Theme 8: Enhancing the productivity, diversity and sustainability of cotton-based production systems through efficient resource management

8.1Project Name: Alleviating soil compaction – a production constraint in cotton

D. Blaise (PI); Co-PIs- Dr.A. Manikandan, Er. G. Majumdar and Dr. Savitha Santosh

Importance of the study: Soil compaction is one of the factors that leads to land degradation. A better understanding of the causes and effects of soil compaction in cotton-based systems, will lead to strategies and management practices to alleviate compaction.

Salient findings

Field trials were conducted to study the effect of sub-soiling and crop rotation todevise a suitable plan for ameliorating soil compaction. Deep rooted crops such as pigeonpea, 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 brought down the fuel consumption by approx. 50%. Seed cotton yields were the highest in the rotation plots, except the radish that had the least seed cotton yield.

Sub-soiling with tractor drawn sub-soiler to manage soil compaction in vertisols

8.2Project Name: Integrated farming system to double income of cotton farmer

Dr. Ramkrushna G.I (PI); Dr. RachnaPande, Dr. A. Manikandan, Dr. U.V. Galkate

Importance of the study: Single or sole crop systems are risk prone. Diversification of cropping systems is needed to better utilize natural resources and improve farm income of small farmers.

Salient findings

Out of one-hectare Integrated farming system (IFS)model, pigeon pea was intercropped in cotton (2:6 ratio) in one-acre area, in which, seed cotton yield was 823 kg and pigeon pea was 152 kg. In another one-acre area, soybean was grown in *kharif*, followed by chickpea + mustard in *rabi*. During the *kharif*, 864 kg

soybean was harvested, while, in *rabi* 1060 kg chickpea and 75 kg mustard were harvested. A goat (Usmanabadi) unit was established at KVK farm, and a net return of₹15,812 wasrealized from the goat unit with the generation of 120man-days. A poultry (Giriraja) unit (100 birds in two batches) was established atthe farmer field, which gave a net profit of ₹65,614. Fruit and vegetables (custard apple, papaya, french bean, okra, tomato, cucurbits, etc.) is taken as a horticulture component in IFS, yielded a net profit of ₹29,134 in a year. Overall, the IFS model produced 70.2 q/ha cotton equivalent yield with B:C ratio of 1.95. During the year (2019-20), 3020 kg feed, 1590 kg fodder, and 2.50 t manure were produced in the system and were used as input for different enterprises. Water harvested in 20 x20 m^2 pond was used for life-saving irrigation in *rabi* and vegetable crops. Overall, one-hectare IFS could generate 492 man-days during the one-year cropping season.

Components of IFS

8.3 Project Name: Efficient nitrogen fixing legumes for cotton based cropping systems

Dr. A. Manikandan(PI); Co-PIs- Dr. D. Blaise, Dr. P. Nalayini, Dr. VS. Nagrare

Importance of the study:
Legumes fix atmospheric nitrogen,and intercropping of legumes with cotton will help in rural livelihood and food security. The prime objective of our study was to evaluate the best legume-intercropping system for rainfed and irrigated cotton.

Salient findings
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 nitrogen content (kg ha^{-1}) compared with the sole cotton (Table 8.3.1). The higher soil nitrogen is attributed to the nitrogen fixation by legumes intercropped. Under irrigated conditions (Coimbatore), *Desmanthusvirgatus*was found to be the most suitable perennial legume for alley cropping under cotton – maize system.

Table 8.3.1:Soil nitrogen contentin the legume and cotton rows under rainfed conditions

Intercrop	Cotton row	Legume row
Black gram	118.3	287.0
Cluster bean	121.0	294.3
Green gram	126.7	275.7

Cowpea	129.7	275.7
Groundnut	125.7	282.3
Soybean	129.7	277.3
Cotton	125.0	

8.4Project Name: Studies on sorption of sulphur formulations and commercial nitro phosphate fertilizers to different soils

Dr. A.Manikandan (PI); Co-PI- Dr. D. Blaise

Importance of the study: Sulphur (S) is the fourth major nutrient for cotton, and specifically S is involved in cotton seed quality. To understand the role of slow release S bentonite formulations (Bensulf, FRT-Bensulf and micronized sulphur),we examined the S mobility and sorption in five soil types of cotton-growing areas (Bhandara, Ludhiana, Sindhudurg, Nagpur, and Wardha). We also conducted pot study to determine the effects of four nitrophosphatefertilizers on cotton growth and nutrient uptake with the above-mentioned soils.

Salient findings

Among theS formulations, micronized S had an advantage over the grits of bensulf formulations ((Bensulf, FRT- Bensulf) with regard to maximum S releaseon all the five soils (Fig.8.4.1).In pot culture studies, application of Nitrophosphate as basal dose improved cotton (Mallika BGII), no significant differences were observed between the nitrophosphate treatments. In Bhandarasoils, the boll numbers ranged from 10.5 to 13.6 bolls per plant as compared to 5.8 in the control. For the Nagpur, Ludhiana and Wardha soils, the boll numbers ranged 4.9 to 8.6, 3.1 to 5.6 and 4.3 to 6.3 bolls per plant. The Sindhudurg soil types had the least boll numbers per plant (1.5 to 1.9).

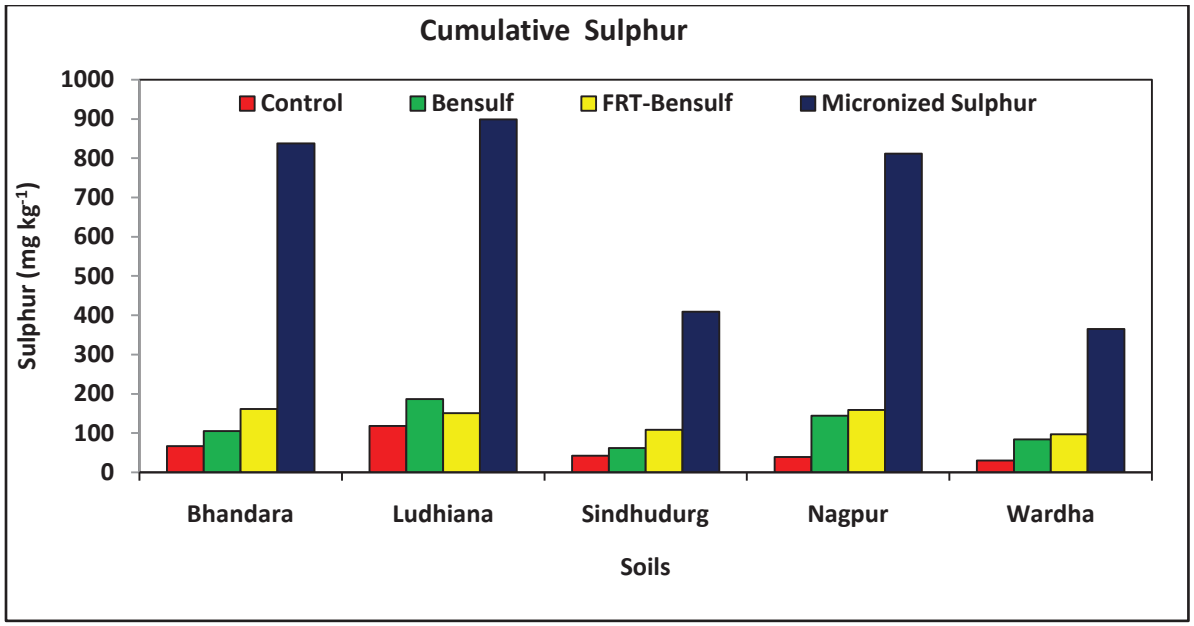


Fig 8.4.1: Sulphur release (mg kg^{-1}) from different Sformulations

8.5Project Name: Evaluation of PGPR and microbial inoculants to alleviate drought stress in cotton (G.hirsutumL.)

