Annual Report
2021-22

Central Cotton Research Institute Multan

Pakistan Central Cotton Committee
Ministry of National Food Security & Research
Government of Pakistan

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ANNUAL REPORT

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PREFACE

The year 2021 remained blissful both for the revival of cotton crop in the country as well as for the CCRI, Multan. The country harvested substantially higher cotton production to the level of 9.374 million bales against 7.064 million bales during last year depicting an increase of 33 percent (Source: CCAC/CRS). This robust recovery in cotton production is attributed to favourable weather (lesser rains, moderate temperatures), availability of good quality seed, generous government support measures including announcement of support price of seed cotton @ Rs. 5000 per maund and provision of subsidies on seed, fertilizer, pesticides, financial credit and farm machinery. All these factors helped in reviving cotton crop. The efforts are now underway for enhancing cotton production to meet domestic industrial demand and export requirements. Similar upward trend was observed in textile exports. With the strenuous government support for textile industry and substantial rise in cotton production, the textile industry achieved remarkable exports to the level of US$ 17.35 billion against US$13.066 billion during 2020-21 showing a 33 percent rise (Source: PBS/NTU).

The Punjab Seed Council in its 55th meeting held on 20.09.2021 approved 15 cotton varieties for commercial cultivation. Out of these, 05 cotton varieties of CCRI Multan, highest ever from any public sector institution, were approved for general cultivation. The varieties included Bt.CIM-663, Bt.CIM-678, Bt.CIM-785, Bt.Cyto-535, and Cyto-226 (Non-Bt). The CIM varieties covered 9 percent area in the cotton zone of Punjab and Sindh provinces during the crop season 2021-22. (Source: CRS Departments of Provincial Governments). Farmers liking for the CIM varieties is substantially rising and it is hoped that CIM varieties will cover >20 percent cotton area in the coming cotton season.

The research work conducted by the Institute has greatly been appreciated across the country by the farming community as well as the cotton stakeholders. In recognition of research contributions, Dr. Zahid Mahmood, Director of the Institute was awarded with the “Quaid-e-Azam Gold Medal Award” on 25th December 2021 by the Istahkam-e-Pakistan Foundation upon his meritorious services in cotton research and development.

Pink bollworm has been a serious pest management issue for the last several years. To address this issue, CCRI Multan organized the first national seminar on pink bollworm management in 2015 and the activity remained continue every year until 2021. In the year 2021, an international seminar was arranged in which foreign researchers were also invited to share their findings to understand the Pink bollworm and its management more holistically. Local scientists, pesticide and seed industry personnel, cotton farmers, extension agents and policy makers participated in the seminar. Dr. Keshav Kranthi from ICAC, USA and Prof. Dr. A.G. Sreenivas from India shared their research findings. An exhibition of input suppliers who also arranged for the interest of participants. The seminar earned heavy attendance and the recommendations were placed before provincial and federal governments for implementation and policy formulation.

The Institute actively remained engaged with international cotton organizations in cotton promotion and development programs throughout the year. The celebrations of World Cotton Day on 7th October, launching of Cotton Innovation Newsletter from the platform of International Cotton Researchers Association (ICRA) Secretariat based at the Institute, and active participation in virtually organizing the 79th Plenary Meeting of the International Cotton Advisory Committee (ICAC) are few of the major activities.

The Institute has fabricated Mechanical Boll Picker called “Pink bollworm Manager” for eradication of leftover bolls that host Pink bollworm larvae during winter. This machine proved to be very effective in eradicating Pink bollworm at CCRI, Multan. Consequently, the demonstrations of the PBW Manager were carried out successfully at various locations including Multan, Bahawalpur, Khan Pur, Sahiwal and Faisalabad during the season. Farmers and Agriculture Extension workers participated in these demonstrations.

The changing climatic conditions (rising temperatures, rains and drought) and rise in the cost of production is greatly affecting the cotton cultivated area and its production. The cotton production and yield improvement is becoming a big challenge under the current scenario. The cost of production is continuously increasing with reduced profitability over time. The Institute has thus introduced a new eco-friendly technology called “Low Expenditure & Environment Friendly (LEEF)” for sustainable cotton production. The LEEF technology uses mulches from crop-based residues placed at the beds after planting cottonseeds. The plant residues applied included straws, husks, grasses, compost, and manures. This technology not only saves seedlings from scorching sunlight, maintains moderate soil temperatures, conserves moisture, prohibits weed emergence, and improves microbial activities. Moreover, the mulches after decaying add up to the soil health in the form of organic matter and nutrients.

The strong backup and firm support from the Ministry of National Food Security & Research in the form of arrangement of finances and approval of cotton development projects is highly appreciated. I am also thankful to Dr. Khalid Abdullah, Cotton Commissioner and Dr. Muhammad Ali Talpur, Economic Consultant for their continuous support for the Institute. I am also thankful to the cotton stakeholders mainly All Pakistan Textile Mills Association (APTMA), Pakistan Cotton Ginners Association (PCGA), Seed Association of Pakistan (SAP), Pakistan Crop Protection Association (PCPA), CropLife Pakistan, and Pakistan Kissan Ittehad (PKI) for their continued support in cotton development programs. I am greatly thankful to the entire scientific, administrative and field staff of the Institute who have worked hard to their utmost despite acute shortage of financial resources.

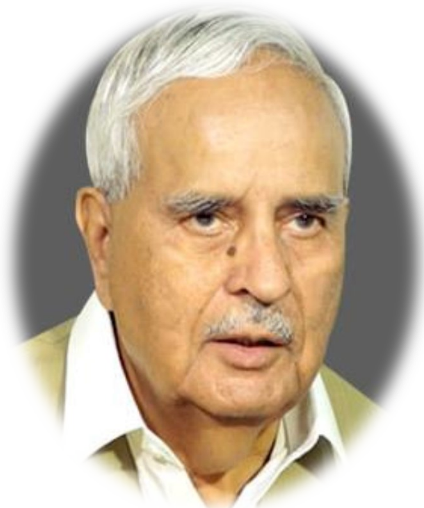
I also wish and pray to Allah for the betterment of cotton in the country, wellbeing of farming community and for all the trading bodies engaged in cotton business in the years to come. May the upcoming years bring happiness and prosperity for us all (Aameen).

Dr. Zahid Mahmood
Director

March, 2022

Dedication

Dr. Zahoor Ahmad (1942-2021)



The CCRI Multan Says Farewell to DR. ZAHOOR AHMAD, *A truly dedicated and legendary cotton scientist*

Dr. Zahoor Ahmad, a leading cotton scientist of Pakistan, suffered from Corona virus and passed away on 21.04.2021. Dr. Ahmad joined CCRI, Multan in 1972 and served the Institute for 30 years. Dr. Ahmad promoted cotton IPM program in Pakistan and contributed many basic and applied research trials to answer pest management issues. His dedicated leadership resulted in development of high yielding cotton varieties, which dominated in the cotton acreage across the country over two decades. He earned remarkable reputation among farmers and the entire cotton fraternity and received numerous awards including the Presidential Pride of Performance Award (1996), Dr. Borlaug Award (1995), FAO Gold Medal (1995), and Chaudhry Muhammad Afzal Award (1996). Dr. Ahmad was also the founding Chairman of the Asian Cotton Research & Development Network of ICAC, established in June/July 1999. Dr. Ahmad as Director, Central Cotton Research Institute, Multan, hosted a Regional Consultation on Insecticide Resistance Management in Cotton. The Consultation resulted in the formation of the Network, one of the strongest among the four Networks supported by the ICAC. The milestones achieved at the Institute under his dynamic leadership will remain a role model for the scientists to come. May Allah bless the departed soul highest place in Heaven (Aameen).

