Name of entry	Seed Cotton Yield (kg/ha)	GOT (%)	UHML (mm)	Tenacity (g/tex)	Micron aire	Uniformity Index
Central Zone (Irrigated)						
CICR 22 Bt	981	32.9	27.4	29.4	3.8	82.5
CICR 20 Bt	1099	36.4	25.5	27.7	4.2	81.5
CICR 21 Bt	1240	36.6	24.9	24.4	4.3	80.0
Suraj Bt (C)	1130	34.7	26.0	26.7	4.5	82.0
Central Zone (Rainfed)						
CICR 20Bt	1136	37.5	26.3	25.6	4.5	81.8
183059-5 Bt	784	37.2	26.1	25.8	4.7	81.8
183059-3 Bt	673	37.7	24.3	24.9	5.2	80.5
CICR 21 Bt	1059	36.9	25.7	26.4	4.0	81.1
CICR 22 Bt	1229	35.0	25.8	26.1	4.3	80.6
183059-4 Bt	620	37.4	26.1	25.3	4.2	81.5
Suraj Bt (C)	1090	35.1	25.8	24.9	4.3	80.9
North Zone						
CICR 17 Bt	2770	33.9	26.0	30.0	4.4	82.2
CICR 18 Bt	1960	35.9	25.8	28.0	4.3	81.8
CICR 183059-1 Bt	1370	34.0	26.1	28.6	4.5	81.6
CICR 19 Bt	470	38.4	22.2	25.7	5.3	79.2
CICRS 23 Bt	2840	33.9	26.2	29.4	5.0	82.0
CICRS 28 Bt	2460	34.0	27.7	30.8	4.3	82.8
CICRS 27 Bt	2580	32.4	25.5	29.4	5.0	81.8
PAU Bt (C)	2480	39.3	28.0	30.4	4.2	83.6

ICAR-CICR Bt cotton entries retained in AICRP Bt Varietal trial

Zone	Entries retained
South Zone (Irrigated)	CICR 25 Bt, CICR 26 Bt
South Zone (Rainfed)	CICR 25 Bt , CICR 24 Bt
Central Zone (Irrigated)	CICR 20 Bt, CICR 21 Bt
Central Zone (Rainfed)	CICR 20 Bt, CICR 22 Bt
North Zone	CICR 17 Bt

Release proposals of six of ICAR-CICR Bt varieties namely CICR 16 Bt, CICR 81 Bt and CICR 2017 Bt. identified for Central Zone Irrigated as well as Rainfed.

3.6: Enhancing Resource Use Efficiency through climate smart agro-techniques

3.6.1.Exploring productivity potential of long-linted *G. arboreum* cotton

Desi cotton (*G. arboreum*) is re-emerging as a potential alternative to obtain sustainable yields during the era of climatic uncertainties. However, non-availability of long staple *G. arboreum*, with comparable fibre properties of their hirsutum counterparts is an impediment in popularizing them. This project was conceived to provide location specific long linted desi cotton tailored with an agronomic package to maximize the cotton productivity and climate proof the cotton growers.

Nagpur:

Seven *G. arboreum* genotypes (6 long linted - DLSA 17, PA 528, PA 402, PA 812, PA 760, CNA 1041 and short stapled Phule Dhanwantary were 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 21 and July 5, 2018. The results are summarized below -

- Averaged across spacing, soil types and sowing dates - PA 528 (3532 kg/ha) and CNA 1041 (3579 kg/ha) were more productive than the rest. Across soil types, spacings and genotypes a delay in sowing by 2 weeks reduced the mean seed cotton yield by 600kg. Averaged across genotypes; sowing dates and soil types the yield gain due to HDPS was 275 kg/ha. The yield of Ajeet BGII was 2400 kg/ha and 1621 kg/ha on the Inceptisol under normal and delayed sowing, respectively. The corresponding yield on Vertisol was

2696 and 2022 kg/ha. respectively.

- Due to better hydraulic conductivity, cotton sown on Inceptisols was more productive than that on Vertisols. Averaged over sowing dates, spacing and the genotypes yield gain in Inceptisol was 319 kg/ha.
- Averaged over spacing and genotypes, a delay in sowing by two weeks reduced seed cotton yield by 910 kg/ha in Inceptisol (depth limitation) but only by 173 kg/ha in the deep Vertisol indicating a significant interaction effect between sowing time and soil type **(Figure 3.6.1).**

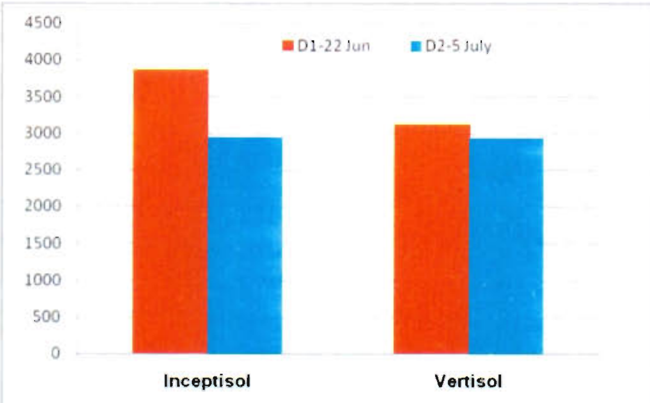


Fig.3.6.1: Influence of soil type on mean seed cotton yield (kg/ha) of *G arboreum* genotypes sown on two dates of sowing

- Expression analysis of two genes of ethylene biosynthesis pathway, coding for key enzymes ACCS (1-aminocyclopropane-1-carboxylic acid synthase) and ACCO (1-aminocyclopropane-1-carboxylic acid oxidase) was performed to correlate their expression with fibre length. The expression of *ACCS* was maximum in PA812, that had the longest fibre length followed by PA528, where as PA402 had minimum expression. There was also a significant difference for *ACCO* transcript level among the genotypes where PA812 showed maximum expression followed by PA760 and PA402 was observed to have minimum ACCO level among all.
- To establish a correlation between few already known genes involved in cell elongation (*Bonzai*, *Myb25* and *Pex1*) and ethylene expression, transcript level of these selected genes were measured at 0, 7 & 14 days post anthesis (DPA)in the ovules of PA812 and Phule Dhanwantary. At all stages, PA812 had more expression of all these genes compared to Phule Dhanwantary, a short stapled genotype. *Myb25* was found to be involved specifically in fibre elongation (7 DPA), whereas *Bonzai* and *Pex1* were more at fibre initiation stage (0 DPA).
- Two cultivars namely PA 255 and Phule Dhanwantary were planted in four row directions. In PA 255, there was no effect of different row direction on seed cotton yield whereas in Phule Dhanwantary, east-west direction of row orientation significantly improved yield over other row orientations. There was no significant effect of row direction planting on soil temperature recorded at forenoon and afternoon in both the varieties.
- Long-linted *G. arboreum* genotypes were evaluated at regular intervals for bacterial blight, grey mildew, root rot and leaf spot diseases. Root rot was negligible during initial stages; it appeared in severe form during September. Grey mildew disease was observed during August-September with severity ranging from 8.53 to 41.07%, and maximum severity in PA 402.
- Seed treatment in *G. arboreum* genotype PA-255 with mycorrizal biofertiliser grown in acrylic tubes showed higher root length and root dry weight compared to untreated plants.
- Foliar application of mepiquat chloride (MC) @500 ppm had significantly improved germination, length and vigour index of fuzzy seeds of cotton variety PA 255.
- Detopping, detopping+side shoot removal, side shoot removal and foliar application of MC significantly improved germination over control. The other quality traits remained non-significant in delinted seeds of cotton variety PA 255.

Coimbatore:

- Normal date of sowing of six long linted *G. arboreum* genotypes viz. DLSA 17, PA 760, PA 812, PA 402,PA 528, K12 along with a short staple genotype Phule Dhanwantary produced significantly higher seed cotton yield (2450 kg/ha) than late planted cotton to the tune of 680 kg/ha.
- Two contrasting genotypes (K 11 and DLSA 17) were planted under HDPS in three row directions, north-south, east – west and diagonal. Significant interaction effect was observed wherein diagonal sowing of K 11 registered significantly highest seed cotton yield (1720 kg/ha).

3.6.2 : Agronomic studies on ELS cotton

3.6.2.1 : Effect of sowing time and foliar nutrition

A field experiment was conducted at Coimbatore with three dates of sowings (9 July, 4 August & 29 August), three foliar spraying of nutrients (N1: Recommended Dose of nutrients (RDN), N2. RDN+Foliar application of K_2SO_4 @ 1% at 75,100,125 DAS and N3.RDN+Foliar application of KNO_3 @ 1% at 75,100,125 DAS) with two genotypes (Suvin, MRC 7918 BG II) to assess the effect of environment and foliar spraying of nutrient on seed cotton yield and quality parameters. Seed cotton yield was significantly influenced by dates of sowing, genotypes and foliar spraying of nutrients. Sowing on 4 August registered significantly higher seed cotton yield (19.1 q/ha) which was on par with 9 July (19.0) but was significantly higher than 29 August. (7.3 q/ha) sowing. The genotype, MRC 7918 BG II registered significantly higher yield (21.1 q/ha) than Suvin (9.1 q/ha). Amongst foliar spraying of nutrients. application of RDN with KNO_3 (1%) in 75,100,125 DAS registered significantly higher yield (17.1 q/ha). The interaction results revealed that planting of MRC 7918 BG II on 4 August and RDN + foliar application of KNO_3 (1%) in 75,100,125 DAS registered the highest yield of 23.8 q/ha.

The late sowing (29 August) registered the least 2.5% span length (34.5mm) and fibre strength (25.0 g/tex) and micronaire. The application of recommended nutrients with foliar spray of KNO_3 (1%) at 75, 100, 125 DAS observed significant improvement in micronaire in second (3.4) and third (3.0) picking and fibre strength in second (28.7 g/tex) and third picking (27.2 g/tex).

3.6.2.2 : Effect of edaphic factors on quality parameters

Soil properties of three soil series (Palladam, Irugur and Peelamedu) located at Vadaputhur village of Kinathukadavu, Coimbatore were correlated with quality parameters of ELS cotton with objective to find out influence of edaphic factors on quality parameters. Analysis indicated that 2.5% span length was significantly and positively influenced by soil productivity grades (r=0.839), and available potassium (r=0.699). Fibre strength (g) was significantly influenced by land capability class (r=0.884) and available potassium (0.928). Micronaire was positively significantly influenced by soil productivity grades (r=0.793)

3.6.2.3 : Relationship between Crop phenology with quality parameters

An experiment was conducted with *G. barbadense* genotypes (Suvin & CCB 29) with inter specific (MRC 7918 BG II, Ankur HB2210 BGII and RCH 625 BGII) and intra hirsutum hybrid (RCH 659 BGII) to find out the influence of duration of phenological phase on quality parameters at Coimbatore. The seed cotton yield of RCH659 BGII (Hx H) (28.4 q/ha) had out performed MRC 7918 BG II (26.84 q/ha), Suvin non Bt (11.4 q/ha), RCH 625 BG II (20.1q/ha), Ankur HB2210 BG II (19.58 q/ha) and CCB 29 non Bt (12.8 q/ha). The duration to first squaring, 50% flowering, and 50% boll were significantly and positively correlated with fibre 2.5% span length and strength.