Dr. J.H.Meshram (PI); Co-PIs- Dr. S. Gawande, Dr. D. Nagrale, Dr. K. Velmourougane, Dr. P.Verma

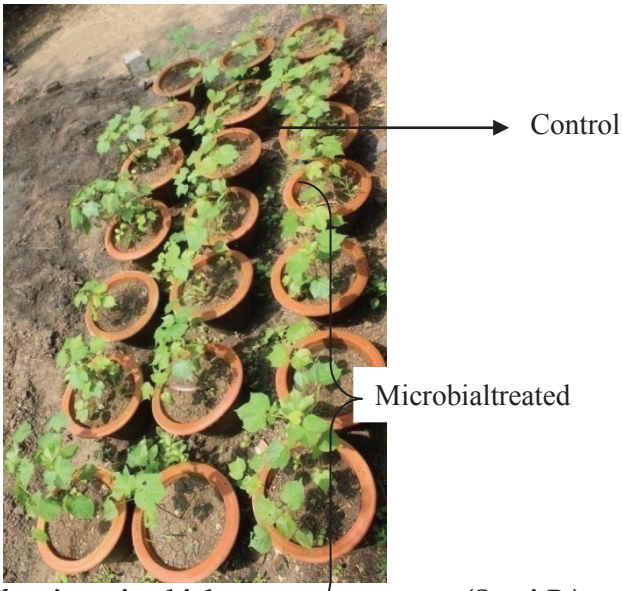
Importance of the study: Microbial inoculants play an important role in imparting drought tolerance in several crop plants. The study investigates the potential of PGPR and microbial inoculants for alleviating drought stress in cotton.The output could provide another sustainable strategy to mitigate the effects of drought in cotton.

Salient findings

A significant difference was observed between the control and identified bacterial isolates in enhancing root and shoot traits in cotton after 45 DAI (days after inoculation). Of the six bacterial isolates evaluated, *Pseudomonas* sp. (5R) showed better shoot and root traits under drought stress conditions.

Table 8.5.1: Morpho-physiological parameters response after inoculated with native microbial strains in *G.hirsutum*

Bacterial Name	Plant Ht (cm)	Root Length cm)	Leaf Temp.(°C)	Leaf Chl SPAD	Shoot FW (g)	Shoot DW (g)	Root FW (g)	Root Dry Wt(g)	Leaf Area (cm²)
Not identified 1	13.6	11.2	29.1	49.6	1.10	0.05	0.18	0.03	13.47
Not identified 2	14.3	9.8	28.8	49.3	0.79	0.04	0.12	0.03	8.82
Not identified 3	15.4	10.3	28.9	35.8	0.79	0.04	0.14	0.02	8.62
Solibacillusisronensis (1R)	15.8	13.1	28.6	40.8	1.28	0.05	0.20	0.04	13.86
Pseudomonas Sp.(5R)	16.0	13.5	29.2	42.1	1.43	0.05	0.26	0.06	18.48
*Sphingomonas*Sp. (6R)	13.9	10.9	29.1	45.7	1.13	0.04	0.22	0.04	12.01
Control	12.3	9.5	29.4	42.4	0.82	0.04	0.16	0.03	8.32
SD	1.34	1.56	0.26	4.92	0.256	0.005	0.050	0.014	3.71
SEM	0.507	0.590	0.10	1.85	0.096	0.001	0.018	0.005	1.40



Effect of native microbial treatment on cotton (Suraj *Bt*) grown in pots

8.6 Project Name: Development of microbial biofilm formulations for cotton: effects on yield, pests, diseases and soil health

Dr. K. Velmourougane (PI); Co-PI - Dr. Savitha Santosh, Dr. Rachana Pande, Dr. Dipak Nagrale

Importance of the study: This project aims to develop multi-species microbial biofilm formulation to enhance cotton root colonization, thereby expected to enhance plant innate immunity against pests and diseases, apart from enhancing plant and soil health attributes.

Salient findings

Based on the three-year insect bioassay, five bacterial isolates for each lepidopteran pest were short-listed for management of Pink bollworm (*Pectinophoragossypiella*), American bollworm (*Helicoverpaarmigera*), Fall army worm (*Spodopterafrugiperda*), and Cotton leaf worm (*Spodopteralitura*). Among the short-listed bacterial isolates *Pantoeaagglomerans*, *Enterobacter cloacae*, *Enterobacter sp.*, *Enterobacter hormaechei*showed higher PBW ovicidal activity (47%-71%). The short-listed bacteria will be used for development of multi-species biofilm formulations using well-known fungal biocontrol agents such as *Trichoderma*, *Beauveria* and *Metarhizium*.Native bacterial isolates (*Pseudomonas sp., Enterobacter hormaechei, Pseudomonas putida, Sinomonas sp., Delftiaacidovorans, Enterobacter ludwigii*) were also short-listed for their biocontrol potential against the major cotton pathogens (*Fusarium, Alternaria, Macrophomina, Myrothecium, Corynespora and Xanthomonas*). The field trail with short-listed bacterial isolates as seed treatment option in Bt-cotton showed increased plant growth attributes (plant height, sympodial branches, SPAD values, LAI, boll numbers, yield and fibre quality) compared to the control.

Table 8.6.1: Effect of native bacterial isolates on major lepidopteron pests of cotton

Pink bollworm (*Pectinophoragossypiella*)		American bollworm (*Helicoverpaarmigera*)		Fall army worm (*Spodopterafrugiperda*)		Cotton leaf worm (*Spodopteralitura*)	
Bacterium	% Mortality	Bacterium	% Mortality	Bacterium	% Mortality	Bacterium	% Mortality
Pantoeaagglomerans	94	*Enterobacter ludwigii*	85	*Enterobacter hormaechei*	91	*Enterobacter hormaechei*	76
Providencia rettgeri	89	*Bacillus subtilis*	80	*Enterobacter hormaechei*	86	*Enterobacter aerogenes*	76
Enterobacter sp.	89	*Providencia rettgeri*	75	*Clostridium sporogenes*	81	*Eubacteriumuniforme*	62
Enterobacter cloacae	83	*Aeromonas hydrophila*	75	*Aeromonas caviae*	81	*Enterobacter hormaechei*	62
Enterobacter sp.	83	*Enterobacter sp.*	75	*Aeromonas finlandiensis*	81	*Providencia rettgeri*	58

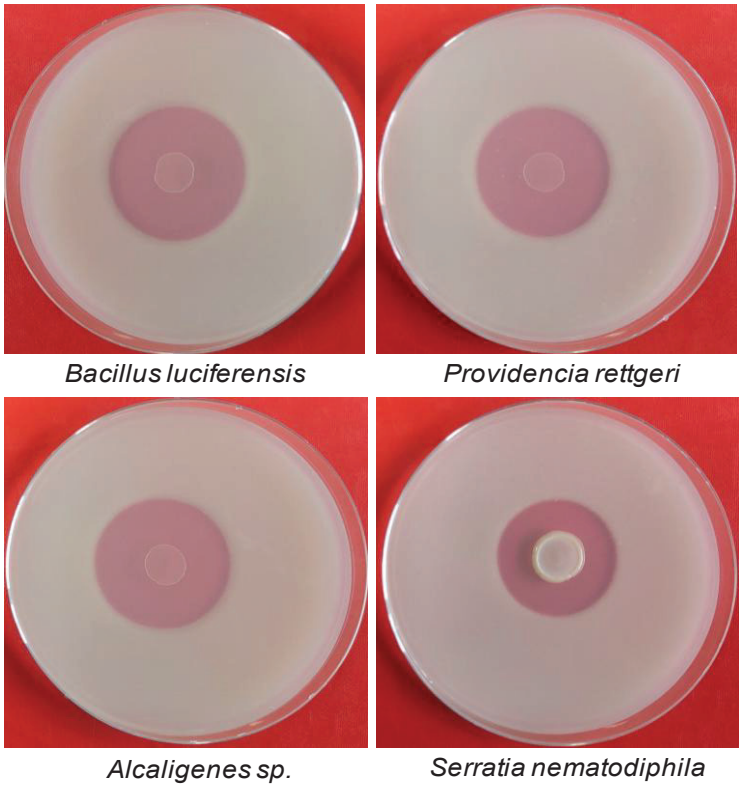
8.7Project Name: Microbial dissolution of carbonate to ameliorate soil sodicity in Black Soil Regions of Maharashtra