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CENTRAL COTTON RESEARCH INSTITUTE, MULTAN
2021-22

I. EXECUTIVE SUMMARY

i). Introduction

Central Cotton Research Institute (CCRI), Multan, the prime research facility of Pakistan Central Cotton Committee was established in 1970. By the grace of Allah, the Institute has completed 50 years of its establishment in the year 2020. The Institute is equipped with different research disciplines including Agronomy, Plant Breeding & Genetics, Cytogenetics, Entomology, Plant Pathology, Physiology/Chemistry, Fibre Technology, Transfer of Technology and Statistics. The research work has been focused on the following main aspects:

i. Study the cotton plant from botanical, genetical, production, physiological, chemical, entomological, pathological and other relevant facets in a coordinated manner.
ii. Undertake research work of national importance, handle problems of inter-regional nature.
iii. To develop cost-effective cotton production technology.
iv. Advance knowledge on the cotton plant responses to environment with a view to better cope with the adverse impacts in the changing climate scenario.
v. Provide education and training on cotton production technology to the agriculture research, extension, teaching staff and other stakeholders.
vi. Identify problems of cotton growers and advocate remedial measures.
vii. Promote mechanization in cotton production system.
viii. Transfer production technology to the cotton growers.
ix. Educate and motivate cotton growers and monitor research outcomes.
x. Provide technical support to the Pakistan Central Cotton Committee in coordinating and developing a national programme for cotton research and development.
xi. Training manpower across the country and other cotton growing countries on "cotton research and development".
xii. Facilitation and research guidance to students at graduate and higher level degree courses.
xiii. Coordinate with the International Cotton Researchers Association through ICRA Secretariat, Multan.

The Institute has so far developed 36 elite cotton varieties since its inception. Developments have been made in earliness, heat tolerance, drought tolerance, disease resistance and fibre quality traits. CCRI Multan pioneered in developing cotton leaf curl virus (CLCuV) resistant varieties when the country suffered a huge loss in cotton production during 1993-94. In addition to the varietal development, the scientsts of the Institute developed water saving planting techniques, pest scouting models and economic threshold levels (ETLs) for various pests, evaluate nutritional requirement of cotton varieties, and addressing soil health issues. Since its establishment, CCRI Multan has made tremendous progress in cotton R&D in various aspects of cotton crop. Some of which are given below:

- Hosting World Cotton Gene Pool comprising 6143 entries in medium and long term storage facilities, and characterizating them for heat, drought and CLCV tolerance.
- Developed short-duration varieties (210 to 150 Days; CIM-506).
- Developed CLCuV resistant varieties (CIM-1100 & CIM-443), high lint percentage (34% - 45%) and staple length (27.0 – 34.7 mm) varieties.
- Developed 11 Genetics Male Sterile (GMS) lines at Breeding & Genetics.
- Maintained living herbarium of 33 species of Gossypium germplasm.
- Hosting facility for Karyotypic analysis of interspecific hybrids (21 hybrids).
- Established a Biotechnology Lab with limited resources.
- Developed 36 varieties (26 Non Bt. & 10 Bt.)
- Developed production technology for various regions and IPM strategies for different pests.

- Providing Fibre Testing Services at Faser Institute, Germany recognized standards.
- Developed Pink bollworm Manager (Mechanical Boll Picker) for management of Pink bollworm.
- Introduced Low Expenditure & Environment Friendly (LEEF) Technology for cotton.
- Providing Training of farmers, extension workers, academia and industry.

In addition to the above mentioned achievements, the ongoing research work carried out by the scientists of the Institute is summarized below:

- Characterization of germplasm for CLCuV resistance, insect-pest and disease resistance, heat tolerance and fiber quality traits.
- Endeavoring to break photo period sensitivity of 52 accessions identified as CLCuV resistant through screening.
- Development of extra-long staple (ELS) strains through introgression of fiber linked genes.
- Development of Mapping population for fibre quality
- Preliminary lab work in progress for transformation
- Ideotype varietal development for mechanical cotton picking
- Screening of advanced material for heat, drought, duration inputs response, and adaptability
- Development and improvement of natural color cotton varieties

At the international fronts, CCRI Multan has been nominated as “Center of Excellence in Cotton Research and Development” by the Ministry of National Food Security & Research, Government of Pakistan under the China-Pak-Economic Corridor (CPEC)’s Agricultural Development Projects. The Institute, since its establishment, remained associated with various international organizations for cotton research and development programs as mentioned below:

- Asian Development Bank (ADB)
- CERA USA (Biosafety Research in Pakistan Grant Program)
- Common Fund for Commodity (CFC) UK
- Economic Cooperation Organization (ECO)
- Faser Institute (Bremen Fibre Institute), Germany
- Food & Agriculture Organization (FAO) of the United Nations
- International Cotton Advisory Committee (ICAC) USA
- International Cotton Researchers Association (ICRA)
- Japan International Cooperation Agency (JICA)
- Natural Resources Institute UK
- Organization of the Islamic Conference (OIC)
- South Asian Association for Regional Cooperation (SAARC)
- United Nations Development Program (UNDP)
- University of Hubei, China
- USDA (USAID PL-480, Pak-US ICARDA Cotton Project)
- Fellowships & Trainings
    - Borlaug Fellowships
    - Chinese Government Trainings
    - Islamic Development Bank Fellowship

ii) Staff Position

A total of 108 staff members including 30 officers and 78 other staff members remained at the Institute during the period under report. The position of technical staff during the year 2020-21 is given in **Annexure-I**.

iii) Budget

The sanctioned budget from the year 2018-19 to 2021-22 is given below: (Rs. Million)

Sr. #	Detail	2018-19	2019-20	2020-21	2021-22
1.	Pay & Allowances	66.15	73.79	72.71	79.11
2.	Medical	0.206	0.50	0.50	0.50
3.	Traveling Allowance	1.529	2.20	1.50	1.50
4.	Group Insurance	0.674	0.599	0.57	0.51
5.	Utility Bills*	11.89	11.81	1.360	13.85
6.	Contingencies	26.56	42.97	33.59	21.78
	Total	**107.017**	**131.87**	**110.24**	**117.24**

* Include Electricity, Gas, WASA, Phone, Internet, and electricity charges for new building

iv) Income

The income of the Institute from the year 2018-19 to 2021-22 is given below: (Rs. Million)

Sr. #	Head	2018-19	2019-20	2020-21	2021-22
1.	Farm Produce	6.838	3.378	1.190	3.081
2.	Non-Farm Produce	1.275	1.328	1.380	0.842
	Total	**8.133**	**4.706**	**2.570**	**4.923**

* Period from 1st July to 28th February

II RESEARCH ACTIVITIES

i) Research Experiments

The research experiments conducted during 2021-22 along with estimated cost for each experiment, carried out by various sections are as follows:

AGRONOMY

Sr. No.	Proposed Title of Study/Experiment/project	Cost (Rs. Per Acre)
1	Effect of time of sowing on productivity of advanced genotypes	67,240
2	Yield response to crop residue management and tillage system in cotton-wheat cropping system	60,150
3	Effect of planting and picking time on cotton seed quality	10,000
4	Effect of time of sowing on productivity of transgenic genotypes	67,240
5	Agro-economic feasibility for cotton-based intercropping systems	35,400
6	Evaluation of the impact of mulching strategies on weed control and seed cotton yield	35,000
7	Synchronizing nitrogen application with crop growth	65,250
8	High density planting system (HDPS): Effect on yield and fiber quality	65,300
9	Weed diversity survey in cotton growing areas of the Punjab	150,000
10	Screening of pre- and post -emergence weedicides in cotton	52,550