3.6.3 : Improving the productivity of cotton on calcareous soils

3.6.3.1 : Secondary and micronutrient management under irrigated conditions

Highly calcareous soils have multiple nutrient deficiencies (N, P, K, S, Zn and Fe). Therefore, farmers apply high doses of sulphur containing P fertilizers in 2-3 splits. Chelated micronutrients applied to soil (2.5 kg ha^{-1}) and 1% foliar application along with biofertilizers consortia (N, P, K, Zn solubilisers) as seed treatment and split soil application of sulphur containing 125% RDF significantly outperformed 125% RDF and conventional micro and secondary nutrients (N, P, K, Mg, S, Fe, Zn) soil application. In highly calcareous Vertisols, sulphur and $ZnSO_4$ soil application (20 kg^{-1}) with two supplemental irrigations improved seed cotton yields by 15% and FUE and net returns by 24% compared to without S in Bt hybrid cotton + pigeon pea strip cropping system.

3.6.3.2 : Mitigating soil moisture and nutrient constraints under rainfed conditions

In order to improve the cotton yield and address the soil moisture and nutrient constraints on rainfed calcareous soils, on-station experiment was conducted with *G. hirsutum* var PKV081 and and BGII hybrid Ankur 3028. In Ankur BG II 3028, opening of ridges and furrows during first intercultural operation and strengthening them at 45 DAS improved soil moisture availability and produced 249 kg/ha more seed cotton than where no moisture conservation measures was adopted. The effect of fertilizer management practices, was non- significant for variety but it was significant for hybrid. In hybrid, compared to the application of RDF+limiting micronutrient, significantly higher seed cotton yield was obtained in the treatments **T12** (125% RDF alone), **T10** (Seed treatment with biofertilizers + 125% RDF (NPK)+ Mg,S (10,10kg ha^{-1})+Micronutrients (Fe,Mn,Zn,B) as per soil test+Opening of ridges & furrows after 1st interculture+Chelated micronutrients 0.5% (Foliar Spray) @ 45 DAS + Humic acid seed treatment + 0.5% Foliar Spray of Chelated micronutrients) and **T9** 'Seed treatment with biofertilizers + 125% RDF (NPK)+ Mg.S (10,10kg ha^{-1})+Micronutrients (Fe,Mn,Zn,B) as per soil test + Opening of ridges & furrows after 1st interculture + Humic acid seed treatment + Chelated micronutrients soil application 2 kg ha^{-1})

Ridges and furrows strengthened at 45DAS of cotton in black calcareous soil

3.6.3.3 : Performance of diploid cotton for rainfed calcareous soils

Seven desi cotton varieties (HD-123, HD-432, CISA-614, CISA-310, PA-255, Phule Dhanwantary, AKA-7) were tested in 60 x 30 cm spacing with seven different fertilizer treatments under shallow to medium deep black calcareous soil **(Table 3.6.1).**

Table 3.6.1: Seed cotton yield (kg/ha) of *desi* cotton varieties under different input management regimes on a rainfed black calcareous soil (2018-19)

	Control	RF only	(100%) +MN	(100%) +MN+RF	(100 +25 % Split) +RF	(125%) +MN+AM+ RF	(125%) +CMN +RF	Mean
HD-123	1046	1750	2018	2794	2887	2427	2301	2175
HD-432	1273	1723	2118	1890	2199	2265	1401	1838
CISA-614	1576	1730	2093	2882	3006	2605	2068	2280
CISA-310	2059	1817	2709	3497	3449	2908	2684	2732
PA-255	2324	2957	3044	4040	4735	4147	3728	3568
Phule Dhanwantary	2181	2318	3624	2427	2828	3495	3829	2957
AKA-7	2080	2304	3193	2364	2883	3107	3275	2744
Mean	1791	2086	2686	2842	3141	2993	2755	

CD 5% varieites and input management = 87.0

RF- Ridges & furrows, MN-Micronutrients Zn(125 kg/ha+B (5 kg/ha), AM- Animal Manure @ 2 t/ha in the root zone, CMN-Chelated micronutrient (Zn & B)

The varieties recommended for central zone (PA 255, Phule Dhanwantary and AKA 7) significantly out yielded the varieties recommended for the north zone (HD 123, HD 432, CISA 614 and CISA 310). Averaged over varieties among input management practices, soil moisture conservation through ridges and furrows gave an additional yield of 295 kg/ha over control. Compared to the application of 100% RDF + limiting micronutients alone, the application of 25% higher fertilizer dose along with animal manure @ 2 t/ha and soil moisture conservation through ridge and furrows resulted in an additional yield of 307 kg/ha.

3.6.4: Validation of inputs for Bt hybrid cotton + pigeon pea stripcropping on marginai soils

Performance of NPK solubilisers as a seed treatment alongwith 75% recommended dose of fertilizers (RDF) was at par with 100% RDF i.e. 90:45:45 kg ha^{-1} N: P_2O_5 and K_2O in shallow, stony and marginal soils at Nagpur.

- Seed treatment with *Sagarika* (a sea weed extract based metabolic bio enhancer) alone produced 5% more seed cotton yield over 100% RDF. *Sagarika* granules (25 kg ha^{-1}) application alongwith 100% RDF improved yield by 8%. *Sagarka* contains 60 ppm GA and 40 ppm cytokinin which promotes root/ shoot proliferation, produces dark green foliage and delays senescence. It improved plant height, biomass and boll numbers by better apportioning of nutrients towards bolls.
- NPK solubilisers as seed treatment were effective in improving seed cotton yield. *Sagarika* seed treatment along with 75% RDF and foliar application of water soluble fertilizer produced 14% more seed cotton yield over seed treatment alone.

$ZnSO_4$ (20 kg ha^{-1}) soil application produced 16% more seed cotton yield over control. *Sagarika* and foliar application of (2%) water soluble fertilizer had positive effect only when soils were fertilized with at least 90%

RDF. Soil application of $ZnSO_4$ (12 kg ha^{-1}) under two supplemental irrigations and *Sagarika* granules + foliar application of *Sagarika* once (2ml L^{-1}) water at vegetative stage improved seed cotton yield by 3.0 q ha^{-1} in medium deep soils at recommended fertilizer levels. Soil application of conventional fertilizers @ RDF 120:60:60 $N:P_2O_5:K_2O$ and fertigation with additional 40% RDF of water soluble fertilizers (NPK,. NP, NK) along with chelated micronutrients 5 kg ha^{-1}, Mg SO 20 kg ha^{-1} produced 35 and 55 q ha^{-1} seed cotton yields in red soil and calcareous *vertisols respectively*.

3.6.5 : Quantitative estimation of carbon and moisture fluxes over the cotton based agro-ecosystem

- Cotton crop growth and crop performance were monitored in 11 fields in the fetch area of flux tower over ICAR-CICR farm, Nagpur. Temporal data on LAI and chlorophyll index and yield variations across fields were documented. Across different fields, the LAI ranged from 1.70 to 3.46 during the peak flowering period and from 1.22 to 1.65 during boll opening period. The values for chlorophyll index ranged from 1.22 to 1.65 during the peak flowering stage. Seed cotton yield ranged from 576 to 3301 kg/ha.
- Flux tower data for radiation and surface energy balance, hourly air temperature, soil moisture and rainfall, carbon flux were collected at 30 minutes interval and analyzed. Seasonal account of carbon flux components viz. Gross Primary Productivity, Ecosystem Respiration (R_{eco}) and Net Ecosystem Exchange (NEE) were calculated for different pheno-phases and for the whole season **(Fig.3.6.2)**. It was observed that during the entire crop season, the NEE was negative and the values ranged from -0.95 during last picking to -2.99 during the period between first open boll to first picking.

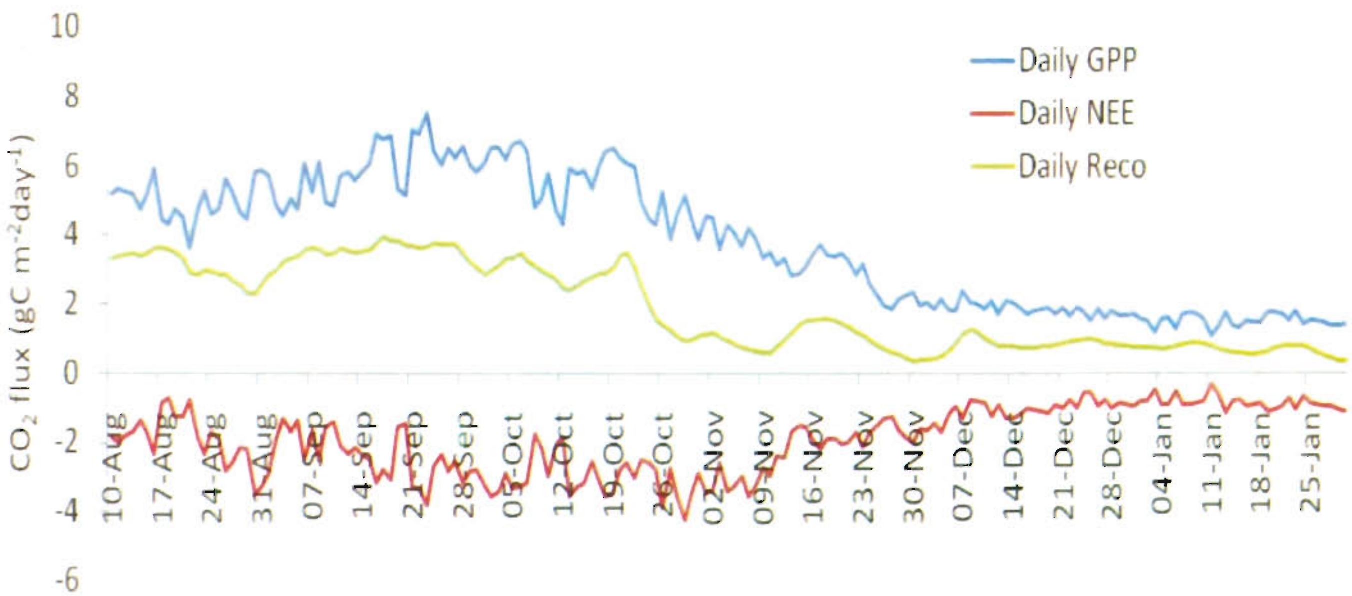
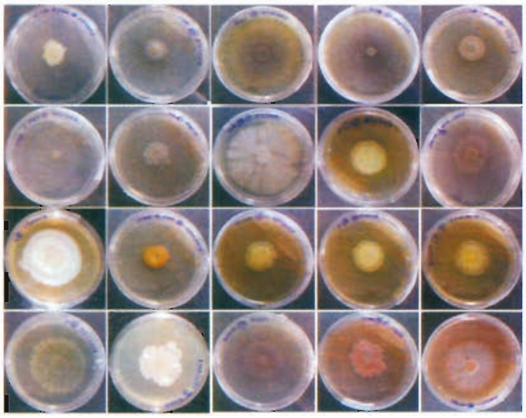