Dr. K. Velmourougane (PI); Co-PI - Dr. A. Manikandan, Dr. D. Vasu (NBSS & LUP)

Importance of the study: Pedogenic formation of calcium carbonate ($CaCO_3$) induces soil sodicity, which affects soil properties (drainage, infiltration rate, nutrient availability) and crop productivity. Hence, there is an urgent need for the reclamation of calcareous soils, as it affects soil physical and chemical properties. Though plenty of literature is available on microbial formation of $CaCO_3$, few studies reported microbial weathering of $CaCO_3$. This study aimed to isolate calcium-dissolving bacteria, and to develop consortia of calcium dissolving bacteria for dissolution of pedogenic $CaCO_3$ in soils throughexogenous application.

Salient findings

Two hundred isolates were tested for $CaCO_3$ dissolution potential using DB (Devenze-Bruni) medium @ 0.5, 1.0 & 1.5% pure $CaCO_3$for 5, 10, 20 days. The bacterial isolates were short-listed based on the following parameters: growth rate (OD_{600}), $CaCO_3$ solubilisation index, pH, carbohydrate and protein content (µg/ml), extra cellular polysaccharide production (µg/L), water-soluble calcium (mg/kg), exchangeable calcium (mg/kg), CO_3 bound calcium (mg/kg). Based on the above attributes, eight $CaCO_3$ solubilizing bacteria (CSB) has been short-listed and taken forward for further studies



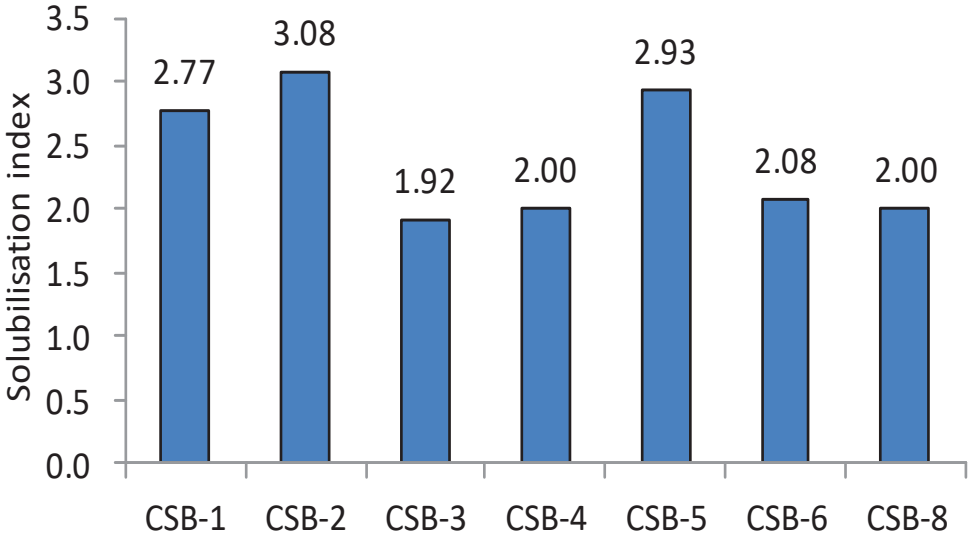


Fig. 8.7.1: $CaCO_3$ solubilisation potential of native bacterial isolates

8.8Project Name: Bioprospecting microbial volatiles for plant growth promotion and sucking pest (Whitefly and Jassids) management in Bt cotton (SERB-DST Project)

Dr. K. Velmourougane (PI)

Importance of the study: Among the sucking pests, whitefly (*Bemisiatabaci*) and green leafhopper (jassids) (*Amrascabiguttulabiguttula*) are deadly and spread throughout the growing season, causing significant yield loss in *Bt* cotton. Microbial volatile organic compounds (mVOCs) are semiochemicals that can attract or repel insects, stimulate oviposition, mimic plant hormones, and induce plant resistance. The aim of this project was to develop ecofriendly and cost-effective microbial volatile formulation for field application to enhance plant growth promotion and management of whiteflies and jassids in *Bt* cotton

Salient findings

Bacterial strains have been screened for their effectiveness in attracting or repelling the whiteflies and jassids, through the production of microbial volatiles (mVOC). Different solvents (Dichloromethane (DCM), Diethyl ether (DE), Ethyl acetate (EA) and Hexane (Hx) were tested for their mVOC extraction efficiency singly and combinations. From the analysis, we found DCM and DE to extract more mVOC (Fig. 8.8.1). In the first batch of experimentation, we tested 25 microbial cultures under field conditions for trap catch of whiteflies and jassids using yellow sticky trap swabbed with 48 h broth grown bacterial cultures (10^8 cells/ml). From the field data, we short-listed top ten potential isolates for further testing (Table 8.8.1). The top ten microbial isolates, which proved better trap catch of whiteflies and jassids under field conditions have been identified through 16S rRNA sequencing

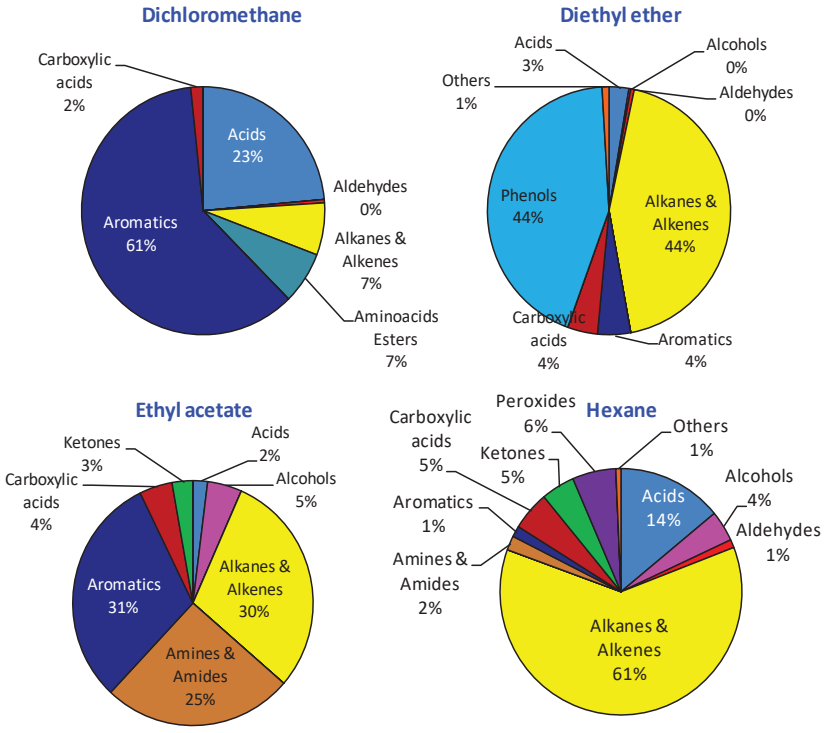


Fig. 8.8.1: Efficiency of solvents in microbial volatiles extraction

Table 8.8.1: Field trap catch data of whiteflies and jassids

	Whiteflies		Jassids	
Bacterium	Total catch	% increase	Total catch	% increase
Clostridium sporogenes	508	125.7	72	60.0
Enterobacter aerogenes	374	66.2	59	31.1
Eubacteriumuniforme	352	56.4	80	77.7
Aeromonas caviae	352	56.4	83	84.4
Aeromonas finlandiensis	350	55.5	101	124.
Enterobacter hormaechei	331	47.1	72	60.0
Providencia rettgeri	325	44.4	65	44.4
Providencia rettgeri	301	33.7	89	97.7
Enterobacter hormaechei	290	28.8	51	13.3
Control	225		45	