PLANT BREEDING & GENETICS

Sr. No.	Proposed Title of Study / Experiment	Cost (Rs. Per Acre)
1	VT – 1: Evaluation of long staple Bt. strains against commercial varieties.	34,000
2	VT – 2: Evaluation of medium long staple and high GOT Bt. strains against commercial varieties.	34,000
3	MVT -1-4: Evaluation of newly bulked medium long staple Bt. strains against commercial varieties	100,000
4	SVT-1: Evaluation of commercial Non-Bt. varieties at CCRI Multan	25,000
5	SVT-2: Evaluation of commercial Bt. varieties at CCRI Multan	25,000
6	NCVT-A to B: To test performance of candidate varieties all over Pakistan	80,000
7	PCVT 1 to 2: To test performance of candidate varieties all over Punjab	80,000
8	F_1 Hybrids: To raise F_2 population for selection according to desirable traits	100,000

9	F_{3-5} Generation Block 1-4: To select the segregates for further Filial generation according the desirable traits.	320,000
10	Testing the performance of strains in Bigger Blocks at PSC farm Khanewal	--
11	To produce nucleus seed of approved varieties i.e. CIM-554, CIM-496, *Bt*.CIM-663, *Bt*.CIM-343, *Bt*.CIM-602, *Bt*.CIM-600, *Bt*.CIM-632,	450,000
12	Early generation seed (Bt) To produce pre-basic seed of approved commercial varieties of CCRI Multan	35,000
13	Early generation seed (Non-Bt): To produce pre-basic seed of approved commercial varieties of CCRI Multan	33,000
14	Fresh crosses	100,000
15	Maintenance of genetic stock	180,000
16	Study of Gene Flow/ out crossing	15,000
17	Performance of exotic varieties verses local	20,000
18	ICARDA Cotton Project Material Screening of US germplasm for CLCuV resistance/tolerance.	100,000
19	Study of phenotypic diversity	15,000

CYTOGENETICS

Sr. No.	Proposed Title of Study / Experiment	Cost (Rs. Per Acre)
1	Permanent Herbarium Block	280,000
2	MVT-1	25,000
3	MVT-2	25,000
4	MVT-3	25,000
5	MVT-4	25,000
6	VT-1	30,000
7	VT-2	30,000
8	VT-3	30,000
9	NCVT-Set -1	40,000
10	NCVT-Set-2	40,000
11	EGS	40,000
12	Mapping population for fiber quality	50,000
13	F1-F6	80,000
14	F1-F6	80,000
15	F1-F6	80,000
16	F1-F6	80,000
17	Interspecific Material (Single lines & Bulks)	180,000
18	Cloning and Transformation of Cry2A and DREB2 Genes Construct	300,000

ENTOMOLOGY

Sr. No.	Proposed Title of Study/Experiment	Cost (Rs. Per Acre)
1.	Pink bollworm infestation in green bolls in major cotton growing area	60,500
2.	Assessment of pesticides based on moth catches of PBW in traps	77,000
3.	Management of pink bollworm using attractants and different colored adhesive plastic sheets in relation to its abiotic factors	13,800
4.	Studies on Eco-friendly Management of Pink Bollworm	72,500
5.	Monitoring of population dynamics of different lepidopterous pests	72450
6.	Impact of sowing period on the Dusky cotton bug infestation	58,500
7.	Incidence of arthropods abundance on light and normal green cotton leaves in relation to commercial aspect	58,500
8.	Impact of pesticides on the crop physiology/shape/canopy	68,500
9.	Monitoring of insecticide resistance	68,500
10.	Screening of new and commercially available insecticides	63,500
11.	Efficacy of different insecticides at different infestation levels of Whitefly	80,000
12.	Rearing of cotton insect pests and natural enemies in labs.	206,350

PLANT PHYSIOLOGY / CHEMISTRY SECTION

Sr. No.	Proposed Title of Study/Experiment/project	Cost (Rs. Per Acre)

1.	**Studies on genotype - Environment Interactions**	
1.1	Adaptability of genotypes to high temperature stress	110,000
1.2	Physiological, biochemical and Molecular analysis to examine the effect of seed priming on heat stress tolerance mechanisms in *Gossypium hirsutum*	350,000
1.3	Characterization of cotton germplasm for heat tolerance	80,000
2.	**Soil Health and Plant Nutrition**	
2.1	Long term effects of reduced tillage on soil health and cotton-wheat productivity	50,000
2.2	Does phosphorus application time affect root development and cotton productivity?	105,000
2.3	Improving resource use efficiency and soil health by integrating rice crop in cotton	110,000
2.4	Enhancing nutrient use efficiency (NUE) by synchronizing application rate and methods	110,000
3	**Plant-Water Relationships**	
3.1	Adaptability of genotypes to water stress conditions	85,000
3.2	Exogenous application of bio-chemicals to improve drought tolerance in cotton	120,000
3.3	Seed coating with PGPR's to ameliorate drought stress and enhancing nutrient use efficiency in cotton	95,000
4.	**Seed Physiology**	
4.1	Effect of seed priming on heat tolerant and susceptible genotypes at different sowing time in improving the cottonseed health and quality	50,000

TRANSFER OF TECHNOLOGY

Sr. No.	Proposed Title of Study/Experiment	Cost (Rs. Per Acre)
1.	Integrated Multi-Media Publicity Campaign	--
2.	TeleCotton SMS Service	2,000,000

FIBRE TECHNOLOGY

Sr. No.	Proposed Title of Study/Experiment	Cost (Rs. Per Acre)
1.	Testing of Lint Samples	350,000
2.	Testing of Commercial Samples	60,000
3.	The effect of bio-chemicals' application on cotton fibre properties to improve drought tolerance	20,000
4.	Effect of planting & picking time on cotton fibre quality	20,000
5.	Quality survey of lint collected from ginning factories	200,000
6.	ICA-Bremen Cotton Round Test Program, Faser Institute, Germany	15,000
7.	Collaborative Study with Ginning/Spinning Industry	150,000

FARM MANAGEMENT

Sr. No.	Proposed Title of Study/Experiment	Cost (Rs. Per Acre)
1.	POL	15,59,425
2.	Daily Paid Labour	31,50,935
3.	Fertilizer	16,00,000
4.	Pesticides	24,65,000
5.	Repairs of Tractor & Machinery	760,900

ii) Approval of Cotton Varieties

The Punjab Seed Council in its 55th meeting held on 20.09.2021 approved 15 cotton varieties for commercial cultivation. Out of these, 05 cotton varieties of CCRI Multan, highest ever from any public sector institution were approved for general cultivation. The varieties included Bt.CIM-663, Bt.CIM-678, Bt.CIM-785, Bt.Cyto-535, and Cyto-226 (Non-Bt). The CIM varieties covered 9 percent area in the cotton zone of Punjab and Sindh provinces during the crop season 2021-22. (Source: CRS Departments of Provincial

Governments). Farmers liking for the CIM varieties is rising substantially and it is hoped that CIM varieties will cover >20 percent cotton area during the forthcoming cotton season.

Bt Varieties

	Characteristics		Characteristics
Bt.CIM-663 	Lint %age: 40.0 Staple Length : 28.43 Micronaire: 4.28 Strength: 29.17	**Bt.CIM-678** 	Lint %age: 40.0 Staple Length : 28.6 Micronaire: 4.01 Strength: 30.6
Bt.CIM-785 	Lint %age: 40.0 Staple Length : 29.0 Micronaire: 4.61 Strength: 31.96	**Bt.Cyto-535** 	Lint %age: 41.0 Staple Length : 28.2 Micronaire: 3.8 Strength: 28.2

Non Bt Varieties

	Characteristics
Cyto-226 	Lint %age: 40.3 Staple Length : 29.79 Micronaire: 4.6 Strength: 29.5

The varieties have cleared all their regional and adaptability trials. All the varieties have excellent fibre quality traits with high yield potential. The approval and cultivation of these varieties will pave way for enhancing cotton productivity in the country.

iii) Cotton Biotechnology

The Cotton Biotechnology Lab has been established to develop local cultivars with export quality lint and also resistant to drought stress and bollworms. Apart from lab work, the impact of abiotic & biotic stresses on cotton fiber quality are also studied. The lab is equipped with basic instruments that are necessary to carry out genetic transformation and GMO testing of cotton genotypes. The genes of different traits synthetically synthesized for transformation in local cotton cultivars as detailed below:

Name of Gene	Function
Cry2A	Pink Bollworm Resistance
DREB2	Abiotic stresses including drought tolerance
MYB (Family Gene)	Fibre Improvement

Milestones Achieved

Genetic transformation of Cry2A, DREB2, and Gt-Gene for bollworm, abiotic stress (drought stress), and glyphosate resistance genes, respectively, into commercial cultivars, have been accomplished and are now under evaluation for gene stability and other molecular analysis to develop resistance against bollworms, abiotic stress, and herbicides.