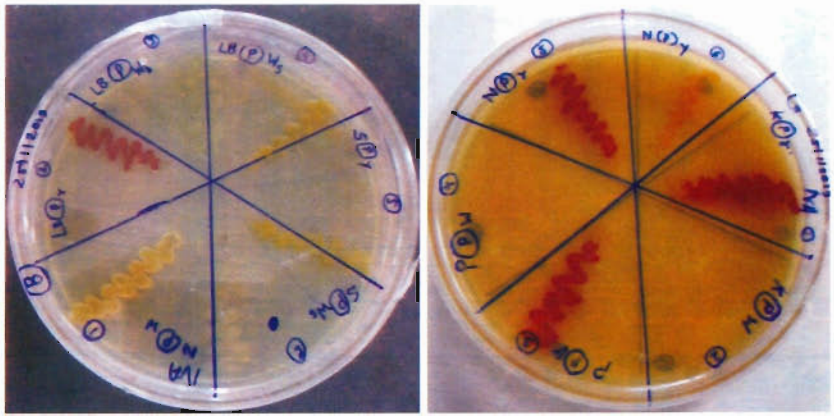
Fig.3.6.2: Seasonal account of the carbon fluxes (NEE, GPP, R_{eco}) over cotton ecosystem

3.6.6: Microbial biofilm formulations for cotton

One hundered and seventy bacterial strains were isolated from cotton rhizosphere and from *Helicoverpa*, *Pectinophora* and *Spodoptera* using soil baiting technique. The bacterial isolates were purified and submitted for identification (16 S rRNA sequencing). To short list bacterial partners for biofilm development, these bacterial isolates were tested for their biocontrol potential against the major cotton pests (*Helicoverpa*, *Pectinophora* and *Spodoptera*) through insect bioassays (two sets of experiments with 24 larvae/treatment in three replicates). The maximum mortality recorded were 77%, 96% and 85%, respectively *for Helicoverpa*, *Pectinophora* and *Spodoptera*. Presently the microbial isolates are being tested against major cotton pathogens (*Fusarium*, *Rhizoctonia*, *Xanthomonas*, *Macrophomina*, *Corynespora*, *Sclerotium*, *Colletotrichum*). The shortlisted bacterial partners will be used for development of biofilm with proven fungal partner *Trichoderma*, *Metarhizium*, *Beauveria*, *Paecilomyces*).



Native bacterial strains isolated from cotton rhizosphere



Bacterial strains isolated from *Helicoverpa*, *Pectinophora* and *Spodoptera*

3.6.7: Response of hybrid Bt-cotton to Smartchem Technologies Limited (STL) Complex CNS Fertilizer

A field trial was conducted to study the response of hybrid Bt-cotton to the STL complex CNS fertilizer under rainfed conditions with six treatments and four replications. The results indicated no significant difference among fertilizer practices and CNS grade fertilizers (Complex CNS grade-STL practise recommendation) and RDF 100:50:50 kg NPK ha^{-1}. However, CNS grade fertilizers and RDF produced significantly higher yield than the farmers practice.

Field view of complex fertilizer

3.6.8: Evaluation of Nutrient Expert Fertilizer Decision Support System of IPNI

Nutrient Expert Fertilizer Decision Support System for hybrid cotton was evaluated alongwith other nutrient management options. viz., CICR-recommended fertilizer dose (RDF), soil test crop response (STCR) and farmer fertilizer practice (FP). Differences were observed (0-120DAS) among the treatments in all the morphological parameters. Variations in the extent of deficiency was greater in farmers fertilizer practice. Leaf reddening was also observed in farmers fertilizer practice. Nutrient Expert system improved SCY of on-station (3240 kg ha^{-1}) trial than farmers fertilizer practice (2376 kg ha^{-1}). The average seed cotton yield with Nutrient Expert was 3051 kg ha compared to 2097 kg ha^{-1} with farmers fertilizer practice.

Evaluation of nano-formulated micronutrients

3.6.9 : Evaluation of structured water for cotton production

A field experiment was conducted at Coimbatore to find out the efficacy of structured water irrigation through drip. Structured water and bore well water treatments were allotted to main plot and scientific scheduling of irrigation at 0.4, 0.6, 0.8 and 1.0 ETC with conventional irritation were allocated to sub plot. The cropping season received a very high rain fall of 452 mm and the effective rainfall worked out to be 220mm. The total evaporative demand as recorded from class A open pan evaporimeter during the cropping period was 731.4 mm. The total water requirement at 1.0 ETc of Mallika BGII cotton for various growth stages were 158.3 mm (0-25 DAS), 262.7 mm (26-70 DAS), 282 mm (71-120 DAS) and 28.4 mm (121-125 DAS). The total water requirement for Mallika BG II cotton at 0.4,0.6,0.8,1.0 ETC and conventional irrigation were 381.5mm, 442.2mm, 502.8mm, 563.4mm and 947mm respectively. Saving of water due to drip ranged from 383 to 565mm (40-60 per cent) over conventional irrigation. The seed cotton yield due to structured water irrigation ranged from 2937 to 3613 kg/ha as compared to 2707 to 3336 kg/ha under bore well irrigation (Table 3.6.2.) Structured water irrigation recorded an average 2.7 q/ha additional seed cotton than bore well water irrigation but differences were not significant. Among the irrigation schedule, 0.6 ETC through drip was on par with 0.8 and 1.0 ETc through drip and significantly superior to 0.4 ETc through drip and conventional irrigation, The water use efficiency due to structured water irrigation ranged from 32.8-76.9 kg/ha cm as against 29.6 – 70.9 kg/ha cm under bore well irrigation.

Table 3.6.2.: Seed cotton yield (kg/ha) of Mallika BG II cotton as influenced by irrigation treatments

Irrigation Scheduling	Structured water	Bore well water	Mean
Drip at 1.0 ETc	3613	3336	**3474**
Drip at 0.8 ETc	3440	3104	**3272**
Drip at 0.6 ETc	3223	3009	**3116**
Drip at 0.4 ETc	2937	2707	2822
Conventional Irrigation	3104	2812	2958
Mean	3263	2994	

CD 5% - Irrigation scheduling: 421*, Structured vs borewell water: NS, Interaction: NS

3.6.10: Evaluation of nano-formulated micronutrients foliar spray for yield maximization in different cotton genotypes

To evaluate the effectiveness of different dosages of best performed commercially available nanofertilizers like Nualgi and Nanomol with or without surfactant on cotton, field experiments were carried out during 2016-17 and 2018-19 at ICAR-CICR (RS), Coimbatore. Results indicated that application of normal recommended dose (100 %) of Nualgi with surfactant and Nanomol without surfactant showed significant improvement in nitrate reductase activity, reducing sugar content and seed cotton yield.

Field experiments were also carried out 2016-17 & 2018-19 at Coimbatore to study the interaction effect of best metal oxide nano-particles of zinc, iron, copper and magnesium along with organic fertilizer (seaweed liquid fertilizers). Among the single form of metal oxide nanoparticles like Zn, Mg, Cu and Fe, the highest average seed cotton yield was produced by foliar application of 100 ppm of ZnO nanoparticles (50 nm) (1662 kg/ha). Likewise, among the combined form metal oxide nanoparticles, foliar application of ZnO+MgO+CuO showed a significant increase in average seed cotton yield (1604 kg/ha) which was on par with ZnO+CuO (1523 kg/ha), ZnO+Fe_3O_4 (1535 kg/ha), ZnO+MgO+Fe_3O_4 (1513 kg/ha) and ZnO+MgO+CuO+Fe_3O_4 (1547 kg/ha) except ZnO + MgO (1334 kg/ha). The performance of inorganic form of metal oxide nanoparticles either single or combined were superior in increasing the seed cotton yield than combined sources of inorganic (metal oxide nanoparticles) and organic (seaweed liquid fertilizer) sources of fertilizers

3.7: Sustainable farming systems through conservation agriculture and precision techniques

3.7.1 : Alleviating soil compaction – a production constraint in cotton

Problems of soil compaction are increasingly being experienced due to excessive use of machinery but this leads to sub-soil compaction. Consequently, root and crop growth are adversely affected. Field studies were conducted to alleviate sub-soil compaction either by mechanical sub-soiling or using deep rooted crops as a rotation crop to cotton. Deep rooted rotation crops such as pigeonpea, radish, sesbania and sunnhemp effectively broke the hard pan. Among the rotation crops, seed cotton yield was the least (24.8 q/ha) with radish. Pigeonpea had significantly greater yield levels (35.3 q/ha) and was followed by sunnhemp and sesbania (28 to 29 q/ha) with similar yield levels. Random sub-soiling did not differ with the control plots. However, sub-soiling the planting row resulted in significantly greater yields than the control. Crop root growth was also adversely affected by the sub-soil compaction. Laboratory studies also clearly indicated a reduction in the rooting depth, root dry matter as well as the plant dry matter. Root length of the American cotton variety (Suraj) or the desi variety (AKA-8) and the BGII Bt hybrid (Ajeet 155) were not affected at normal soil bulk density. Increase in bulk density beyond 1.6 g/cc resulted in a drastic reduction in root length of the Bt hybrid but the varieties showed a decline beyond 1.7 g/cc. Comparing the desi variety and the BGII hybrid, plant growth of the desi cotton variety was not affected with increase in soil bulk density, but the reverse was the case with the BGII hybrid **(Fig.3.7.1).**

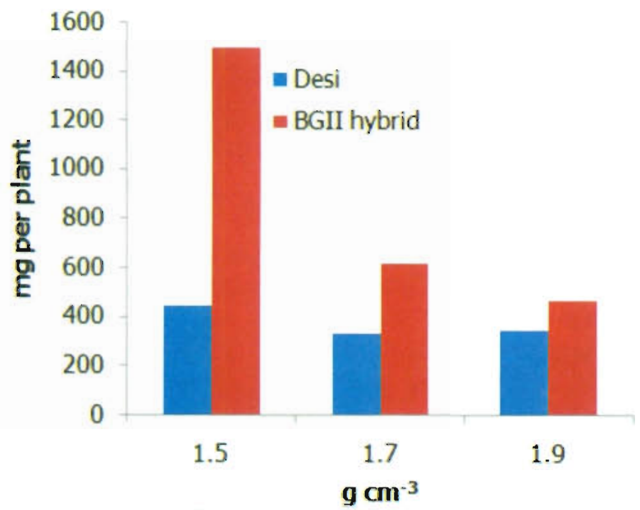


Fig. 3.7.1: Effect of increasing soil bulk density on the plant dry matter

3.7.2: Cotton based cropping systems under conservation agriculture

Coimbatore

Conservation agriculture based field experiments were conducted with cotton based cropping system from 2015 onwards for improving system productivity and soil quality under irrigated condition with Farmer's practice, [M_1], CA system with minimal land reshaping and partial (50% of residue from above ground biomass and 100% roots) residue recycling [M_2] and CA system with 100% residue recycling [M_3] as main plots and cropping systems viz., Cotton-Black gram-Maize (for grain purpose) [S_1], Cotton-Maize (for green cobs)+Pigeon pea (Strip cropping@4:2 ratio) [S_2], Cotton-Groundnut (for table purpose)+Pigeon pea (Strip cropping@8:2 ratio) [S_3], Cotton-Fallow (Control) [S_4] as sub plots. For CA treatments, beds and furrow system (60 x 30 cm) was used while for conventional system, ridges and furrows system for cotton and flat beds for other crops was used. The plots involving CA treatments are being maintained on permanent basis.

The results indicated that cotton-black gram - Maize (for grain purpose) is a potential candidate cropping system to implement conservation agricultural practices under irrigated conditions as it registered significantly higher Cotton Equivalent Yield (4247 kg ha^{-1}) than the conventional Cotton – Fallow system (CEY 1996 kg ha^{-1}) (Fig. 3.7.2). The results also indicated that beds and furrows system is suitable for raising cotton and other component crops under conservation agricultural practices viz., minimum tillage and residue recycling. CA system with 100% residue recycling registered significantly higher CEY of 3438 kg ha^{-1} than Farmer's practice (CEY of 3128 kg ha^{-1}).

