

developed and evaluated in large plot field trial at ICAR-CICR Regional Station, Sirsa. The tested EPF formulations provided highest mortality in whitefly nymphs and lowest CLCuD PDI (%) next to the insecticidal treatment of spiromesifen.

Crop Production Division

- Soils rotated with deep rooted crops - pigeon pea, sunnhemp, *daincha* and radish had less penetration resistance than those without a rotation. The least resistance was observed with the deep sub-soiling treatment. However, deep sub-soiling treatment had a high fuel consumption of 9.5 lph compared to 7.2-7.8 lph for the shallow sub-soiling treatments. Sub-soiling in alternate rows reduced fuel consumption by 50%. Seed cotton yields were the highest in the rotation plots, except radish.
- Among six medium long to long linted genotypes of *G. arboreum* L. (PA 812, PA 760, PA 528, PA 402, DLSA 17, CNA 1041) and a short staple check- Phule Dhanwantary were evaluated at two spacing (60 × 10/15 cm – HDPS and 60 × 30 cm-normal) on two dates of sowing (timely with the onset of the monsoon (D1) and late around 14 days after the first (D2) indicated that, genotypes CNA 1041 and PA 528 were the highest yielders, followed by PA 812 and PA 760. Yield was higher at 60x15 cm spacing.
- The night Net Ecosystem Exchange (NEE) was 5-10 µmol m^{-2} s^{-1} for cotton crop. The day time NEE reached its peak during 12:00 to 14:00 hrs depending on the net radiation and clear sky condition. The peak NEE during 1 Aug (nearly 30 DOS) was found to be -10 µmol m^{-2} s^{-1}. It has increased to -20 to -25 µmol m^{-2} s^{-1} during September- November at flowering and peak boll development stage.
- The total Water footprint (WF) of rainfed cotton at Nagpur was 16384 m^3/t of seed cotton, of which the green WF was 12187 m^3/t, and the grey water foot print was 4198 m^3/t. The total WF of drip-irrigated cotton was 13310 m^3/t. The ridge and furrow-irrigated cotton at Coimbatore recorded a WF 26541 m^3/t. Among the agro-techniques evaluated to reduce WF, broad bed and furrow with polymulch intercropped with green gram yielded higher SCY (3288 kg ha^{-1}) with less water requirement.
- Integrated farming system (IFS) model produced 70.2 q/ha cotton equivalent yield with B:C ratio of 1.95. one goat (Usmanabadi) unit gave a net return of Rs.15,812 and a poultry (Giriraja) unit (100 birds in two batches), gave a net return of Rs. 65,614. Fruit and vegetables (custard apple, papaya, french bean, okra, tomato, cucurbits) as a horticulture component in IFS, yielded a net profit of Rs. 29,134 in a year. Overall, one-hectare IFS could generate 492 man-days during the one-year cropping season.
- Under rainfed conditions (Nagpur), cotton intercropped with legumes had higher leaf N compared to sole cotton. Similarly, legume rows had one-fold increase in soil N compared with the sole cotton. Under irrigated conditions (Coimbatore), *Desmanthus virgatus* was the best perennial legume for alley cropping under cotton – maize system.
- Among the Sulphur (S) formulations, micronized S was superior to the grits of bensulf formulations ((Bensulf, FRT-Bensulf) with regard to S release.
- Fifty-one cotton genotypes were screened for *in-gel* oxalate oxidase (OxO) activity under control and drought conditions.

The expression of OxO activity was higher in cotton under drought stress compared to control. Genome–wide identification of the *GLP1* isoforms/oxalate oxidase was performed and 50 such isoforms were identified in *G. arboreum*. These were further characterized for their tissue-specific expression (leaves, squares, ovules and cotyledon).