Future Prospects

Genetic Manipulation of the cotton crop to improve abiotic stress tolerance abilities such as water scarcity and sucking insect (whitefly) is the major factor that affects the cotton yield. To cope with this situation, the biotechnology lab currently working on genetic transformation of synthetically developed drought resistance and sucking pest resistance-conferring genes in the commercial cultivar. Dehydration responsive element binding proteins (DREB) are members of a larger family of transcription factors, many of which have been reported to contribute to plant responses to abiotic stresses in several species. A sequence of 438bp transcribes the mRNA that translates 146 amino acids. The other one (Cry2A) transcribed insecticidal proteins. The gene sequence got from NCBI, the origin of this protein is from *Bacillus thuringiensis* that constitute the active ingredient in many biological insecticides and biotech crops expressing *B. thuringiensis* genes (Bt crops). For the control of lepidopteran pests, *B. thuringiensis* Cry1 and Cry2 class proteins are being used either in sprayable products or in transgenic plants. A sequence of 1905bp transcribes the mRNA that translates 1635 amino acids.

iv) Cold Storage of Cotton Germplasm

The Institute has developed sub-zero cotton seed storage facility for long term storage that comprises of more than 6143 accessions (Local: 1290 and Exotic: 4853) that have been collected from various national and international resources. The seed of different varieties is preserved for short (25 years), medium term (50 years) and long term (100 years) basis and is in hand to be used by researchers to develop new varieties. The germplasm is shared with various local / international organizations / universities for breeding purpose.

v) Blackening of Cotton Leaves / Sooty Mold

Sooty molds become a serious problem on cotton from last few years. Sooty mold was found on cotton crop that have previously or contently been fed by sucking insects. The mold grow son honeydew, a sticky sugary secretion that is dropped by sucking insects. The scientists of CCRI Multan conducted a survey of different farmers' fields to record the data, collect the samples and identify the cause. The samples of cotton leaves showing blackening of the leaf surfaces were collected from Mohammad Arshad farm, Mouza Wahi bakhar, Tehsil Shuja Abad. The infected leaves were observed carefully to identify the presence of insects /pests. Whitefly nymphs and honeydew secretion on the lower side of cotton leaves and the upper side of the leaf was covered with black soot like fungus i.e. alternaria confirmed with microscopic examination. For best control, use pesticides which control whitefly adult and nymph and spray fungicide three days after pesticide spray. Never use mixture of insecticide, fungicide and sulfer, it can cause stress. 80% sulfer @ 2kg/ace also inhibit sooty mold spores to reproduce.

vi) LEEF Technology

The changing climatic conditions (rising temperatures, rains and drought) and rise in the cost of production is greatly affecting the cotton cultivated area and its production. The cotton production and yield improvement is becoming a big challenge under the current scenario. The cost of production is continuously increasing with reduced profitability over time. The Institute has thus introduced a new eco-friendly technology named "Low Expenditure & Environment Friendly (LEEF)" for sustainable cotton production.

The LEEF technology uses mulches from crop-based residues placed on the beds after planting cottonseeds. The plant residues applied included straws, husks, grasses, compost, and manures. This technology not only saves seedlings from scorching sunlight, maintains moderate soil temperatures, conserves moisture, prohibits weed emergence, and improves microbial activities. Moreover, the mulches after decaying add up to the soil health in the form of organic matter and nutrients.

vii) Demonstration of "Pink bollworm Manager", a mechanical tool to control Pink bollworm

Pink Bollworm (PBW), an insect that feeds on cotton flowers and seed inside the bolls. The insect overwinters as larvae inside the damaged bolls, which remain attached to cotton plants stored to be used as kitchen fuel, year round, in rural area. Emerging moths from such cotton sticks invade early sown cotton and built population high enough to infest normal cotton crop. The massive infestation of PBW caused considerable damage and ranked as one of the top three production constraints. CCRI-Multan with indigenous resources has developed a machine that picks the leftover bolls (damaged or unopened) once cotton picking is over. The machine will be a landmark in PBW management and hopefully bring to end the debate of early sowing; storing cotton sticks for fuel purpose etc. The machine picks up more than 95% of left over bolls mostly infested with PBW and collects in a bin. Since PBW is a monophagous pest and can be easily controlled with this machines instead of chemical sprays. The collected bolls also give 2-3 maunds of additional lint, which is more than enough to trade off the running cost of the machine. CCRI Multan has successfully demonstrated the operation of this machine at Rahim Yar Khan (Nov 01, 2021), Multan (Nov 02), Bahawalpur (Nov 03), Sahiwal (Nov 11) and Faisalabad (Nov, 24) to farmers and various other visiting groups for feedback during the month. CCRI Multan also plans to optimize machine and fabricate few more for demonstration purpose in different cotton growing areas of the country, before going for mass production by the private sector.

viii) Intercropping Experiment

The cotton growing communities are not satisfied with the current profitability scenarios of cotton. However, intercropping may be opportunity to tackle the issue as it contributes more returns per unit area and time. The objective of intercropping is to obtain a maximum yield of cotton crop along with additional returns from intercrops. In intercrops, at least two or even more crops are grown together; it improves biodiversity and attracts predators to make the integrated pest management possible. The Agronomy Section of the institute is conducting the plenary experiments to evaluate the compatibility of intercropping of fodder maize, mung bean and sesame for improving farmer's profitability.

Mulching involves the covering of soil surface through plastic sheet and crop residues etc. The basic objective of mulching is to discourage weed growth along with moisture conservation and soil health improvement. In either ways, it improves the cotton yield and minimizes the cost of weed control and reduces the amount of irrigation water. The significant amount of crop residue is available which may be utilized for mulching. The experiment is in process to evaluate the feasibility of wheat, rice and maize residue as mulch material.

Cotton and Mungbean planted 75 cm apart rows on bed and furrow constituting a pattern of two rows each on one furrow

Cotton and Peanut planted 75 cm apart rows on bed and furrow constituting a pattern of two rows each on one furrow

Cotton and Sesame planted 75 cm apart rows on bed and furrow constituting a pattern of two rows each on one furrow

ix) Research Collaborations

The Institute initiated cotton research collaborations with various national and international organizations. The following main collaborations were proposed during the period:

Collaborating Partner	**Scope of Work**
➢ BioCentury Transgene (BT) China; ➢ M/s Fauji Fertilizer Company Pakistan ➢ China-Pak Economic Corridor (CPEC) Authority	Development and transfer of transgenic cotton production technology in Pakistan
Bahauddin Zakariya University, Multan Center for Excellence in Molecular Biology (CEMB), Lahore	Plant Breeding & Biotechnology ➢ Development of Climate Resilient Transgenic Cotton ➢ Metabolic Engineering of Gossypol Biosynthesis to Breed Local Cotton (*Gossypium hirsutum* L.) to Enhance Resistance against Whitefly (*Bemisia tabaci*)

x) Activities under Cotton Research & Development Projects

Pink bollworm Project: Cotton Productivity Enhancement through Eco Friendly Pink bollworm Management and Capacity Building in Punjab under PM Emergency Program

Pink bollworm has been a serious pest management issue for the last several years. To address this issue, CCRI Multan organized the first national seminar on pink bollworm management in 2015 and the activity remained continue every year until 2021. In the year 2021, an international seminar was arranged in which foreign researchers were also invited to share their findings to understand the Pink bollworm and its management more holistically. The seminar earned heavy attendance and the recommendations placed before provincial and federal governments for implementation and policy formulation.