Soil penetration resistance (Cone index) was recorded using cone penetrometer. Pooled analysis of depth wise soil penetration resistance using MSTATC over three cropping sequences revealed that CA system with 100% residue recycling significantly reduced the soil penetration resistance upto 9" soil depth vis-à-vis Farmer's practice (Fig. 3.7.3).

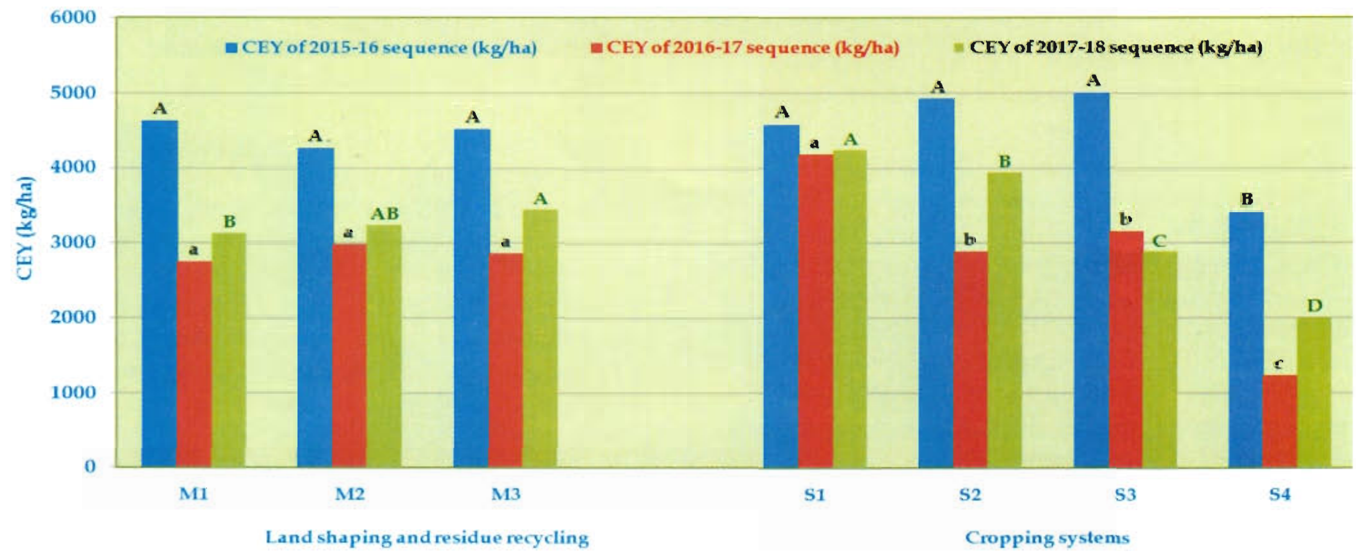


Fig 3.7.2: Cotton Equivalent Yield (CEY) of the system (kg CEY ha^{-1}) during 2015-16, 2016-17 and 2017-18 cropping sequences *(Different upper case, lower case and coloured alphabet indicate significant difference among treatments within the group; M1: Farmer's practice, M2: CA system with minimal land reshaping & partial residue recycling, M3: CA system with 100% residue recycling; S1: Cotton - Black gram - Maize (for grain purpose); S2: Cotton - Maize (for green cobs) + Pigeon pea (Strip cropping@ 4:2 ratio); S3: Cotton - Groundnut (for table purpose) + Pigeon pea (Strip cropping @ 8:2 ratio) and S4: Cotton - Fallow (Control))*

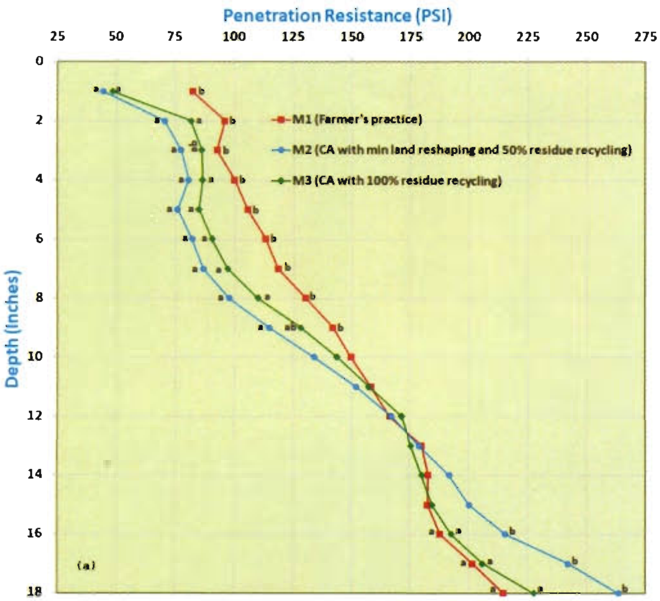


Fig 3.7.3:. **Soil Penetration Resistance (PSI) recorded at different soil depths (inches) in (a) different land shaping & residue recycling treatments and (b) cropping systems (Different lower case letter indicate significant difference among treatments within the group)**

Sirsa

- A new experiment with permanent / fixed lay out plan was initiated at experimental farm of ICAR-CICR, Regional Station, Sirsa, Haryana during the 2018-19 cropping season. The experiment was planned under split-plot design with six main plot treatments and cotton based cropping systems (seven numbers) involved as sub-plot treatments and three replications. As 2018-19 cropping season is the 1st year (starting year) of the experimentation, thus zero tillage / permanent narrow raised bed system as well as crop residue retention / incorporation of various crops during sowing of cotton crop could not be applied as the entire field was deep ploughed with mould board plough and then laser levelled before start of the experiment. Bt-cotton Hybrid RCH 776 (BG-II) was cultivated with recommended package of practices except the applied treatments. Non-significant differences among the tillage, land configuration and cropping systems were observed for othe plant growth parameters and yield.

3.7.3 : Efficient N fixing legumes based cotton production systems

3.7.1: Nagpur : Cotton + legume intercropping

Legumes (blackgram, clusterbean, cowpea, greengram, groundnut and soybean) of short, medium and long duration were sown as intercrop to reduce the input cost of N fertilizers under rainfed cotton *(G. hirsutum var Suraj* and *G. arboreum var Phule Dhanwantary)*. On deep black soil, cotton was raised under high density planting system (HDPS) with a spacing of 90 x 10 cm in randomized block design and intercropped with legume. Intercropping, irrespective of the duration of legume improved soil organic carbon and reduced soil pH and EC. After harvest of legume, in legumes rows, the soil N was comparatively high than cotton rows. However, due to shortage of moisture at 120 DAS the transport of this N was not evident . Sucking pest dynamics during the *kharif* season indicated that legumes were efficient component of integrated pest management. Under rainfed, short duration legumes had synergistic effect on seed cotton yield compared to medium and long duration legumes. For *G. hirsutum var Suraj*, better performing intercropping system is cotton + soybean (2718 kg ha^{-1}) and cotton

+blackgram (2652 kg ha^{-1}). For *G. arboreum var Phule Dhanwantary*, the identified intercropping system is cotton+greengram (2519 kg ha^{-1}) and cotton+cowpea (2429 kg ha^{-1}).

Coimbatore

3.7.4: Cotton + *Desmanthus* virgates alley cropping

Field experiment was conducted in randomized block design with four replications to find out the feasibility and sustainability of growing perennial legume, *Desmanthus virgatus* (DV) as alley cropping with cotton under graded levels of N (75 %, 100% and 125% RDN) at Coimbatore. Alley cropping with DV added 61.6 t/ha of fresh biomass in 32 months since 2016 which was 19.9 t on dry weight basis with the average nitrogen content of 3.15% that translates to 625 kg N/ha. Soil organic carbon status improved to 0.69% from 0.57% under sole cotton. The average leaf chlorophyll content across perennial legume treatments was 2.14 mg/g of leaf on 110 DAS as against 1.96 mg/g. of leaf under sole cotton. Alley cropping of DV with cotton resulted in significant yield enhancement of 2796 kg/ha **(Fig. 3.7.4)** as against sole cotton (1935 kg/ha at 100 % RDF). The seed cotton yield at 75% RDN with Desmanthus was 2265 kg/ha as compared to 2037 kg/ha recorded at 125% RDN under sole cotton (Fig.) Boll numbers /plant was significantly higher due to alley cropping of DV over sole cotton. The boll weight was also higher due to addition of pruned biomass of DV. The fiber quality index, integrating fiber length, strength and micronaire was higher (452) due to alley cropping of *Desmanthus* as compared to lower fibre quality index (409) recorded with sole cotton.

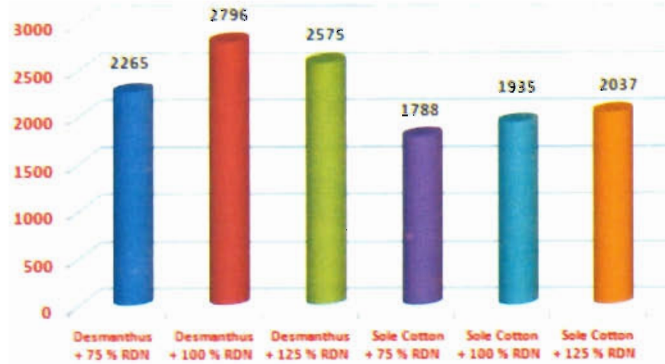


Fig. 3.7.4 : Seed cotton yields (kg/ha) as influenced by alley cropping of Desmanthus and graded levels of N

Healthy cotton with alley cropping of Desmanthus

3.7.4: Long term trial on cropping system

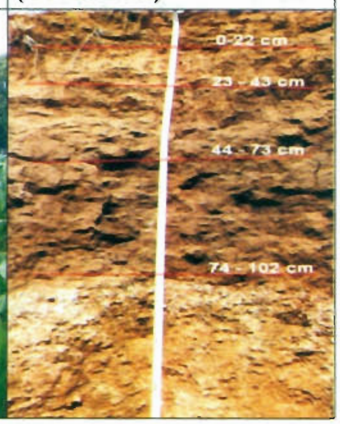
3.7.4.1: Coimbatore

Long term nutrient management project was initiated in 2018-19 in south zone with cotton – maize. Before cotton sowing, uniform soil fertility trial was carried out by sowing of maize to bring the same fertility status in the selected field. Soil profile of experimental field was studied. The depth of soil profile was >170 cm. Soil samples collected from each soil layer were analyzed for physico chemical and chemical properties which showed that available nutrients like nitrogen, phosphorus and potassium decreased but alkalinity increased with increased soil depth however (upto 102 cm), there were no change in electrical conductivity. At 103 – 135 cm soil depth, soil characters were varied due to the presence of Lime.

First year of the study indicated that application of NPK + secondary nutrients ($MgSO_4$) and micro nutrients ($ZnSO_4$ + Borax) + FYM (5 t/ha) once in two years significantly improved plant growth (plant height, root volume, shoot and root dry matter production) and seed cotton yield.