8.9Project Name: Microbial interventions for potassium nutrition in cotton

Dr. SavithaSantosh (PI); Co-PIs-Dr. Ramkrushna, G.I, Dr. A. Manikandan

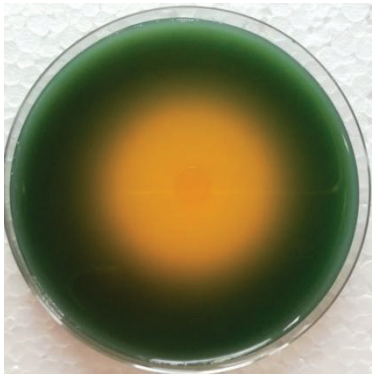
Importance of the study: Though Indian soils have medium to high levels of potassium (K), most of the K stocks are reported to be in plant unavailable form. Exogenous application of K solubilizing microorganisms (KSM) was shown to enhance K availability in several crop plants. However, such studies are scarce in cotton. In this study, our aim was to identify efficient KSMs for solubilization of soil-bound K in cotton-grown soils.

Salient findings

The K solubilization index of selected KSMs on Alexandow media supplemented with bromothymol blue ranged from 1.3 to 4.0. The KSMs are also found to produce plant growth-promoting hormone, Indole-3 acetic acid (IAA) ranging from 10 to 18.7 µg/ml/24h. These isolates were further studied for their efficiency of potassium solubilization under pot culture and field conditions.

Table 8.9.1: K solubilisation index of on Alexandrow media+ BTB

Isolate Code	Zone of Solubilization (mm)	Colony size (mm)	Solubilization Index
KSM1	03^{e}	10^{c}	1.30^{e}
KSM2	07^{d}	12^{a}	1.58^{d}
KSM3	10^{c}	10^{c}	2.00^{c}
KSM4	03^{e}	10^{c}	1.30^{e}
KSM5	17^{b}	11^{b}	2.54^{b}
KSM6	30^{a}	10^{c}	4.00^{a}
CD (0.05)	0.4	0.2	0.05



K solubilization by KSM 6 isolate

8.10Project Name: Metabolite Exploration of Drought stress in Cotton

Dr. PoojaVerma (PI); Co-PI - Dr. Ramkrushna G I

Importance of the study: Droughtis the major abiotic stress, which affects cotton productivity. Recently, a calcium oxalate (CaOx) crystal has been explored for its functional role in supplying carbon (CO_2) for photosynthesis under drought stress conditions. Based on it, a hypothesis is put forward that CaOx could be used as a biochemical pump to collect C from the organ interior under drought stress conditions in cotton as well. Alternatively, metabolic changes under drought stress conditions in cotton will more clarify the mechanism to support the above as well as to identify the new metabolic indicator of drought in cotton.

Salient findings

Fifty-one cotton genotypes were screened for *in-gel*OxO activity under control and drought conditions. Band intensity of oxalate oxidase showed more expression in cotton under drought stress compared to their respective controls. 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).

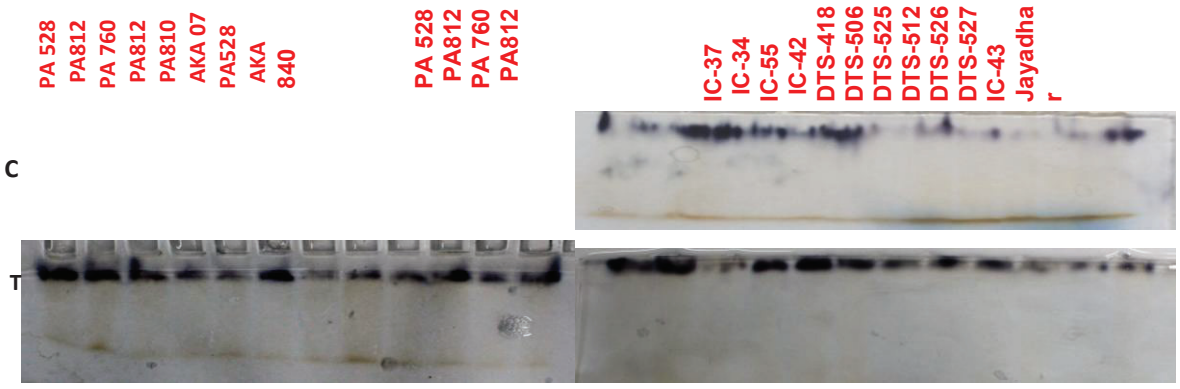


Fig. 8.10.1: Screening of cotton germplasm lines/genotypes for oxalate oxidase (*In-gel*) (C: Control; T: drought stress)

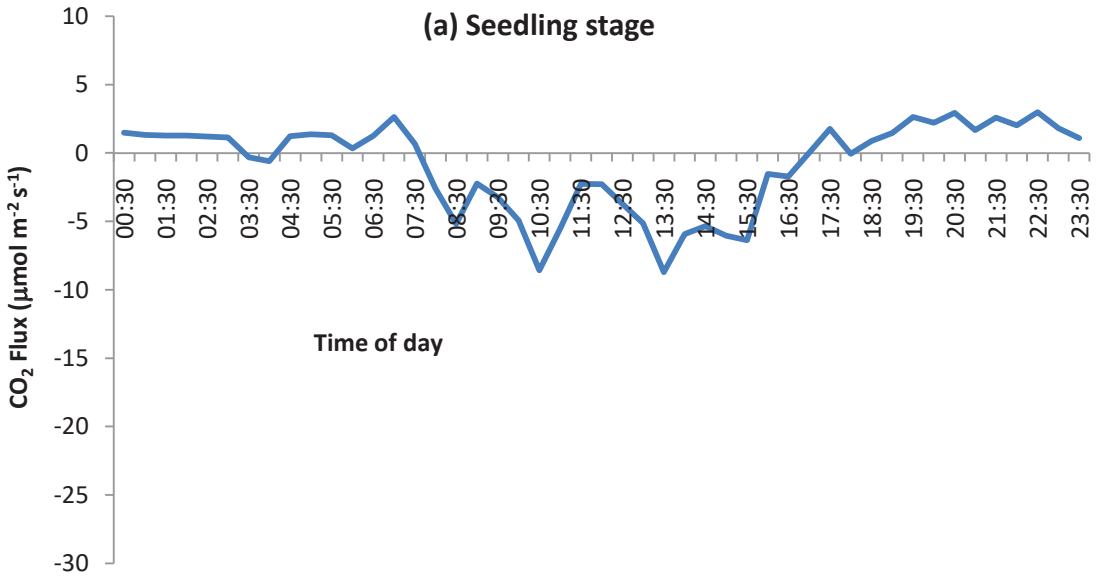
8.11Project Name: Quantitative estimation of carbon and moisture fluxes over the cotton based agro-ecosystem: Integrating ground observations, satellite data and modeling

Dr. MV.Venugopalan (PI); Co-PI -Dr. A Manikandan

Importance of the study: The project aims at a quantitative assessment of carbon/moisture fluxes and energy balance components over the cotton-based agroecosystems. The understanding and quantification of the spatial and temporal dynamics of the carbon, moisture and energy fluxes and stocks would help in modeling the net carbon sequestration at regional level. The outputs would be helpful for making policy decisions on environmental issues.