The Institute has also fabricated Mechanical Boll Picker called "Pink bollworm Manager" for eradication of leftover bolls that host Pink bollworm larvae during winter. This machine proved to be very effective in eradicating Pink bollworm at CCRI, Multan. Consequently, the demonstrations of the PBW Manager were carried out successfully at various locations (Multan, Bahawalpur, Khan Pur, Sahiwal and Faisalabad) during the season. Farmers and Agriculture Extension workers participated in these demonstrations.

Training programs on "Pink bollworm Management" were organized for officials of Agriculture Extension Department, Pest Warning & Quality Control of Pesticides Punjab and Adapative Research Wing of the Extension Department. The training programs were conducted on December 14-16, 21-23 and 28th December 2021.

Survey was also conducted in the cotton areas of Punjab to check the performance of cotton varieties and infestation of Pink bollworm. Artificial diet has been prepared. Rearing of Pink bollworm has successfully been completed on this artificial diet. Now 9th generation of the Pink bollworm is present in lab to make it susceptible generation. Efforts for the mass rearing are being made to conduct resistance studies.

BCI Project: Better Cotton Initiative (BCI) for Sustainable Cotton Production in Pakistan

The project "Better Cotton Initiative (BCI) for Sustainable Cotton Production in Pakistan" is in operation in Punjab and Sindh provinces for management of cotton in line with the BCI principles. The project objectives include use of quality seed of approved varieties, adoption and promotion of better management practices (BMPs), implementation of Integrated Pest Management (IPM) practices, optimized use of pesticides, fertilizers, irrigation water, soil health improvement, and adoption of descent work practices by farm and farmers, and promotion of Clean Cotton production and picking practices through training of women pickers. The project aims to reduce the cost of production by up to 20-25% by ensuring the sustainability of production resources (soil, water and environment).

The project activities were carried out partially due to limited release of funds and COVID-19 restrictions. The major activities included registration of 22,731 farmers for BCI practices, 06 farmers training programs, 08 Better Cotton Knowledge Network (BKN) meetings with BCI officials and 24 monthly meetings with BCI staff during the period.

Farmer's Registration (2020-2021)

District	Number of Farmers		Covered Area (Acres)	
	2020-21	2021-22	2020-21	2021-22
Shaheed Benazirabad	1,498	2,201	8,768	11,297
Noshero Feroze	1,177	0	4,858	0
Multan	9,001	3,148	14,832	7,107
DG Khan	3,123	2,583	10,733	8,732
TOTAL	**14,799**	**7,932**	**25,842**	**27,136**

In addition, technical material in Urdu and Sindhi languages were also printed for distribution among the farmers during training programs conducted at CCRI Multan and in the project areas.

III COTTON PROMOTION & DEVELOPMENT ACTIVITIES

i) World Cotton Day

The Central Cotton Research Institute (CCRI), Multan celebrated the World Cotton Day (**WCD)** with great enthusiasm and in a befitting manner. The day is being celebrated with reassurance for the betterment of cotton crop in the country. The following major activities were carried out:

- Cotton Walk for commemorating importance of cotton crop in national economy
- Exhibition of Farm Machinery and Stalls of Companies
- Seminar challenges confronting cotton production and measures for its revival
- Perspectives of Stakeholders (Farmers, Ginning, Textile, Pesticide, Seed, Fertlizer)

The event highlighted the issues in cotton production and trade, and recommend measures for boosting cotton production in the country. The collaborative and joint efforts by the government functionaries, stakeholders and cotton trading bodies will bring back the momentum of cotton production back to the level where it was few years before and will bring prosperity for the nation at large. The year 2019 led to launch the initiative of declaring World Cotton Day by the ICAC and WTO, followed by events and celebrations around the world commemorating the importance of cotton crop. The United Nations has also declared 7th October as the UN World Cotton Day in 2021. Pakistan being a leading cotton producing country holds responsibility to showcase solidarity with world cotton community. Cotton is not only the lifeline for Pakistan's economy but also has a unique association with mankind.

ii) Supply of Cotton Germplasm to Tanzania and Zimbabwe

The Institute continued cooperation with national and international organizations for distribution of cotton germplasm of varied characters to help in cotton varietal development. In this context, the Institute provided 700 grams cotton seed each for Tanzania Cotton Board and Cotton Research Institute Zimbabwe. The germplasm included short & compact, earliness, good fibre properties for medium and long staple, pest tolerance against Jassid & Mealybug, disease resitance against Verticillium wilt & Bacterial blight, and high cotton yield features.

iii) Publications of "The Pakistan Cottongrower"

CCRI, Multan has initiated publication of a quarterly journal "The Pakistan Cottongrower". The journal is bilingual, published in Urdu and English languages. Articles related to cotton agronomy, nutrition management, varietal development, insect pests & diseases management, and post-harvest handling are published. Moreover, weather conditions (temperature, rainfall), cotton market news and world cotton outlook of the subject quarter are also regular features of the Journal. Articles of researchers and technical field officers of private pesticide/seed/fertilizer industry are also encouraged for publication with approval by the Editorial Board. The journal is being distributed among cotton researchers, academicians, private pesticide & seed association and most importantly the cotton farmers.

iv) Website & Social Media

The Institute also initiated highlighting of cotton research and development activities carried out during crop season 2021-22 utilizing social media tools (www.fb.com.pk/CCRIM.PK). This has attracted cotton farmers, researchers, and students very effectively. The followers and members appreciated the activities carried out by the Institute. The Institute has also upgraded the website (www.ccri.gov.pk) of the Institute highlighting major cotton research and development activities, brief program of various disciplines, cotton market rates, weather situation and other related activities.

IV. SEMINARS / WORKSHOPS / TRAINING PROGRAMS / METINGS

SEMINARS

Date	Topic	Key Speakers	Participants
17.11.2021	International Seminar on Pink bollworm Management	Dr. Keshav Kranthi, ICAC, USA Prof. Dr. A.G. Sreenivas, India Dr. M. Arshad Shakeel, Dr. Mushtaq Ahmad, Dr. Zahid Mahmood	Cotton researchers, pesticide industry, farmers
12.08.2021	National Workshop on "Sustainable Solutions for Revival of Cotton in Pakistan	Syed Hussain Jahania Gardezi, Agriculture Minister, Punjab Dr. Khalid Abdullah, Cotton Commissioner, Dr. Zahid Mahmood, Director CCRI Multan	Textile and Ginning Industry, Farmers, Cotton Experts
22.06.2021	6th National Seminar "Pink Bollworm Management"	Mr. Saqib Ali Ateel, Secretary Agri South Punjab Dr. Muhammad Ali Talpur, VP, PCCC; Dr. Khalid Abdullah, Cotton Commissioner, MNFS&R; Mr. Bilal Israel, Chairman Cotton R&D Board; Dr. Zahid Mahmood, Director CCRI Multan. Dr. Shah Nawaz Khuro	Cotton Researchers, Pesticide Industry, Farmers

HIGH LEVEL MEETINGS

Date	Topic	Key Speakers	Participants
23.08.2021	Meeting "Future of Cotton Research"	Syed Fakhar Imam, Federal Minister for National Food Security Dr. Shahid Mansoor, NIBGE Dr. Mehbub ur Rehman, NIBGE Dr. Manzoor, NIAB Dr. Saghir Ahmad, CRI Multan Dr. M. Iqbal Bandesha, IUB Dr. Zahid Mahmood, CCRI Multan	Cotton researchers
09.08.2021	Meeting "Revival of Cotton Crop"	Mr. Jamshed Iqbal Cheema, Special Advisor to the Prime Minister on Food Security Dr. Khalid Abdullah, Cotton Commissioner MNFS&R; Mr. Saqib Ali Ateel, Secretary Agriculture South Punjab Dr. Muhammad Anjum Ali, DG Agri Ext Punjab; Mr. Khalid Khokhar, Chairman Pakistan Kissan Itehad	Cotton Experts, Rpresentatives of Irrigation, MEPCO; PCPA, APTMA, PCGA, Farmers