Uniform soil fertility trial with maize crop

Soil Profile study in permanent field trial (Coimbatore)



Field view of cotton -maize cropping system

Field view of cotton-wheat cropping system

3.7.4.2: Sirsa

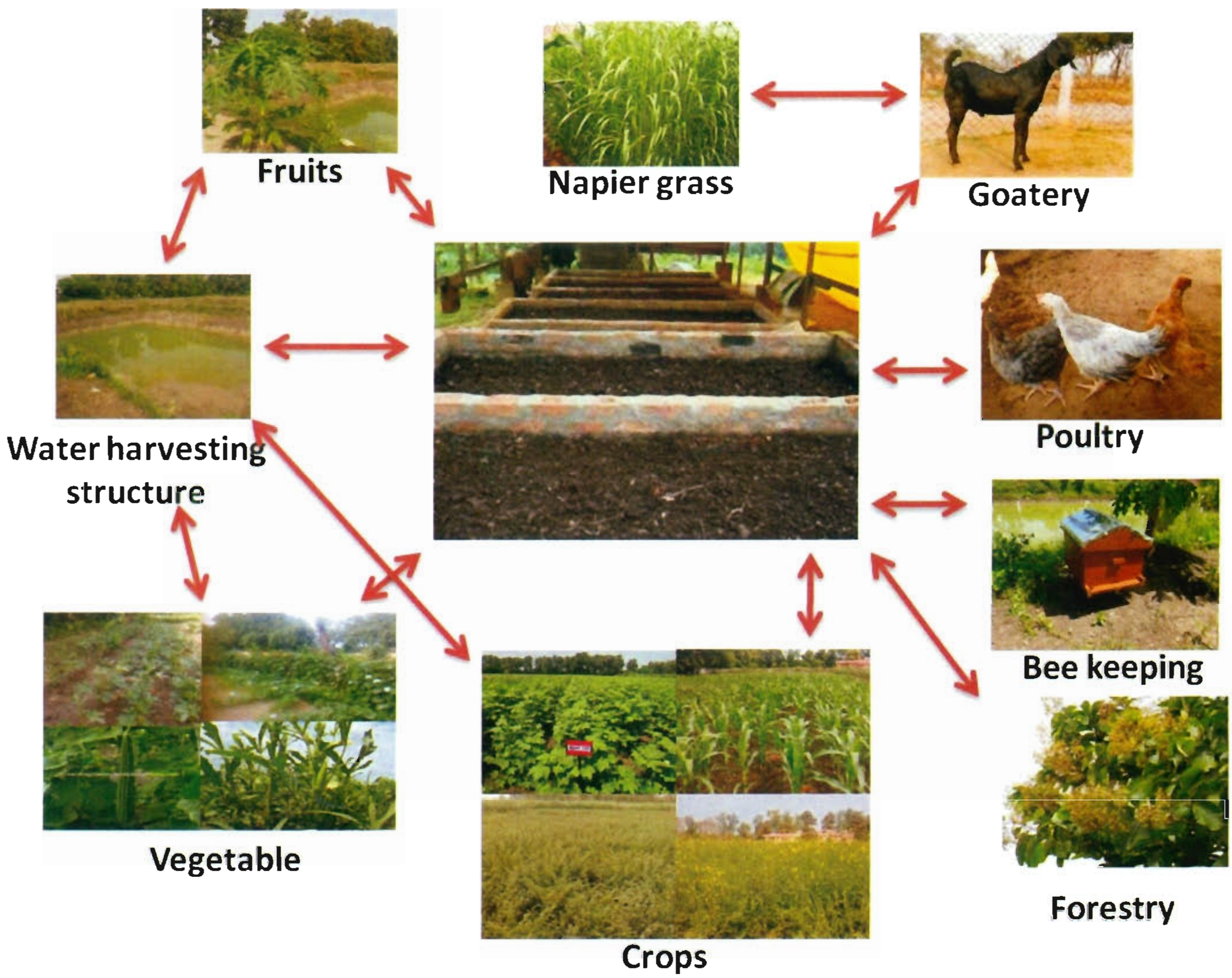
Long-term trial with five cropping systems (as main plot) and five sources of nutrients (as sub plot) was laid out at Sirsa. The yield attributes as well as seed cotton yield of Bt cotton hybrid was significantly superior over both Bt as well as non Bt cotton varieties, but was at par with non Bt cotton hybrid. Significantly higher values of plant height, yield attributes (except boll weight) and seed cotton yield were obtained with application of recommended dose of NPK along with $MgSO_4$ and micro nutrients $ZnSO_4$ and borax) than all other treatment combinations including absolute control.

3.7.5: Cotton based Integrated Farming System (IFS) model for Nagpur

Pigeon pea was planted as intercrop in cotton with 6:2 ratio in 0.4 ha area. Seed cotton yield was 21.0 q/ha and pigeonpea as intercrop yielded 3.76 q/ha. During *kharif* season, soybean and maize were sown in 0.4 ha area but due to wild boar and blue bull problem, no crop yield was obtained. Chickpea (2036 kg/ha), mustard (2026 kg/ha) and linseed (915 kg/ha) crop were cultivated during *rabi* season. A pond (of size 30m x 30m) was developed in the farm. Rain water was harvested in the pond and used for life saving irrigation during dry spell. In vegetables, 85 kg *bhindi* was harvested from 200 m^2 area and 40 kg brinjal harvested from 25 m^2 area on pond dyke. Bottle gourd and ridge gourd were planted on field fence. Seed cotton equivalent yield (SCEY) from 0.8 ha area was 1659 kg from crop and horticultural components. Data recording of goat (Usmanabadi) farming is in progress at KVK farm where four kids took birth during the year. Poultry (Giriraja) unit was taken to farmers' field and first batch of poultry gave farmer Rs 5092 net profit with 15 birds in four months. Second batch was given in February. Three honeybee colonies were established under beekeeping unit during September 2018. Data on number of foragers/2minute were recorded to make assure that colony was in active condition. Number of foragers/2minute ranged from 20 to 34 in all three colonies at different time period. Fruit plants (papaya, aonla, guava and ber) were planted on the pond dyke.

3.7.6: Field validation of Nitrogen Guru

A replicated pot culture experiment was set up taking ten different N concentrations (10-100 %). Split doses of N were provided using Hoagland solution. Nitrogen Guru was modified based on transmittance mode and the IR/LED. (IR: Infra red (940 nm); LED: Light Emitting Diode (650 nm)) ratios were recorded under varying N concentrations. To correlate, N content was estimated in the same leaves. An R^2 of 0.8 was observed between N content and IR/LED ratio (**Fig.3.7.1**).



Components in cotton based IFS model

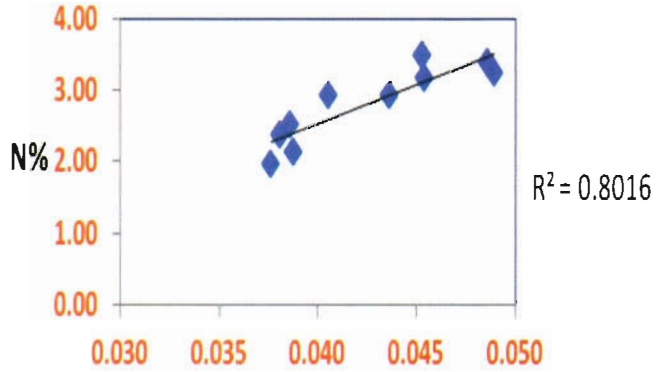


Fig. **3.7.1:** Correlation between nitrogen content of cotton leaf and IR/LED value of N Guru

3.7.7: Phenotyping of root system architecture in cotton (*Gossypium hirsutum* L.) for adaption to drought tolerance

Forty five cotton genotypes were evaluated for studying their root architecture in acrylic glass tubes. Cotton genotypes were grown in the tubes and water was with held for a week period after 20, 30, 40 DAS along with control up to 60 days. The mixture used for growing cotton seedling in acrylic tubes was sand, FYM and vermicompost in 2:1:1:1 (w/w) ratio. After 60 days of sowing, plant characters were recorded and best genotypes were identified based on root architecture (Table 3.7.1).

Table 3.7.1: Root /shoot characteristics of cotton accessions (60 day after sowing) grown in acrylic

Sr. No.	Root /shoot characteristics of cotton accessions (average of 12 plants)	
1	Highest root length	PKV 081 - 58.6 cm IC 359834 - 56.5 cm IC 359240 - 55.8 cm Nagpur 9 - 55.0 cm
2	Highest fresh shoot weight	Nagpur-9 - 16.8 gm IC 359834 – 15.49 gm PKV 081 - 14.58 gm
3	Highest fresh root weight	PKV 081 – 7.45 gm IC 359240 – 6.0 cm DTS 108-09 – 5.95 gm
4	Highest shoot dry weight	Nagpur 9 - 4.25 gm IC 359834 - 4.21 gm PKV-08 - 4.04 gm
5	Highest root dry weight	Nagpur 9 - 1.31 gm PKV 081 - 1.23 gm Suraj – 1.03 gm
6	Highest root/shoot dry weight ratio	LRA-ZFP, F 1226 and Suraj – 0.33 Nagpur 9 and PKV 081- 0.31 IC 377103 – 0.29
7	Highest root/shoot fresh weight ratio	4376 – 0.8 F 1226 and LRA-DREB/A – 0.7 LRA-ZFP and 4480 – 0.62
8	Highest root/shoot ratio on length basis	Nagpur 9 – 1.64 1993 – 1.63 LRA-ZFP and IC 359528 1.60

Root characters in different germplasm accessions at initial growth stage of *G.hirsutum*

3.7.8 : Evaluation of root traits in PVC pipes in rainout shelter.

Hundred *G.hirsutum* germplasm accessions were grown in PVC Pipes and evaluated. Accessions IC-356876, DTS-108-09, CNH-09-7 performed better under drought stress with efficient root traits such as root length, root dry weight and lateral root length than control **(Table 3.7.2)**.

Root characters in different germplasm accessions at initial growth stage of *G.hirsutum*

Table 3.7.2: Mean Root/Shoot characteristics of cotton accessions (80 DAS) & 15 days drought treatment in PVC Pipes

S. No.	Cotton Accessions	Root /Shoot Characteristics
1.	Nagpur 9,1791, CNH09-7	highest tap root length in water deficit : 53.9 cm
2.	DTS-108-09, 1791,2678	highest shoot dry weight inwater deficit: 31.9 g
3.	DTS-108-09,1791	highest dry root weight in water deficit: 2.5 g
4.	DTS-108-09,1791, IC-356876	highest fresh root weight in water deficit: 8.2 g
5.	DTS-108-09, Nagpur 9, CNH09-7	highest root/shoot dryweight ratio water deficit 0.24 g

3.7.9: Metabolite Exploration of Drought stress in Cotton

A study was initiated to explore the existence of "Alarm Photosynthesis" pathway in cotton along with characterizing the effect of drought stress on metabolites at different stages of growth. All the four *Gossypium* spp. (*G. hirsutum*: DTS-44, DTS-155 and DTS-108 as drought tolerant & IC-357637, IC-359834 and IC-357055 as drought susceptible, *G. arboreum*: Phule Dhanwantary, *G. barbadense*: Suvin, *G. herbaceum*: G-Cot 25) were subjected to drought stress and samples were collected. As per temporal (day-night) expression analysis (qRT-PCR), the GLP1/oxalate oxidase expression was more in leaves during day time when compared with the leaf samples collected during night (Fig.3.7.2). Oxalate content, which is supposed to be broken down by oxalate oxidase (OxO), was more in stressed leaf samples collected during the night time as compared to the ones collected during day time, thus validating the day night variation observed for OxO expression and activity in respective samples. For its confirmation at protein level, *In-gel* activity assay of OxO was first standardized with positive control (purified OxO from barley seedlings) and then performed with leaf samples of cotton but could not show its presence in cotton samples so far. Further, to identify all the *GLP1* isoforms present in cotton, a genome-wide scan was performed and 37 such *GLP1* isoforms were identified for *G. arboreum*.