Salient findings

The diurnal Net Ecosystem CO_2 Exchange (NEE, µmol m^{-2} s^{-1}) at different crop stages is shown in Fig8.11.1 (a to c). Cotton crop behaved as a net C source during night time due to respiration. Whereas, it acted as a net carbon sink during day time as photosynthesis prevails over respiration.The night 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 during µmol m^{-2} s^{-1} September-November during flowering and peak boll development stage.The total carbon sink decreased afterward as the senescence of cotton crop started from December to January. The peak NEE on 1 Jan was found to be -5 µmol m^{-2} s^{-1} during the day time.



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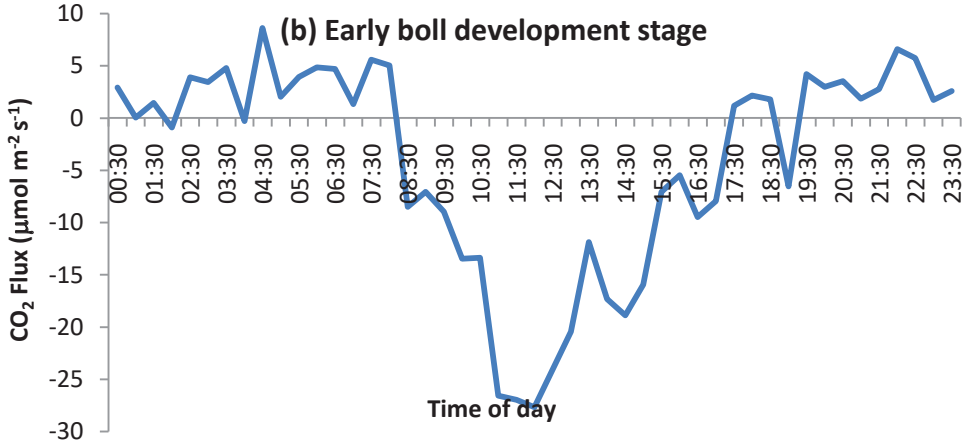

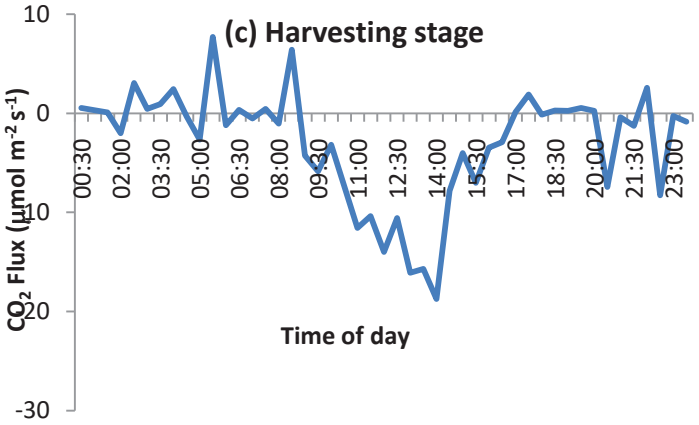

Fig. 8.11.1: Diurnal Net Ecosystem CO_2 Exchange (NEE, µmol m^{-2} s^{-1}) at different crop stages

8.12Project Name: On-station assessment of water footprint of cotton

Dr. Bhargavi. B (PI); Co-PIs -Dr. Blaise Desouza, Dr. P. Nalayini, Dr. K. Velmourougane

Importance of the study: Water footprint (WF) represents the extent of water consumption by the crop (green and blue water), and the amount of water required to dilute the ground water pollutants (grey water). Estimation of water footprint helps inthe optimization of limited available water resources. As cotton is primarily grown as rainfed crop, the estimation of water footprint helps in sustainable water management in cotton cultivation.

Salient findings

On-station experiment was conducted to estimate the water footprint of cotton production under three water management practices (Rainfed, Furrow irrigated, and Drip irrigated) at Nagpur and Coimbatore (Under ridge and furrow system). Cotton yield (t ha^{-1}) and crop evapotranspiration (mm) for rainfed and irrigated cotton were used to calculate the green and blue WF. The grey WF was estimated considering the effect of N fertilizer only. The total WF of rainfed cotton was 16384 m^3/t of seed cotton (Fig 8.12.1), 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 higher WF 26541 m^3/t.Among the various agro-techniques evaluated to reduce water foot print, broad bed and furrow system with polymulch intercropped with green gram yielded higher SCY (3288 kg ha^{-1}) with less water requirement. While, ridges and furrows system yielded lesser SCY (1801 kg ha^{-1}).

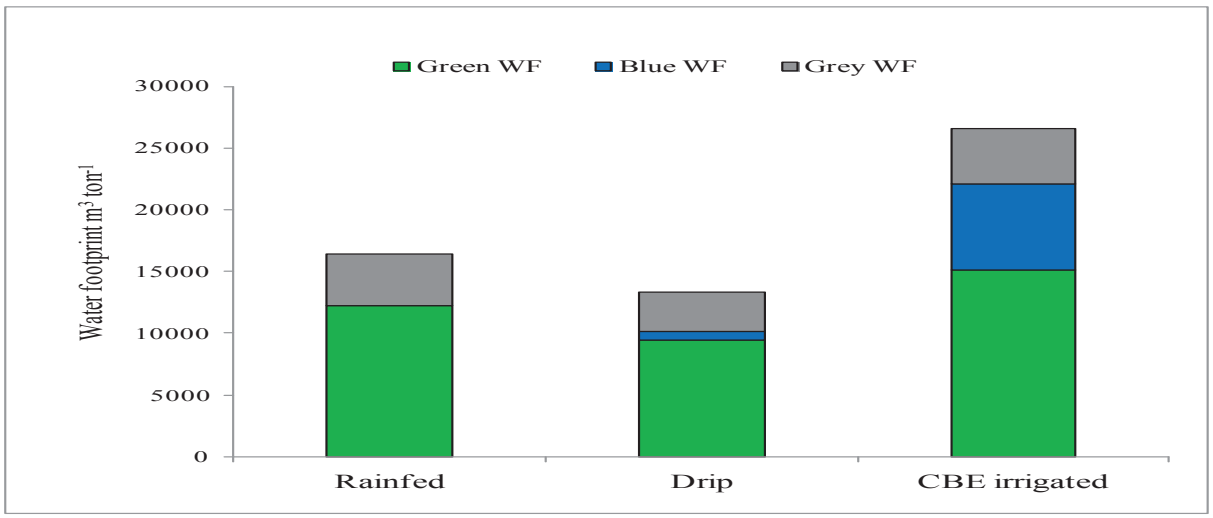

Fig. 8.12.1 Water footprint under different water management practices

BBF cotton intercropped with green gram

8.13 Project Name: Exploring the productivity potential of long-linted G. arboreum cotton

Dr. MV Venugopalan (PI); Co-PIs- Dr.K Sankaranarayanan, Dr. Jayant Meshram, Dr. GI Ramkrushna, Dr. PoojaVerma, Dr. SS Mahajan, Mr. TN Madhu, Dr. Neelakanth Hiremani, Dr. M Sabesh

Importance of the study: The project provides location-specific long lintedarboreums tailored with an agronomic package to maximize their productivity of cotton despite the uncertainties posed by climate change and rainfall aberrations.

Salient findings

Field experiments were conducted at Nagpur for 3 years 2017-18 through 2019-20 on two soils-a medium deep VerticInceptisol and a deep Vertisol. 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- PhuleDhanwantary 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)). The study indicated that, genotypes CNA 1041 and PA 528 were the highest yielders, followed by PA 812 and PA 760. The fibre quality of PA 812 and PA 760 were significantly superior to the rest (Table 8.13.1).