TRAINING PROGRAMS

Date	Topic	Trainers	Participants
14.12.21	Pink bollworm Management	Dr. Zahid Mahmood Dr. Rabia Saeed	Agri Extension Punjab
15.12.21	--do--	--do--	--do--
16.12.21	--do--	--do--	--do--
21.12.21	--do--	--do--	PWQC Punjab
22.12.21	--do--	--do--	--do--
23.12.21	--do--	--do--	--do--
28.12.21	--do--	--do--	Adaptive Research
24.06.21	Cotton Plant Mapping	Dr. Fiaz Ahmad	30 officials of CRS Punjab

10.06.21	Pink bollworm Management	Dr. Zahid Mahmood Dr. Rabia Saeed	12 from CRS; 19 from Agri Ext; 11 from Agri Secretariat South Punjab; 5 from Adaptive Research and 5 from PWQC Punjab
23.06.21	Better Cotton Production	Dr Zahid Mahmood, Dr Fiaz Ahmad, Mr. Sajid Mahmood, Mr. Kumail Fiaz, Producer Unit Manager	Lead Farmers from DG Khan
19.06.21	Better Cotton Production	Dr Zahid Mahmood; Dr. M. Naveed Afzal Dr Fiaz Ahmed Mr. Abdul Wahab Soomro, BCI Coordinator (Sindh),	Lead Farmers from Sindh
07.06.21	Better Cotton Production	Dr Zahid Mahmood; Dr. M. Naveed Afzal Dr Fiaz Ahmed	100 farmers from Multan
03.03.21	Refresher Course on Cotton Production Technology	Dr. Zahid Mahmood Dr. M. Naveed Afzal Dr. M. Idrees Dr. Fiaz Ahmad Dr. Rabia Saeed Ms Sabahat Hussain Mr. Ilyas Sarwar Mr. Sajid Mahmood	100 technical officers from Pesticide, Seed, Fertilizer Industry

viii) Internships at the Institute

The Institute being equipped with latest infrastructure (laboratories, advanced instruments, glasswares/chemicals, farm machinery and the experimental area) remained attraction point for the university students to complete their graduate/post-graduate internships. The highly qualified scientific staff provides updated information, guidance and training on various aspects of research disciplines (agronomy, plant breeding, biotechnology, entomology, plant pathology, plant physiology) to the visiting internees from various agriculture universities all around the country. Following students got practical training and completed their internships:

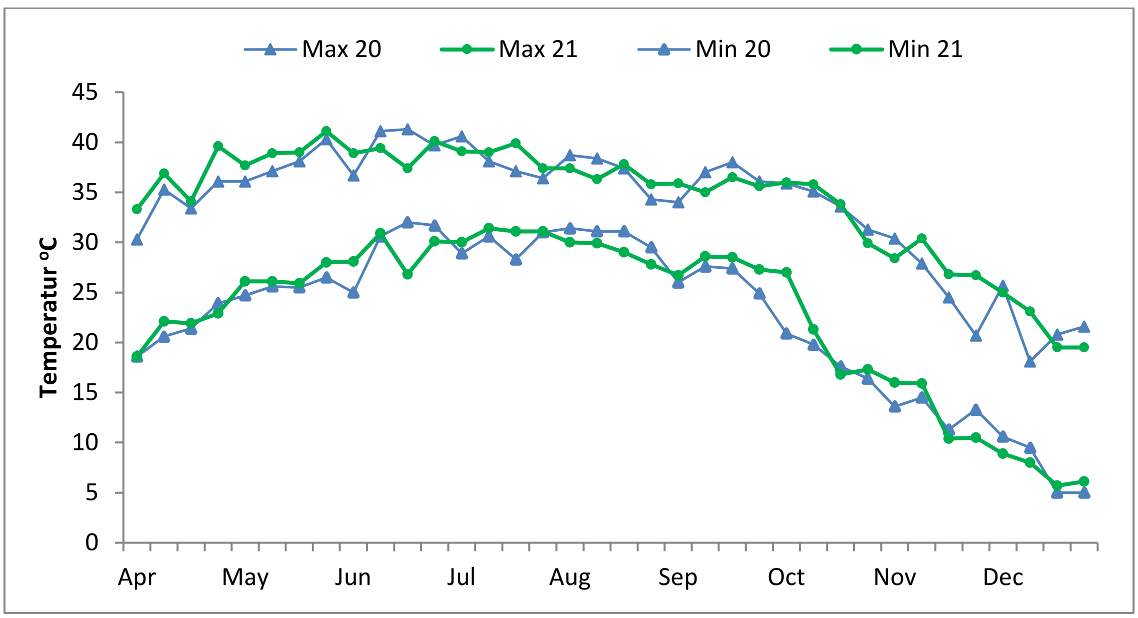
Students Name	Major Discipline	Internship Duration	University
Ume Aiman Khalid	Agronomy	24.06.21 to 30.07.21	BZU, Multan
Shahir Bano	Agronomy	02.08.21 to 03.09.21	BZU, Multan
Areej Fazal	Agronomy	02.08.21 to 03.09.21	BZU, Multan
Waheed Abbas	Agronomy	13.07.21 to 03.09.21	BZU, Multan
Asad Akram	Agronomy	13.07.21 to 03.09.21	BZU, Multan
Muhammad Jamshed	Agronomy	13.07.21 to 03.09.21	BZU, Multan
Muhammad Rajab Gill	Agronomy	01.06.21 to 03.09.21	BZU, Multan
Haseeba Akbar	Agronomy	01.06.21 to 03.09.21	BZU, Multan
Muhammad Rizwan	Agronomy	22.04.21 to 13.08.21	BZU, Multan
Mubashir Abbas	Agronomy	06.01.21 to 12.03.21	Ghazi Uni, DG Khan
Habib-ur-Rehman Saith	Plant Breeding	01.07.21 to 01.09.21	UAF, (Burewala)
Mr. Muhammad Talha	Plant Breeding	01.07.21 to 01.09.21	UAF, (Burewala)
Haseeb Mehmood	Plant Breeding	01.07.21 to 01.09.21	UAF, (Burewala)
Amna Bashir	Biotechnology	07.09.21 to 03.11.21	BZU, Multan
Riffat Malik	Biotechnology	30.06.21 to 01.09.21	BZU Multan
Aneela Bashir	Biotechnology	26.07.21 to 03.09.21	BZU, Multan
Mary Ann Minal Javaid	Biotechnology	05.08.21 to 11.11.21	BZU, Multan
Hafiza Fatima Riaz	Biotechnology	05.08.21 to 11.11.21	BZU, Multan
Moattar Fatima	Biotechnology	05.08.21 to 11.11.21	BZU, Multan
Mahrukh Naeem Jaswal	Biotechnology	05.08.21 to 03.11.21	BZU, Multan
Nimrah Yamin	Biotechnology	26.07.21 to 09.10.21	BZU, Multan
Saher Fatima	Biotechnology	30.06.21 to 28.08.21	BZU, Multan
Kawish Rafay	Entomology	01.03.21 to 31.05.21	Uni Punjab, Lahore