For identification of metabolites in cotton, three different protocols for GC-MS were used and standardized. A difference in relative abundance of various compounds such as, caryophyllene, squalene, bergamotene, fatty acids and their esterified forms, neophytadiene were observed for control and water stressed leaves of cotton

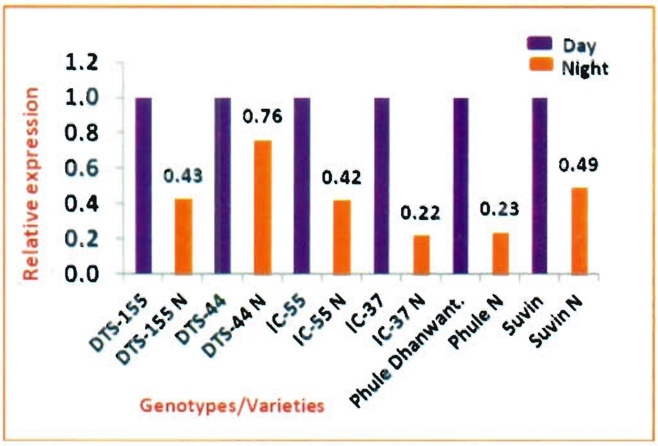


Fig:3.7.2: Day night variation in expression of *OxO/GLP1*

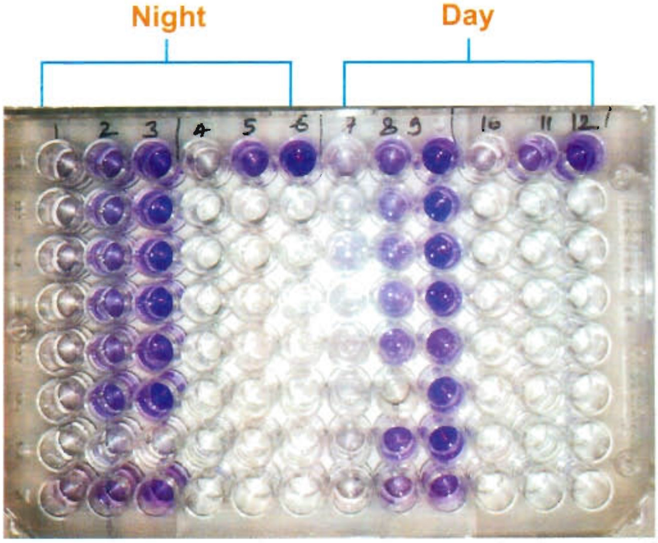


Fig:3.7.3: Oxalate content estimation in leaves of Cotton

3.7.10: Exploiting the epigenetic transgenerational inheritance of stress responsive traits for imparting abiotic stress tolerance to cotton

The epigenetic regulating chemicals (ERC) treated Suraj and LRA 5166 cotton plants were screened for drought tolerance in the second generation. The plants were subjected to drought stress during pin head stage of squaring by withholding irrigation for 10 days (**Fig 3.7.4:**). Control plants were maintained for each treatment. 5- Azacytidine (5-AZC) @ 10 µM and sulfamethazine (SMT) @ 10 µM treated plants recorded high relative water content of 86.1% and 84.7% respectively as against control (68.7%) under stress conditions in Suraj. In LRA 5166 sulfamethazine @ 10 µM and 5- Azacytidine @ 40 µM recorded high relative water content of 69.7% and 68.3% respectively under stress conditions as against control (51.5%). 5-Azacytidine @ 40 µM treated plants exhibited high proline content **(Fig. 3.7.4a)** under stress conditions as against control (LRA 5166). In case of Suraj, 5-Azacytidine 10 µM treated plants recorded high proline content **(Fig.3.7.4b)** under stress conditions as against control and also high epicuticular wax content **(Fig. 3.7.4c) (Fig. 3.7.4d)** under stress conditions as compared to the control. Sulfamethazine (10 µM) treated plants exhibited high peroxidase activity in both Suraj and LRA 5166. Thus ERCs like 5- Azacytidine and sulfamethazine improved drought tolerance by maintaining high water content in tissues, by conserving water through increased epicuticular wax content, by improving osmotyte production and by scavenging free radicals.

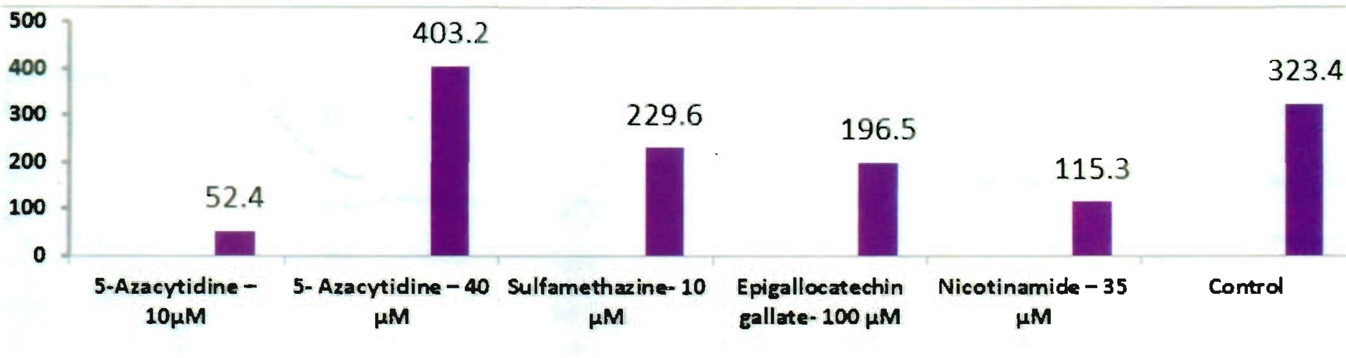


Fig3.7.4a. Effect of ERCs on proline content ug/g fresh weight of cotton leaves (var. LRA 5166) under stress conditions

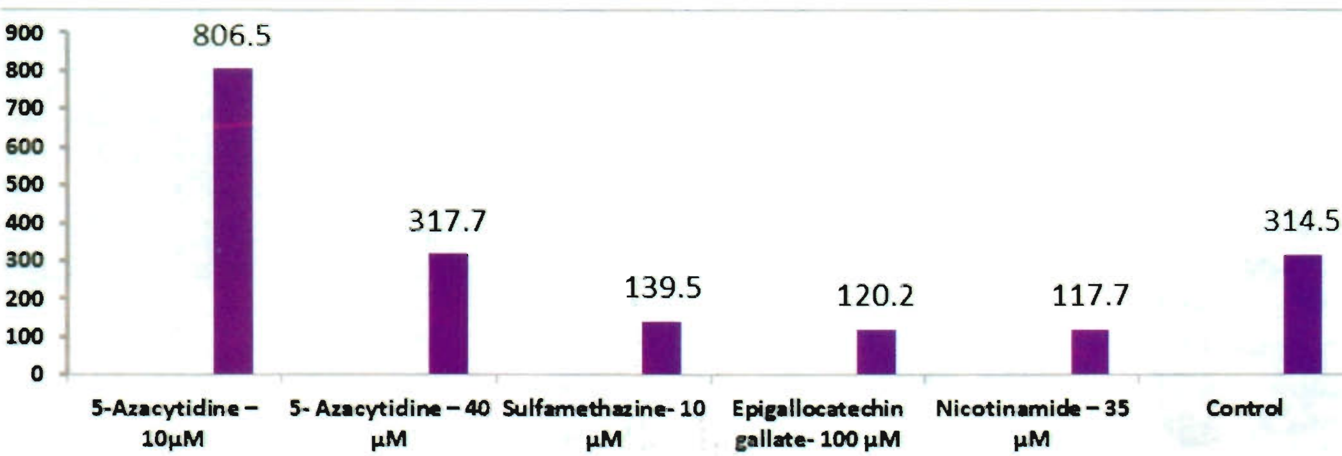


Fig 3.7.4b. Effect of ERCs on proline content ug/g fresh weight of cotton leaves (var. Suraj) under stress conditions

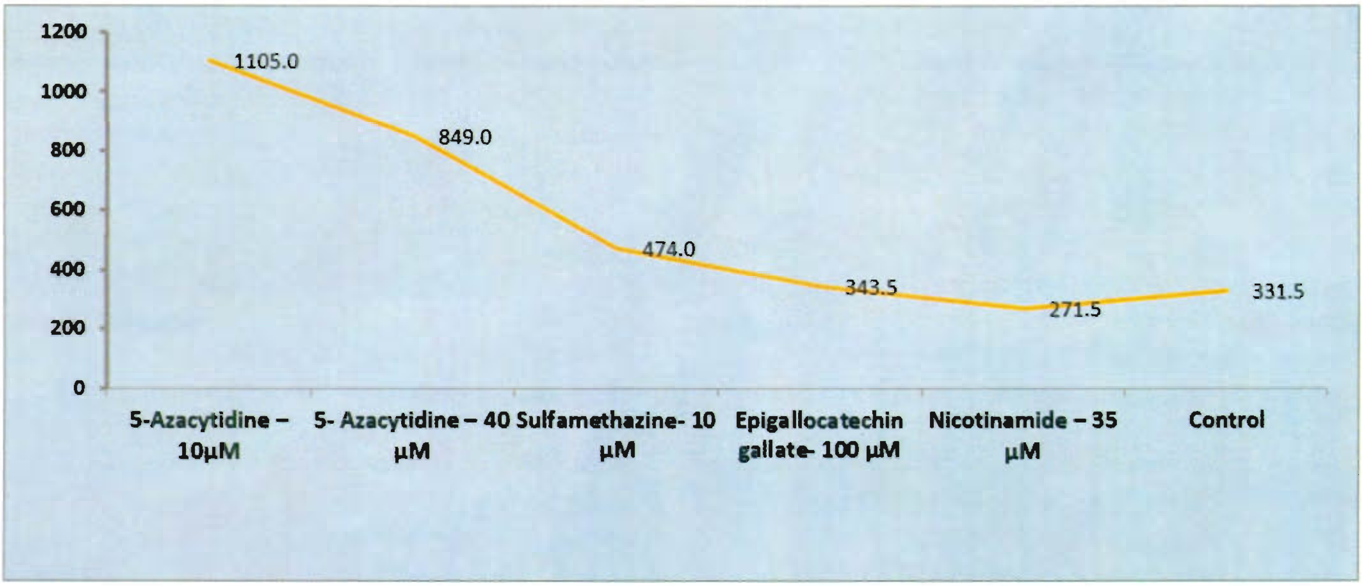


Fig 3.7.4c. Effect of ERCs on epicuticular wax content ug/g sq. cm of cotton leaves (var. LRA 5166) under stress conditions