Table 8.13.1: Fibre quality attributes of *G. arboreum* genotypes

Genotype	UHML(mm)	UI (%)	MIC (µg/inch)	BS (g/tex)	El (%)
DLSA-17	27.3	81.1	4.89	28.3	5.9
PA-528	27.0	81.0	5.21	28.5	5.9
PA-402	25.3	79.8	5.18	27.9	6.1
PA-812	29.1	82.3	4.75	30.8	5.8
PA-760	28.9	82.7	4.66	30.2	5.86
CNA - 1041	24.8	79.3	5.6	28.6	6.2
PhuleDhanwantari	16.9	69.6	6.8	22.1	6.8

Salient findings

- The mean seed cotton yield gain due to HDPS was 228 kg/ha. However, there was a wide variation among genotypes ranging from 85 kg/ha in PA 402 to 352 kg/ha in PhuleDhanwantary
- The mean loss in yield due to a delay in sowing 411 kg/ha. However, the loss ranged from 67 kg/ha in P Dhanwantary to 570 kg/ha in PA 528.
- The VerticInceptisol was more productive than Vertisols for arboreum. The mean yield advantage was 330 kg/ha.
- DLSA 17 and PA 812 had a lower incidence of Grey mildew
- Stage-specific transcriptome analyses during fibre growth identified many genes preferentially expressed at fiber initiation, early and later elongation stages. *ACS* and *ACO* genes of ethylene biosynthesis pathways regulate ethylene release and its downstream signaling pathways. Ethylene may positively regulate the cotton fiber growth by promoting the fiber elongation, possibly due to acting on genes directly involved in fiber growth or by activating some downstream pathways which control the fibre traits in cotton.
- There was no effect of row orientation on the productivity of *G arboreum* under HDPS either at Coimbatore or at Nagpur.
- At Coimbatore, 4 August sowing realized seed cotton yield of 1346 kg/ha compared to 537 kg/ha with 4 September. P Dhanwanthry, K 12 and DLSA 17 were promising.
- Application of mepiquatchloride twice @ 25 g a.i./ha and de-topping+side shoot removal modified plant architecture, increased seed cotton yield, harvest index and seed quality

8.14 Project Name: Crop-weed interactions under ambient and elevated CO2 conditions

Dr. P. Nalayini (PI), Co-PI- Dr.A.H.Prakash, Dr. M. Amutha

Importance of the study: Anthropogenic increase in CO_2 level is predicted to impact agriculture production and productivity in terms of alteration in weed species and their interactions with crop species. Hence, it is essential to study the crop- weed interactions under elevated CO_2levels and devise

sustainable weed management strategies for changing climate.

Salient findings

Experiments were initiated during winter (August- February) season of 2020-21 cropping season with the following treatments: a) integrated weed management (IWM) under elevated CO_2, b) IWM under ambient conditions, c) Weedy check under elevated CO_2, d) Weedy check under ambient conditions, and e) Weed free treatment under ambient conditions. An elevated CO_2 ambience of 480 ppm was maintained continuously from the true leaf stage of cotton using CO_2 cylinders kept near the OTCs (open-top chambers).

The elevated CO_2 levels enhanced weed and cotton growth. However, there was 108% enhancement in weed dry matter accumulation over its ambient counterpart on 90 days after sowing as compared to 40% enhancement in dry matter accumulation in cotton was during this period.All the cotton growth attributes such as plant height, number of leaves, leaf area, squares,boll numbers, and biochemical parameters (soluble sugars and leaf chlorophyll content) were altered due to elevated CO_2.

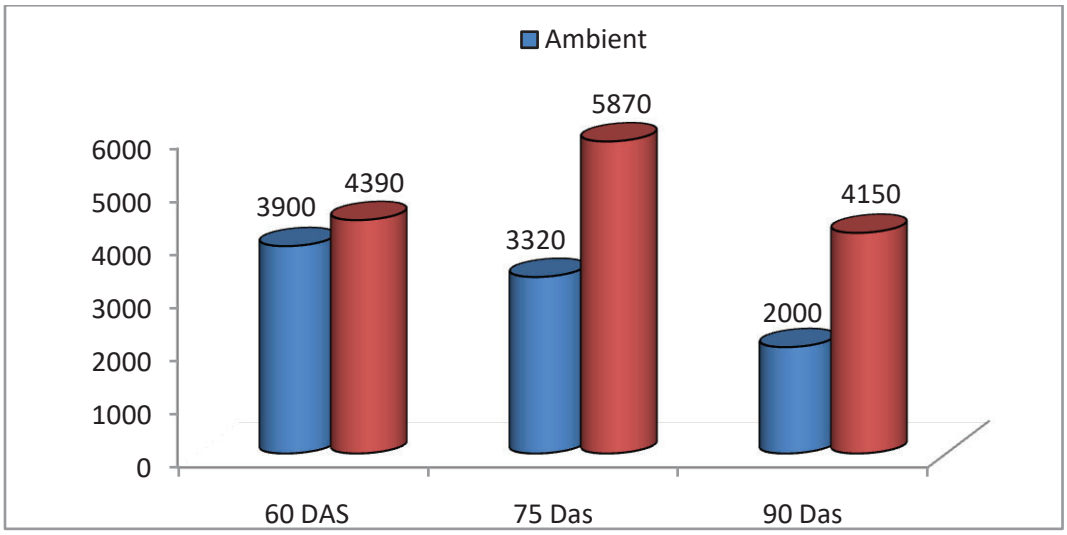

Fig. 8.14.1: Wheat dry matter production (Kg/ha) as influenced by elevated CO_2

Pendimethalin treated Vs. un-weeded under elevated CO_2

Integrated weed management (Suraj Bt) under ambient and elevated CO_2

8.15 Project Name: Evaluating of agrotechniques for overcoming of weather aberration of drought and water logging in cotton

Dr. K. Sankaranarayanan (PI); Co-PI- Dr.Annie Sheeba, Dr.M Amutha, Dr.P. Valarmathi,Dr. J.H.Meshram,Dr. B.Bhargavi

Importance of the study: The erratic distribution of rainfall during cotton growth leads to frequent wet and dry spells. Continuous dry/wet spells during critical crop growth stages such as squaring, flowering and boll development affect the yield and quality of cotton. The project aims to develop contingent measures to mitigate such adversities.

Salient findings

Adoption of soil moisture conservation techniques (ridges and furrows) followed by foliar application of Glycine Betaine @ 100ppm, 5 days after plant drought experience was found to produce significantly higher (29.3%) seed cotton yield (1966 kg/ha), total chlorophyll stability index (77.7%), and nitrate reductase activity (550.8 µ g/g) compared to control (rainfed) at first picking. The adoption of drainage practice (ridges and furrows) followed by foliar application of salicylic acid (0.5mM)3 days after water-logging resulted in significantly higher seed cotton yield (1982 kg/ha), total chlorophyll content (2.3 mg/g), and nitrate reductase activity (650.5 µ g/g) compared to control (water logging) at first picking. Increasing depth of sowing from 2.5 cm to 7.5 cm reduced 15%of the mean germination under control and 10% under water-logged condition (36 hours). Application of FYMduring the seed bed preparation, helpedin increasing the mean germination by 4.5% and 4.7%, for control and water-logging (36 h) conditions, respectively. 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).

8.16 Project Name: Sustainable Intensification of Extra Long Staple Cotton Production in South Zone

Dr.R. Raja (PI); Co-PIs- Dr. Annie Sheeba, Dr. K. Rameash, Dr. K. Rathinavel

Importance of the study: Maintenance of increased plant population per unit area and the judicious use of growth regulators for canopy management are expected to enhance the productivity of Extra Long Staple (ELS) cotton. Field experiment is being conducted at ICAR-CICR Regional Station, Coimbatore from July 2019 onward to study the effect of increased plant population per unit area and use of growth regulators on the productivity of ELS cotton. Two ELS cultivars (V_1: Suvin and V_2: RCHB 625 BGII) were grown under three spacing *viz*., S_1: 90×60 cm, S_2: 90×45 cm and S_3: 90×30 cm. Foliar sprays of growth regulator *viz*., G_1: MC (Mepiquat Chloride) @ 60ppm, G_2: CCC (Chlormequat Chloride) @ 50ppm, G_3: TIBA (2,3,5-triiodobenzoic acid) @ 100ppm and G_4: Water spray were done at 70 and 100 days after sowing based on Height-to-Node Ratio.