Husnain Nawaz	Entomology	01.03.21 to 31.05.21	Uni Punjab, Lahore
M. Nauman	Entomology	01.03.21 to 31.05.21	UAF, Faisalabad
Anwar Ellahi	Entomology	01.03.21 to 31.05.21	UAF, Faisalabad
Qaiser Abbas	Entomology	01.03.21 to 31.05.21	UAF, Faisalabad
Ammar Bin Yasin	Plant Pathology	03.03.21 to 07.06.21	UAF, Faisalabad
Muhammad Zeshan	Plant Pathology	12.04.21 to 13.07.21	UAF, Faisalabad
Maham Khalid Bhatti	Plant Pathology	05.07.21 to 26.08.21	BZU, Multan
Hajra Amjad	Plant Pathology	05.07.21 to 26.08.21	BZU, Multan
Abdul Haseeb	Soil Science	14.04.21 to 30.07.21	MNSUA, Multan
Asad Ullah	Soil Science	04.03.21 to 30.07.21	BZU, Multan
Ameer Hamza	Soil Science	04.03.21 to 30.07.21	BZU, Multan
Sheeza Manzoor	Soil Science	04.03.21 to 30.07.21	BZU, Multan
Bakhtawar Shah	Soil Science	04.03.21 to 30.07.21	BZU, Multan

V) COTTON CROP CONDITION: PUNJAB

i) Weather Condition

The pattern of maximum temperatures during cotton crop season 2021-22 remained higher especially between June-August. The annual average maximum temperature during 2021-22 remained 34.3°C while it was 33.8°C during last year. Similarly, the annual average minimum temperature during current year remained at 22.8°C while it was 22.5°C during last year. The minimum relative humidity remained 78.9% while it remained 78.9% at maximum level, during current season. A total of 68.9 mm rainfall was recorded during the current crop season as compared to 280.8 mm rainfall during the last year.



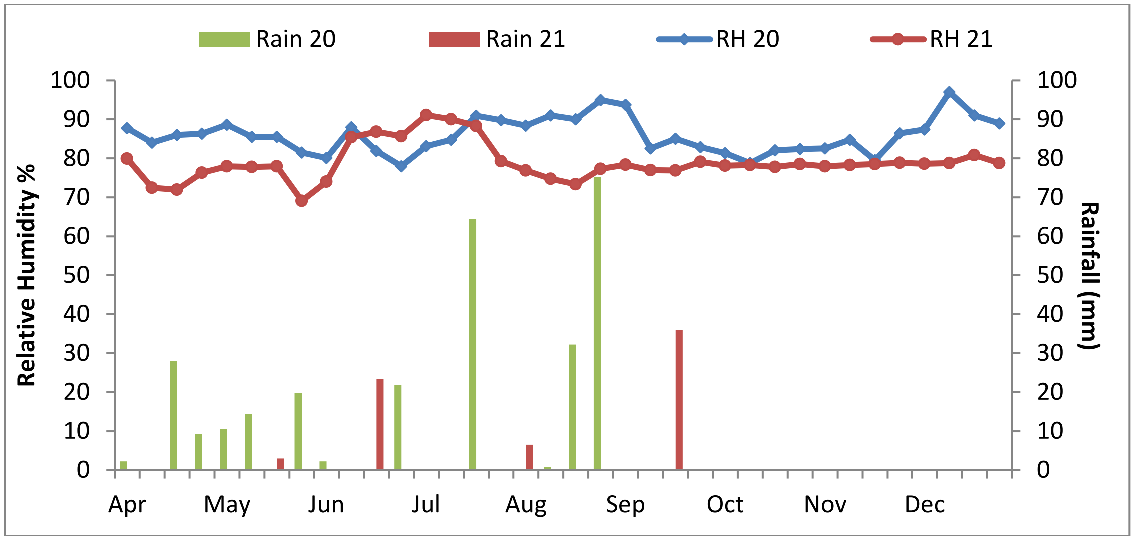


Fig. 1 Weekly Average Temperature, Relative Humidity and Total Rainfall during 2020 and 2021.

ii) Cotton Situation

For the last several years, compared to the low trend of cotton crop, this year's production has come to a great growth. The country harvested substantially higher cotton production to the level of 9.374 million bales against 7.064 million bales during last year depicting an increase of 33% percent (Source: CCAC/CRS). This robust recovery in cotton production is attributed to favourable weather (lesser rains, moderate temperatures), availability of good quality seed, generous government support measures including announcement of support price of seed cotton @ Rs. 5000 per mond and provision of subsidies on seed, fertilizer, pesticides, financial credit and farm machinery. All these factors helped in reviving cotton crop. The efforts are now underway for enhancing cotton production to meet domestic industrial demand and export requirements.

Sowing Position

Province	Target	Area Sown		% Change Over	
	2021-22	2021-22	2020-21	Target	Last Year
Punjab	1.61	1.279	1.546	79.4%	-17.3
Sindh	0.64	0.575	0.475	89.8%	+21.05
Khyber Pakhtunkhwa	0.0022	0.00012	0.00011	5.45%	+12.3
Balochistan	0.07	0.064	0.057	91.4%	+9.1
Total	**2.3222**	**1.918**	**2.078**	**96.02%**	**-7.7**

Cotton Production Assessments 2021

Province	Expected Production (million bales)	
	1st CCAC (01.09.2021)	2nd CCAC (07.10.2021)
Punjab	4.53	5.44
Sindh	3.50	3.50
Khyber PakhtunKhwa	0.00417	0.004
Balochistan	0.430	0.430
Pakistan	**8.460**	**9.374**

Source: Cotton Crop Assessment Committee meetings

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1. AGRONOMY SECTION

Agronomic crop management is practiced to avail the maximum benefits of prevailing weather conditions. These environmental factors influence the various crop growth phenomenon and over all crop productivity. The main focused study areas of this section include soil, water, nutrients, weed management, planting time optimization and planting techniques for candidate and benchmark genotypes (GMOs and Non-GMOs) developed by CCRI with climatic vagaries in mind. In addition to these, performance of genotypes is being tested in high density planting system (HDPS). The feasibility study on mung bean, sesame, peanut, corn and fodder maize as an intercrop in cotton is also being tested to improve the economic returns of the cotton growers. The long term experimentation is being carried out to improve the soil health and productivity of wheat-cotton cropping system through residue incorporation. The main output of the agronomic trials is to increase the cotton productivity while reducing the negative effects of various biotic and abiotic stresses along with harvesting maximum benefits of environment. The daily record of various weather data is the regular activity of this section. The internship training is an important activity of this section with the objective to train the agricultural graduates from various universities. Research facilities extended to M.Phill and PhD scholars is another land mark of this section. The training of agricultural officers, extension workers, field staff of pesticide and seed companies, NGOs, farmers and agriculture graduates is a regular seasonal feature. Moreover, radio programs are arranged for guiding the farming community. The section also participates in the biweekly advisory meetings to guide the farmers time to time during the season as per crop need.

1.1 Effect of time of sowing on productivity of advanced genotypes

Three genotypes i.e. CIM-735, Cyto-228 and CIM-610 were tested at five sowing dates starting from April 01 to May 30 at fifteen days interval. Experimental design was split plot. Sowing dates were kept in main plots and genotypes in sub plots with four repeats. The net plot size was 20 ft x 41 ft. Bed-furrows were prepared after land preparation in dry condition. Sowing was done with delinted seeds by dibbling method followed by irrigation. Dual Gold 960 EC @ 2L per hectare was sprayed after sowing on moist beds. Nitrogen at the rate of 150 kg ha^{-1} was applied in three split doses. Other cultural practices and plant protection measures were adopted as per need of the crop. The data on plant height, number of bolls and boll weight were recorded before final picking. Five plants were randomly selected for plant height and number of bolls per plant. All the bolls from three randomly selected plants were counted, picked and weighed. The average boll weight was measured by dividing the total seed cotton weight with the total number of bolls. The whole plot was manually picked and seed cotton weight was converted on hectare basis. Data on plant height, boll number, boll weight, seed cotton yield and CLCuD incidence percentage are given in Table 1.1.