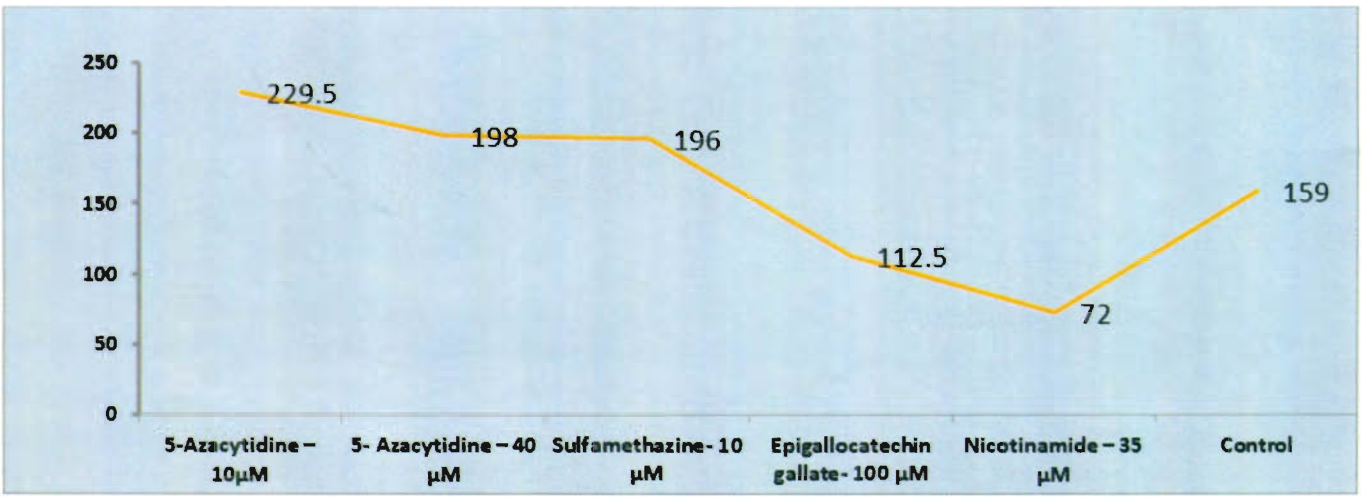


Fig 3.7.4d. Effect of ERCs on epicuticular wax content ug/ sq. cm of cotton leaves (var. Suraj) under stress conditions

3.8: Economics and extension research and e-communication tools

3.8.1: Dynamics of Cropping Pattern in cotton growing districts of Maharashtra

The cropping pattern of a particular area is largely determined by agro-climatic factors. Economic, technical as well as policy related factors can influence its dynamics.

The analysis of secondary data for the period 2000-02 to 2014-15 indicated that cotton area increased in 13 districts (Aurangabad, Beed, Jalna, Dhule, Jalgaon, Nanded, Ahmednagar, Nandurbar, Chandrapur, Parbhani, Wardha, Nagpur and Nashik). In five districts (Amravati, Akola, Washim, Buldhana and Yavatmal) a decrease in cotton area during the study period was recorded. Highest increase was observed in Aurangabad followed by Beed, Jalna and Dhule. Highest decrease in cotton area was observed in Amravati, followed by Akola, and Washim.

Cropping pattern in all the 18 cotton growing districts is highly diversified as indicated by the Simpson index of crop diversification. As the value of Simpson index decreased in almost all the districts during the study period indicating a trend slowly changing towards specialization.

Markov Chain Analysis indicated that cotton area is most stable with an average retaining probability of 0.81 in all the cotton growing districts except Nashik. The analysis indicated that the cotton is gaining area from arhar, minor pulses, maize, urad and castor. Similarly whenever there is a decrease in cotton area it is losing to arhar, maize, soybean, moong and urid. The reasons for preference of cotton by the farmers over other crops include, stable and better price, stable yield, easy to market, less crop losses, better performance in drought conditions and guaranteed income

3.8.2: Impact analysis of shift in global cotton trade on Indian cotton scenario.

The decadal trends in area under cotton from 2007-2018 showed an increase of 17% to 25% of total cotton area in the South Zone (AP, Karnataka and Tamil Nadu). In the North zone though Haryana and Rajasthan showed an increasing trend this was offset by decrease in Punjab. In the Central zone a slight reduction to the tune of 6% was observed during the same period. Odisha registered an increasing trend over the years. While comparing the two periods between 2007-12 and 2012-18, the percentage increase in area was higher in all the zones during the first period when compared to the second period. In case of yield, Central zone showed an increasing trend, while a negative trend in North zone was seen for second period. South zone, a negative trend observed in both the periods though AP showed a positive trend during the second period. The scenario changed during 2012-2018 wherein most of the traditional cotton growing states showed negative trends. Indices were worked based on cost C2 (cost plus imputed value of rent plus interest on own land and capital) A2 VOP (value of product) from 2007-11 and 2011-16 based on CACP data. The results showed that the cotton farmers were able to make profits over cost C2 in almost all the four years with the ratio of 1.25 during the first period. But during the second period, farmers of Maharashtra, Odisha and AP could not reap profits during four years out of five. Whereas, cotton farmers of Rajasthan and Gujarat reaped profits in both the periods. In relation to cost A2 (actual paid out cost) the cotton farmers of all the states reaped profits from 2007-16 except Punjab which incurred loss during one year. Domestic production was found to be significant factor affecting the exports of raw cotton from India.

A unit increase in the domestic production would increase demand export of Indian cotton by about 6%. As the domestic production increases, the surplus cotton after meeting the domestic demand is exported. The export price of Indian cotton had negative impact on the export of cotton. The exchange rate showed negative impact on the exports of cotton from India but it is found to be non-significant. Decomposition analysis was done to find the sources of growth of average export value and variants of export value of Indian cotton. The results indicate that the contribution of change in mean export quantity of Indian cotton was the dominant source for the change in average export value to the tune of 75.80 % during the period 2007 to 2018. Effects of all components of change are to be judiciously taken care of to improve the export and reduce instability of cotton export.

The Nominal Protection Co-efficient (NPC) for cotton export to different destinations.

This technique explains the comparative advantage enjoyed by the commodity in the context of free trade. The estimated NPCs in general indicated that all the countries taken up for the study were found to be competitive for cotton export from India as NPC values are less than one. (Table 3.8.1.) China and Pakistan are highly competitive markets. Gravity model was estimated for 5 country pairs of major importing countries from 2012 to 2018.The explanatory variables included in the model explained 59% of the total variation in export value of Indian cotton. Most of the factors were significant. Distance variable was not a matter of concern for Indian cotton export.

Table 3.8.1 : Nominal protection Co-efficient (NPC) for cotton export for the year 2017

S.No.	Particulars	Unit	Bangladesh	China	Indonesia	Pakistan	Vietnam
1	Wholesale price (Mumbai)	Rs./q	5320	5320	5320	5320	5320
2	Marketing margin (5%)	Rs./q	266	266	266	266	266
3	Port clearing and handling charges	Rs./q	990	990	990	990	990
4	FOB Price	Rs./q	6576	6576	6576	6576	6576
5	Freight charge	Rs./q	690	780	810	670	880
6	Insurance at 2 % of price	Rs./q	106.4	106.4	106.4	106.4	106.4
7	Landed cost	Rs./q	7372.4	7462.4	7492.4	7352.4	7562.4
8	Exchange rate	1$ = Rs.	68.96	68.96	68.96	68.96	68.96
9	CIF price	US $/q	106.91	108.21	108.65	106.62	109.66
10	Reference price	US $ q	128	175	125	145	130
11	NPC		0.84	0.62	0.87	0.74	0.81

The changing pattern of raw cotton exports were estimated by obtaining the transitional probability matrices for the annual export data of raw cotton (in terms of volume) for the period 2007-08 to 2016-17. China was one of the stable importers of Indian cotton with high probability of retention of 91%.

The present study suggests that the sharp decline in the export of raw cotton from India reflects our inability to retain the share in the traditional markets and explore new markets. This call for appropriate policy measures and marketing efforts to sustain in these growing markets. We need to improve our export competitiveness by decreasing costs and improving yield and quality. Varietal development has to be given impetus to meet the international demand of quality cotton. Export promotion with stabilization should be thrusted upon. High dependence on few markets would be risky in the long run. So new markets are to be tapped to export our Indian cotton.

3.8.3 : e-Communication: dissemination of cotton production technology

ICAR-Central Institute for Cotton Research, Nagpur continued the efforts of e-Kapas in the form of e-Communication for dissemination of cotton production technology with the objectives to register new farmers for voice message services/delivery, to issue regular voice messages to 1.5 lakh farmers of Nagpur, Coimbatore and Sirsa, develop Cotton App, document success stories of e-Kapas beneficiary farmers. During the year 4972 new farmers with mobile numbers from Nagpur centre were registered. Uploaded 64,10,034 noise free and clear recorded voice messages i.e. 55,70,280 (Nagpur), 2,69,035 (Sirsa) and 5,70,519 (Coimbatore) in the form of automatic phone calls on 1,39,671 registered farmers mobile numbers. Out of that 15, 11,751 were received successfully (Nagpur 12, 69,716, Sirsa 68,090 & Coimbatore 1,73,945)

Mobile Applications for Cotton

Android mobile based interactive decision support systems for cotton pest management "Grow Good Cotton" with pre-recorded voice modules has been developed. The system has detailed information of major pests and diseases of cotton, including life cycle, ETL, symptoms of damage on leaf, stem, square, flower, boll, open boll etc. Also management options such as chemical control, bio-control, natural or cultural control for each of the pest has been incorporated and discuss. For the chemical control, the list of recommended chemicals with dosage information, along with available brands in the market and their approximate price is provided. The interactive DSS has been embedded with voice module for clear understanding of the information for the users.

The DSS aims to aid the farmers to identify the pests based on the damage symptoms and also help to choose the appropriate pest control measures including selection of brand of pesticide of their choice.

Cotton Portal

ICAR-CICR Cotton Portal was launched in 2001. Later on, another three sites were added in the cotton portal. The portal has a wide variety of information for various stakeholders.

CICR website

KVK Nagpur website

AICRP on Cotton website

3.8.4: Development of Transfer of Technology Innovations for Bridging up the Yield and Knowledge Gap in Cotton

To know the yield gap between potential, attainable and actual yield in cotton, potential yield trial was conducted in an area of one acre in the station and simultaneously FLD was conducted on the farmers' field. Suraj and Bt cotton hybrid Mallika Bt BG II gave seed cotton yield of 2081 kg/ha and 2062 kg/ha respectively on the research farm. The same variety and hybrid yielded 1560 kg/ha and 1820 kg/ha in the FLDs and 1213 kg/ha and 1450 kg/ha in the farmers' practice. This trial revealed that the yield gap between potential yield (Station yield) and attainable yield (FLD) was 521 kg/ha for Suraj and 242 kg/ha for Mallika Bt BGII. The yield gap between attainable yield and actual yield (farmer's practice) was 347 kg/ha (Suraj) and 370 kg/ha (Mallika Bt BGII).

To assess the impact of long running cotton extension program for bridging up the yield and knowledge gap in cotton, primary data were collected from 94 FLD farmers in Dharwad and Belgaum districts of Karnataka through Focussed Group Discussion and individual case studies. Average seed cotton yield in FLD ranged from 1269 kg/ha to 2750 kg/ha. Similarly, average seed cotton yield obtained in farmers' own practices ranged from 1108 to 2610 kg/ha. Yield gap between the attainable yield (FLD) and actual yield (Farmers' practices) ranged from 160 to 350 kg/ha. The net profit in FLD ranged from Rs. 32714 to Rs.70200 and in farmers' practice ranged from Rs. 26230 to Rs. 63200. The additional benefit due to adoption of technologies disseminated through FLD ranged from Rs. 3285 to Rs. 18,400/-. The data collected on the FLD farmers' perception on assessment of FLD as a cotton extension mechanism revealed that majority of the farmers (> 80%) perceived FLD program as an efficient, compatible, observable, trialable and a program with multiple advantage as well as risks. The data collected on the desirable changes happened in the cultivation behaviour of FLD farmers revealed that majority of them adopted the appropriate cotton varieties and hybrids after FLD. There were also desirable changes in adoption of management strategies for weeds, diseases, pests, physiological disorders and in harvesting & post harvesting practices. But the knowledge test conducted among them revealed that more than half of them could not tell the correct answers as regards to (i) how to do? and (ii) principle behind the technologies viz., cotton varieties and hybrids, management strategies for weeds, diseases, pests, physiological disorders and in harvesting & post harvesting practices. This explains the existence of knowledge gap even among the FLD farmers Taking into consideration of the constraint and suggestion expressed as regards Extension Methodology, majority of the (> 95%) of the FLD farmers expressed that continuous information flow is lacking in FLD extension model. So, they suggested for an extension approach which could supply the information continuously during the entire season and suggested extension components which are to be included in the new approach.