Salient findings

The application of growth regulators *viz*., MC and CCC at 70 and 100 DAS significantly reduced plant height in Suvin and RCHB 625 BGII at 125 DAS. Closer planting (S_2 and S_3) of Suvin and RCHB 625 BGII hybrid produced significantly higher number of bolls per unit area compared to normal planting (S_1). 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 kgha^{-1}). Increased plant population and growth regulator application had no significant effecton fibre length, strength and uniformity index.

RCHB 625 BG II at 150 DAS grown under 90 ×30 cm spacing with MC spraying @ 60 ppm at 70 and 100 DAS

8.17 Project Name: Effect of long-term application of organic and inorganic sources of nutrients on continuous cultivation of Bt and non Bt cotton cropping system under irrigated conditions

Dr. D.Kanjana (PI); Co-PIs-Dr. K.Sankaranarayanan, Dr. Amarpreet Singh

Importance of the study: Long-term fertilizer experiments serve as an important tool to understand the changes in soil properties, nutrient dynamics and complex interactions between soil and crops due to continuous cultivation of high yielding crops and continuous application of fertilizers.

Salient findings

Field experiments were conducted in a split plot design during winter of 2018-19 and 2019-20 to study the cotton-maize and cotton-wheat cropping system with organic, inorganic and integrated sources of nutrients. After two years of continuous adoption of

cotton–maize and cotton-wheat cropping system under irrigated conditions, SCYincreased significantly by 26.5% and 134.6%in combined sources of organic (FYM once in two years) and inorganic (NPK + $MgSO_4$ + $ZnSO_4$ + Borax), treatments, respectively,compared to the control. Though, all the growth and yield-related parameters were significantly improved under *Bt* cotton hybrid-maize and *Bt* cotton hybrid-fallow cropping system, the highest SCY was observed under *Bt* cotton variety (HDPS) - maize cropping system. Under cotton-wheat cropping system, higher SCY was recorded in *Bt* cotton hybrid compared to non-*Bt* cotton hybrid, *Bt* and non-*Bt* cotton variety.

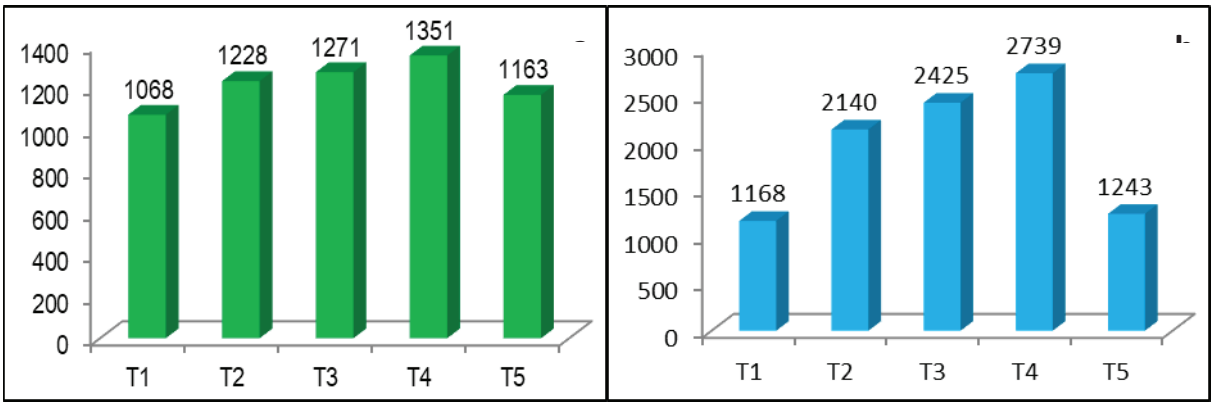

Fig.8.17.1: SCY (kg/ha) under a) cotton-maize and b) cotton-wheat cropping system (Mean of 2 years)

Cotton-maize cropping system (T1 – Control, T2 - NPK (100 %), T3 - NPK +MgSO4+ZnSO4+Borax, T4 - NPK +MgSO4+ZnSO4+Borax + FYM (once in two years), T5 - FYM (every year) + Azophos + Neem cake + Sunnhemp incorporation)

Cotton-wheat cropping system (T1 – Control, T2 - NPK (100 %), T3 - NPK +MgSO4+ZnSO4+Borax, T4 - NPK +MgSO4+ZnSO4+Borax + FYM (once in two years), T5 - FYM (every year)+Azophos+Neem cake+Daincha incorporation)

8.18 Project Name: Exploiting the epigenetic transgenerational inheritance of stress responsive traits for imparting abiotic stress tolerance in cotton

Dr. J. Annie Sheeba (PI)

Importance of the study: If the epigenetic change in response to environmental conditions is inherited, the epigenetic inheritance may allow the plants to continually adjust its gene expression to fit its environment without changing its DNA code. The potential value of epigenetic inheritance is reflected directly by the influence of variations in DNA methylation on important agricultural traits such as flowering time, plant height, drought tolerance and yield. The use of Epigenetic Regulating Chemicals (ERCs) for improving stress tolerance in plants is gaining importance. The following study was devised to explore the possibility of using epigenetic inheritance for imparting abiotic stress tolerance in cotton.

Salient findings

The ERCs treated Suraj and LRA 5166 were subjected to drought stress in the fourth generation and screened for drought tolerance. Sulfamethazine (10 µM) and 5 Azacytidine (10µM) improved the relative water content in Suraj over the control. The

SPAD values were higher in Nicotinamide (35 µM) treated plants (37.8) followed by Sulfamethazine (35) compared to control (23.9) in Suraj. In LRA 5166, Sulfamethazine treated plants recorded higher SPAD value (32.5) followed by Epi gallocatechin gallate (32.0) compared to control (26.2). Nitrate reductase (NR) activity was higher in control (668.9 µg NO_2 /g/h) compared to other treatments, which are followed by 5 Azacytidine 40µM (637.4 µg NO_2 /g/hr). NR activity was higher in 5 Azacytidine 40µM (865.6 µg NO_2 /g/hr) treated plants followed by Epi gallocatechin gallate (739.7) µg NO_2 /g/hr). Proline content is higher in 5 Azacytidine 40 µM treated plants in both Suraj and LRA 5166 over control (Fig.8.18.1). Chlorophyll stability index was positively influenced by the ERCs (Fig.8.18.2).