- Harvested Ankur 3028 BGII and PKV-081 Bt with the modified spindle type Cotton picking head recorded higher trash content (17% and 27%, seed cotton basis), respectively, as compared to 1% in the manually picked cotton.
- A significant difference was observed between the control and bacterial inoculation treatments in enhancing root and shoot traits in cotton at 45 DAI (days after inoculation). Among the six isolates evaluated, *Pseudomonas* sp. (5R) showed better shoot and root traits under drought stress.
- Based on the three-year insect bioassay, five bacterial isolates for each lepidopteran pest were short-listed for management of Pink bollworm, American bollworm, Fall army worm and Cotton leaf worm. Among these, *Pantoea agglomerans*, *Enterobacter cloacae*, *Enterobacter sp.*, *Enterobacter hormaechei* showed higher Pink bollworm ovicidal activity (47%-71%). Field inoculation of selected bacterial isolates as seed treatment showed increased plant growth attributes (plant height, sympodial branches, SPAD values, LAI, boll numbers, yield and fibre quality) compared to the control.
- Bacterial strains were screened for their effectiveness in attracting/repelling the whiteflies and jassids, through the production of microbial volatiles (mVOC). Among the different solvents tested for their mVOC (extraction efficiency), Dichloromethane (DCM) and Diethyl ether (DE extracted more mVOC. Field trap catch using yellow sticky trap swabbed with 48 h broth grown bacterial cultures (10^8 cells/ml) indicated 28%-126% increase in whiteflies and 13%-60% increase in jassids catch compared to control.
- The K solubilization index of selected K solubilizing microorganisms (KSM) on Alexandow media supplemented with bromothymol blue ranged from 1.3 to 4.0. The KSMs also produced Indole-3 acetic acid (IAA) ranging from 10 to 18.7 µg/ml/24h.
- The elevated CO_2 levels enhanced weed and cotton growth. However, there was 108% enhancement in weed dry matter accumulation over its ambient counterpart at 90 days after sowing compared to 40% enhancement in dry matter accumulation in cotton during this period.
- Adoption of soil moisture conservation techniques (ridges and furrows) followed by foliar application of Glycine Betaine @ 100 ppm, 5 days after plant drought experience were found useful to manage drought. Adoption of drainage practice (ridges and furrows) followed by foliar application of salicylic acid (0.5mM) 3 days after water-logging were found useful to manage excess water stress. Water-logging (36 h) reduced germination by 40.5%, 35.0%, 21.0%, 37.6%, 24.5%, and 26.3% respectively, in *arboreum* (PA 528), *barbadense* (Suvin), *hirsutum* (Suraj), *herbaceum* (G Cot 25), H × H (RCH 659 BG II), and H × B (MRC 7918 BGII).
- The application of growth regulators-Mepiquat chloride and Chlormequat chloride at 70 and 100 DAS significantly reduced plant height in Suvin and RCHB 625 BGII at 125 DAS. Planting Suvin at 90 × 45 cm spacing produced significantly higher SCY (1395 kg ha^{-1}) than 90 × 60 cm

(1150 kg ha^{-1}). Planting RCHB 625 BG II hybrid at 90 × 30 cm spacing produced significantly higher SCY (1892 kg ha^{-1}) than 90 × 60 cm (1628 kg ha^{-1}) and 90 × 45 cm (1620 kg ha^{-1}).

- After two years of continuous cotton–maize and cotton-wheat cropping system under irrigated conditions, SCY increased significantly by 26.5% and 134.6% withcombined sources of organic (FYM once in two years) and inorganic (NPK + $MgSO_4$ + $ZnSO_4$ + Borax) treatments, respectively, over control. Under cotton-wheat cropping system, higher SCY was recorded in *Bt* cotton hybrid compared to non-*B*t cotton hybrid, *Bt* and non-*Bt* cotton variety.
- The drought tolerance imparted by epigenetic regulated chemicals (ERCs) through seed treatment, in varieties like Suraj and LRA 5166 was inherited upto fourth generation. This is evident from the fact that the ERCs like 5 azacytidine, sulfamethazine, epigallocatechin gallate and nicotinamide improved the relative water content, SPAD values, proline content, nitrate reductase activity, chlorophyll stability index and total soluble sugars and reduced the excised leaf water loss when compared to untreated control. Among the ERCs, 5 azacytidine improved the key drought tolerant traits in both Suraj and LRA 5166.
- At Sirsa, the seed cotton yield (SCY) was significantly higher under Zero tillage - permanent narrow raised bed with residue retention on surface. Among the cropping systems, significantly higher SCY was recorded under Cotton - Chickpea cropping systems.
- Bt cotton variety (CICR Bt-6) and non-Bt cotton variety (CSH 307) with a combination of early sowing, spacing of 67.5 cm × 45 cm and Mepiquat chloride spray at 60 and 75 DAS were identified as BMPs for high yield. Similarly, for BG II hybrid (SP-7172) a combination of early sowing, spacing of 67.5 cm × 60 cm and Mepiquat chloride spray at 60 and 75 DAS were identified as Best Management PracticesBMPs. When sowing was delayed to the second week of June, planting at closer spacing ie. 67.5 cm × 10 cm for varieties and 67.5 cm × 30 cm for hybrid was a better option.
- Under e-Communication programme, cotton technologies were disseminated among farmers through voice message services covering 1.6 lakh farmers. Uploaded 91,54,264 voice messages during the year. Voice messages on cotton production and protection technologies were disseminated in Marathi, Tamil & Hindi languages.
- Cotton farm profit margin of 35 to 52% over Cost C2 was registered over the years. A unit increase in domestic production of cotton would increase the demand for Indian cotton by 6.02%. TFP growth rate during 2010 to 2016 was in decreasing trend (-6.8%) in all the cotton-growing states except Tamil Nadu. India, to benefit most by concentrating on other potential importers such as Vietnam, Bangladesh, Pakistan, Indonesia, Hong Kong, Thailand and Malaysia.

General

- During the period, a total of 76 research papers of which 30 research papers with >6 NAAS Score and 46 research papers with <6 NAAS Score as well as 30 popular articles were published. 49 training programmes including virtual training programmes were organized where a total of about 5700 beneficiaries including farmers, students, field trainees and extension functionaries participated.

- Linkages were fostered with sister ICAR Institutes, SAUs, other public sector Institutes, private companies, NGOs and farmer producer groups to commercialize and upscale varieties and technologies developed. One MTA and six MoUs were inked during January to December 2020