To assess the yield gap in major cotton growing districts of south zone and to identify the causes for yield gap at farm level, the secondary data on area, production and productivity were analyzed. For the analysis, district-wise cotton area for the years 2013-14 to 2015-16 were taken into account. The total area under cotton was classified into four production zones, namely, primary, secondary, tertiary and 'others' based upon the area under the crop in each district. Fig. 3.8.1. Top districts covering 50% of the total cropped area were categorized into primary production zone. Next group of districts covering 35 per cent (50 to 85 per cent) of the total area were categorized into secondary production zone. Simultaneously to quantify the yield gap, the mean lint yield of districts (2013-14 to 2015-16) (Fig.3.8.2) under various AESR was worked out. The highest yield among the districts of same ASER was regarded as potential yield for that AESR. The difference between potential yield and yield of target district is regarded as untapped yield potential. Among the districts in primary production zone, Guntur had the highest average lint yield (736 kg/ha) and Mahabubnagar had the highest untapped yield gap (453 kg/ha). In the secondary zone, Gulbarga had the highest average lint yield (674 kg/ha) and Dharwad had the highest untapped yield gap (427 kg/ha). In the tertiary zone, Krishna had the highest average lint yield (697 kg/ha) and Chikmagalur had the highest untapped yield gap (466 kg/ha).

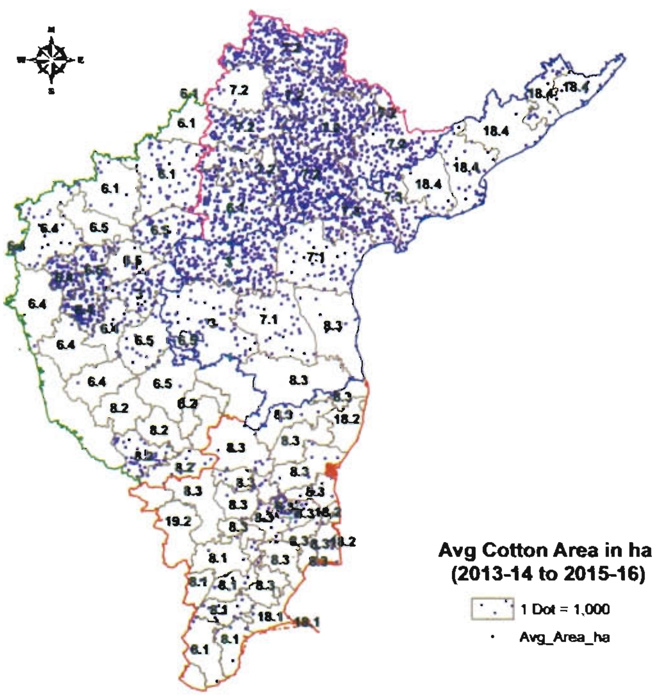


Fig 3.8.1: South Zone Mean Cotton Area (ha) of 2013-14 to 2015-16

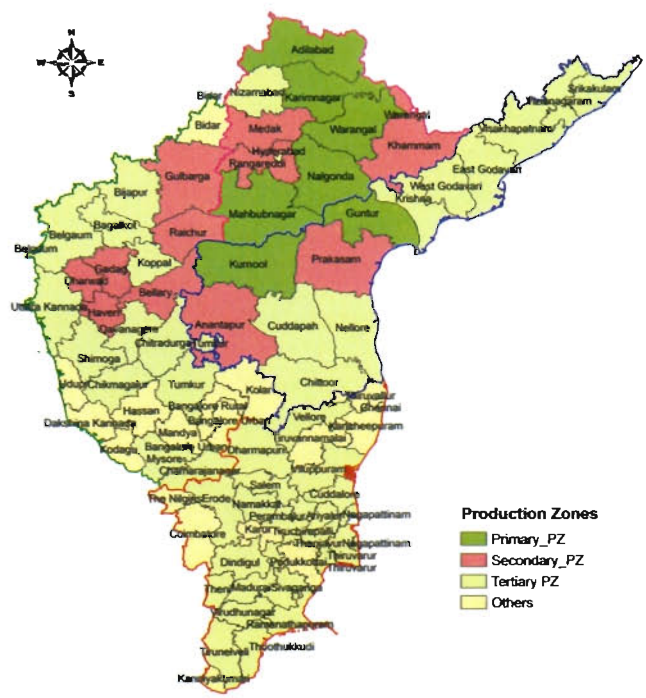


Fig 3.8.2:Cotton Production Zones in South Zone

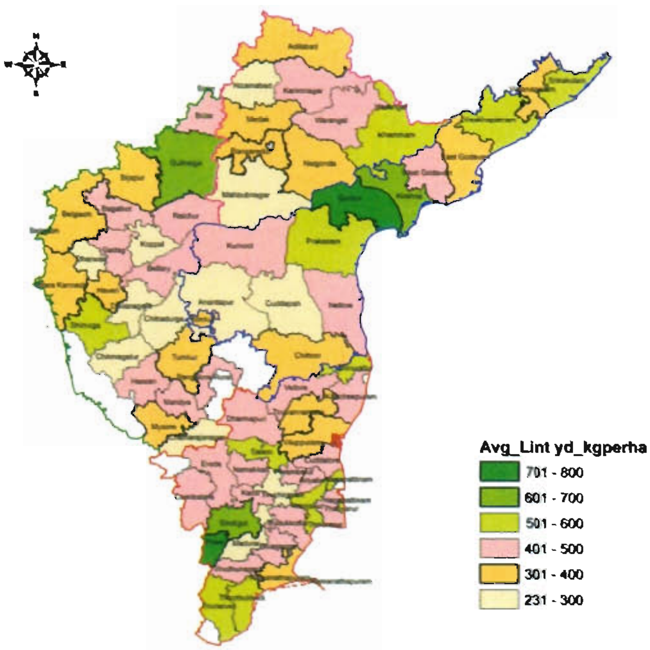


Fig 3.8.3: District Mean Cotton Lint Yield (Kg/ha) of 2013-14 to 2015-16 of South Zone

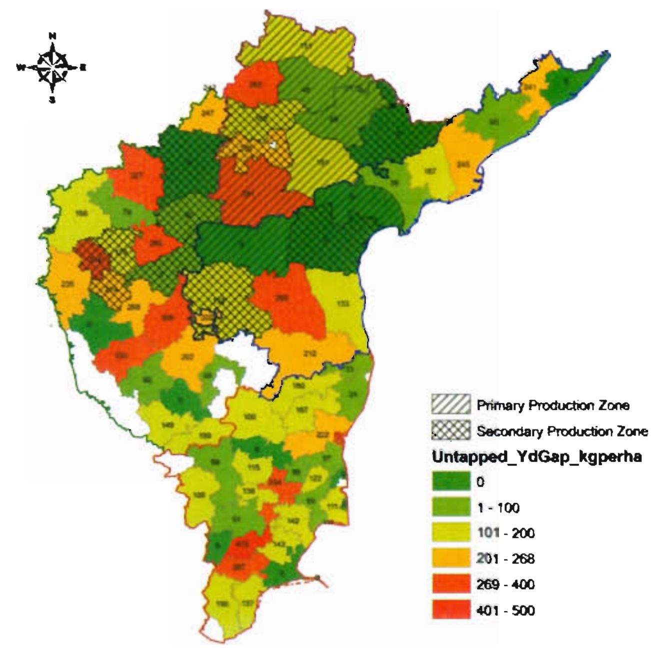


Fig 3.8.4: Untapped Yield Potential (Kglint /ha) of different Production Zones in South Zone

3.8.5: Socio-technological analysis of drip irrigation in cotton cultivation

Field survey was conducted in two districts of Maharashtra states Viz., Jalgaon and Jalna. Major research observations made about drip irrigation from the districts are; a) extending cotton crop beyond the season is a common feature in the two districts. The reasons for extending the crop as reported by farmers are; (i) if the main cotton crop does not gives good yield they extend the crop to get some additional yield, (ii) since water is not available for a second crop they are extending the period of cotton crop, (iii) additional yield during the extended period gives additional profit for them. Regarding the second crop; where ever the water availability is more farmers go for any one short duration crop followed by cotton. Majority of the farmers are cultivating cotton with a spacing of 5x3 / 5x2 / 4x3, average number of drippers for one acre is 6000-7000 and the general discharge level of drip irrigation system differing from 2 LPH to 12 LPH, It was observed that extension of the crop beyond the season and late sowing, led to increased pink bollworm infestation in majority of the farmers' field. Majority of the farmers prefer cotton cultivation because, cotton is the only crop that gives some yield even under drought condition other crops are very sensitive to drought. Average yield in the study area as reported by the farmers under rainfed condition is 3-4 q/ac and that under drip irrigation is 8-9 q/ac.

Major constraints reported by the cotton drip farmers beyond the regular constraints like clogging and rat bite are; a) comparatively less subsidy amount from the government, majority of the farmers going bank loan for drip installation and the banks are providing the loans under term loan basis for five years, b) Whether they irrigate or not, once farmers get EB connection they have to pay Rs. 5000 per year as electricity cost to the government, c) the farmers received electricity only for 8 hours per day and the time schedule also change each week. Therefore, farmers have to go for irrigation even during the night time based on the electricity availability.

Further, the data analysis of socio technological status of Tamil Nadu state revealed that majority of the small and marginal farmers are adopting drip irrigation for cotton cultivation. The reason may be that the subsidy amount for small and marginal farmers is comparatively more. Majority of old age category farmers (55%) are adopting drip irrigation more when compared to middle (41%) and young (3%) farmers. Majority of the farmers 62.5% had 2 to 8 years experience in drip irrigation . The impact analysis indicated significant impact of drip irrigation on yield efficiency, income efficiency, water use efficiency, labour use efficiency and input use efficiency. The constraint analysis revealed that majority (91%) of the farmers reported that clogging of emitters is the foremost problem in drip irrigation followed by rat biting (72%) and high investment despite subsidy (68%).

Field survey in Maharashtra

Field survey in Jalgon district of Maharashtra state

Field survey in Jalna district of Maharashtra state

3.9: New eco-compatible pest management strategies

3.9.1: Bollworms

Push-Pull strategy for management of pink bollworm Pectinophora gossypiella Saunders

The 'push-pull' approach is an ecological based novel pest management tool that utilizes attractant and repellent (deterrent) components in combination. Fatty acids and their methyl esters identified in the previous year were quantified using 99.99% purity standards and evaluated for oviposition deterrent effect. Upon quantification oleic, linoleic and palmitic acid were identified as major compounds from the faecal pellet extract