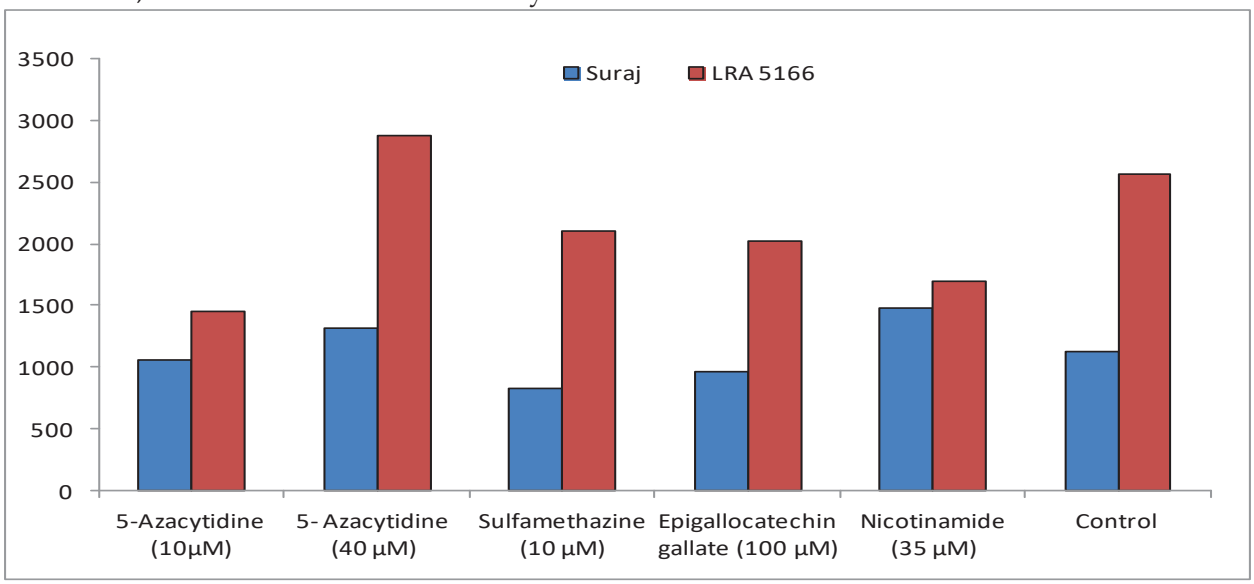

Fig. 8.18.1: ERC on proline content (µg/g fw) under stress conditions

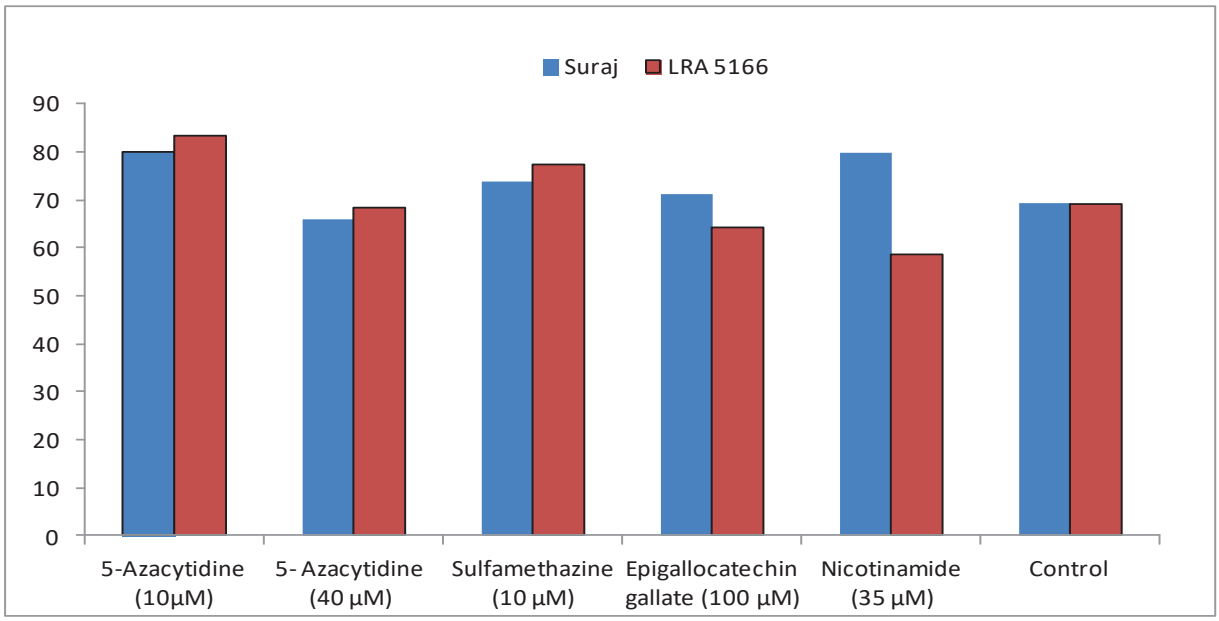

Fig. 8.18.2:ERC on chlorophyll Stability Index (%) under stress conditions

8.19Project Name: Development of cotton based cropping systems under conservation agriculture for North-Western Indian conditions

Dr. Amarpreet Singh (PI); Co-PIs-Dr.S.K. Sain, Dr. Rishi Kumar, Dr. K. Velmourougane

Importance of the study: The factor productivity (nutrient, water, energy) is declining under the irrigated cotton-wheat system due to the degradation of the soil system under conventional agriculture. Adoption of conservation agriculture systems can reverse this degradation process. There is a need to develop a suitable technology for conservation agriculture under cotton based cropping systems.

Salient findings

The seed cotton yieldwas significantly higher under M_6 (Zero tillage - permanent narrow raised bed with residue retention on surface) among all other treatments. The lowest seed cotton yield was obtained under M_1 (Conventional Tillage - Flat Bed without residue incorporation; i.e., farmers practice). However, it was at par with M_3 (Zero Tillage - Flat Bed without residue retention on surface). Among the cropping systems, significantly higher seed cotton yieldwas recorded under (S_3) [Cotton - Chickpea (Bengal gram)] compared to all other cropping systems. The second-best cropping system with respect to the SCYwas (S_2) [Cotton - Mustard (Raya)], which was at par with (S_7) [Cotton - Berseem (Fodder)] and (S_1) Cotton - Wheat cropping system. seed cotton yieldunder (S_1) Cotton - Wheat and (S_4) Cotton -Barley cropping systems were at par with each other. Lowest seed cotton yieldwas obtained under (S_5) [Cotton - Winter Maize (Spring Maize)] cropping systems.

Plate 1a

Plate 1b

Plate 1c

Plate 1a: Field view of Cotton based cropping systems during the cotton season; Plate1b: Mustard crops residue mixed in soil and cotton seedlings; Plate 1c: Berseem residue on soil surface (raised beds) & cotton

8.20 Project Name: Enhancement in productivity of cotton through improvement in agrotechniques under North-Western Indian conditions

Dr. Amarpreet Singh (PI); Dr.Rishi Kumar, Dr. S. K. Sain

Importance of the study: Under this project, three separate experiments were conducted with (a) Bt cotton variety (b) non-Bt cotton variety and (c) Bt cotton hybrid under split-split plot design with four dates of sowing as main plots, three plant spacing as sub-plots and three levels of MC application as sub-sub

plots at ICAR-CICR, Regional Station, Sirsa, Haryana 2020-21 cropping season.

Salient findings

(a). Bt cotton variety (CICR Bt-6) and non-Bt cotton variety (CSH 3075):

- Early sowing of Bt cotton variety (CICR Bt-6) and non-Bt cotton variety (CSH 3075) during [4th week of April] gave significantly higher SCYthan sowing at later dates.
- Spacing of 67.5 cm × 45 cm was superior to closer spacing at 67.5 cm × 10 cm.
- The response to the application of MC was significant.Spraying MC twice (20 g ai/ha) at 60 and 75 DAS was superior to a single spray at the same rate at 60 DAS.
- The interaction between sowing date and spacing was significant indicating when sowing was delayed until the second week of June; closer spacing (67.5 cm × 10 cm) gave higher yield than wider spacing (67.5 cm × 10/30 cm).

(b). Bt cotton hybrid (SP-7172):

- Early sowing of Bt cotton hybrid (SP-7172) during [4th week of April] gave significantly higher seed cotton yield than sowing at a later date.
- The optimum spacing was 67.5 cm × 60 cm.
- Application of Mepiquat chloride at 60 and 75 DAS significantly improved the seed cotton yield.
- The spacing × sowing date effect was significant. When sowing was delayed to the second week of June, planting at closer spacing (67.5 cm ×30 cm) gave higher yields than planting at wider spacing's (67.5 cm × 60 cm or 67.5 cm × 45 cm).