Table 1.1 Effect of sowing dates on plant height, seed cotton yield, yield components and CLCuD incidence

Sowing dates	Genotypes	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (Kg ha^{-1})	CLCuD incidence (%) at 90 DAS
April 01	CIM-735	130.3	27	2.72	2744	6.9
	Cyto-228	108.5	27	2.41	2591	0.4
	CIM-610	117.0	29	2.65	2897	0.8
April 15	CIM-735	123.3	21	2.78	2088	30.6
	Cyto-228	98.7	20	2.44	1962	2.2
	CIM-610	108.6	20	2.69	2022	18.2
May 01	CIM-735	123.1	20	2.83	2040	58.7
	Cyto-228	95.5	18	2.48	1656	23.4
	CIM-610	104.4	17	2.71	1675	47.5
May 15	CIM-735	117.8	16	2.86	1563	53.2
	Cyto-228	95.1	15	2.50	1366	41.1
	CIM-610	103.5	14	2.75	1388	61.1
May 30	CIM-735	101.6	13	2.90	1338	100.0
	Cyto-228	93.0	13	2.52	1192	80.5
	CIM-610	99.5	13	2.80	1330	78.4

DAS* = Days after sowing

Sub-effects

Sowing Dates	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (Kg ha^{-1})	CLCuD incidence (%) at 90 DAS
April 01	118.6	28	2.59	2744	2.7
April 15	110.2	20	2.64	2024	17.0
May 01	107.7	18	2.67	1790	43.2
May 15	105.5	15	2.70	1439	51.8
May 30	98.0	13	2.74	1287	86.3

Genotypes	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (Kg ha^{-1})	CLCuD incidence (%) at 90 DAS
CIM-735	119.2	19.4	2.82	1955	49.9
Cyto-228	98.2	18.6	2.47	1753	29.5
CIM-610	106.6	18.6	2.72	1862	41.2
C.D 5%					
Sowing date (SD)	9.40	3.07	ns	304.59	5.28
Genotype (G)	4.13	0.50	0.11	50.81	3.19
SD x G	ns	1.13	ns	113.62	7.15

The data presented in Table 1.1 indicated that on overall average basis of sowing dates, genotype CIM-735 produced significantly higher seed cotton yield as compared to Cyto-228 and CIM-610. The genotype CIM-735 produced 11.5% and 5.0% higher seed cotton yields than Cyto-228 and CIM-610, respectively. Averaged across the genotypes, plant height, number of bolls and seed cotton yield decreased as sowing was delayed (Fig. 1, 2, 4). While, boll weight increased as the sowing was delayed (Fig.3). Among all sowing dates maximum boll weight (2.74 g) was produced from May 30 sown crop. The maximum bolls per plant (28) and seed cotton yield (2744 kg ha^{-1}) were harvested from April 01 sown crop.

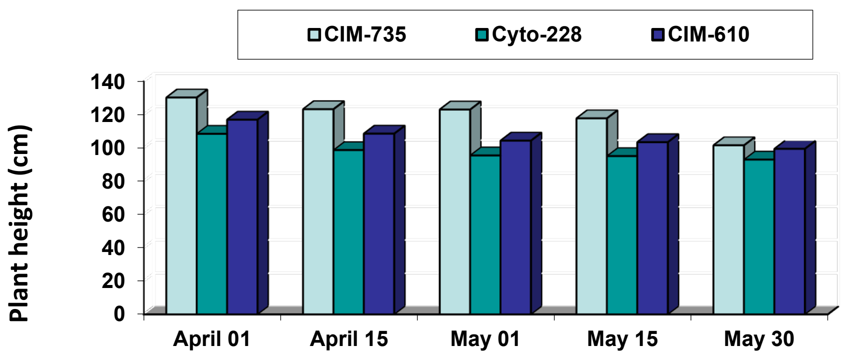

Fig. 1 Plant height as affected by interactive effects of sowing dates and genotypes

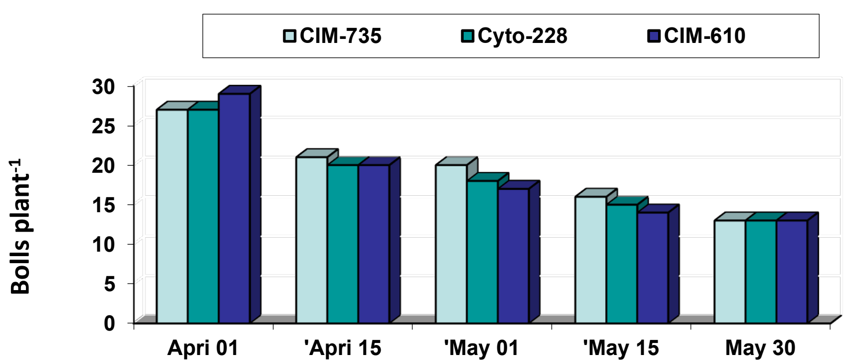

Fig. 2 Bolls plant^{-1} as affected by interactive effects of sowing dates and genotypes

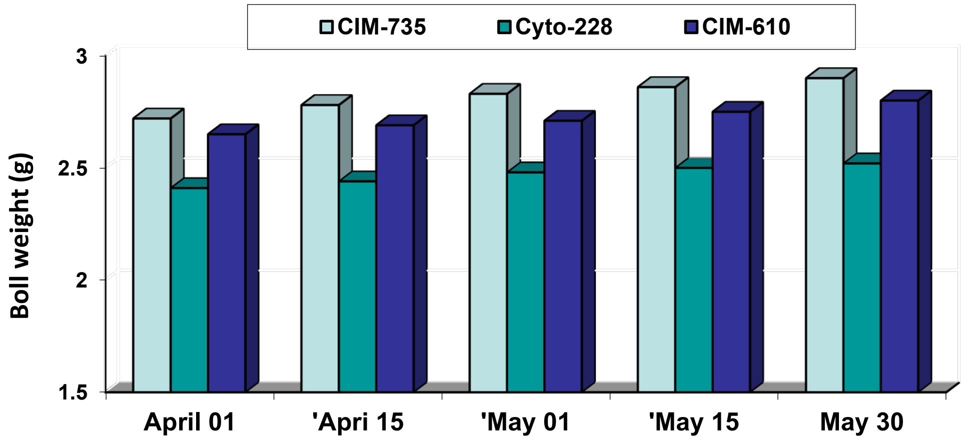

Fig. 3 Boll weight as affected by interactive effects of sowing dates and genotypes

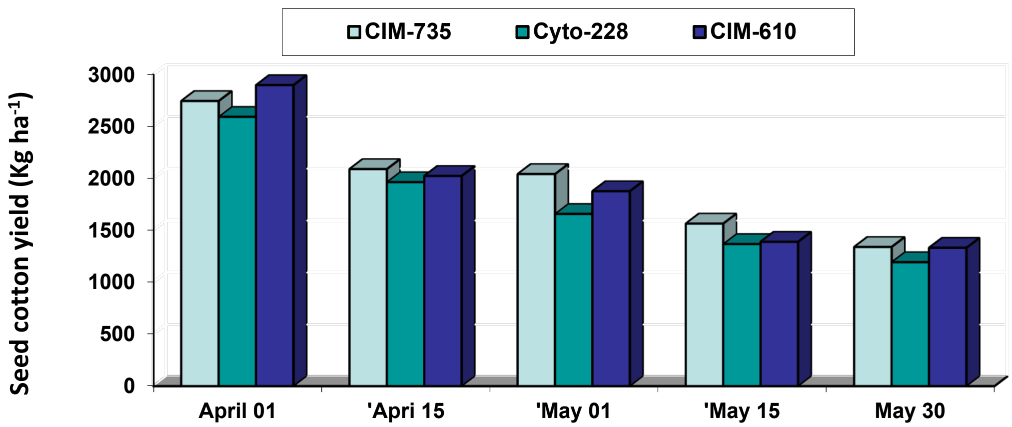

Fig. 4 Seed cotton yield as affected by interactive effects of sowing dates and genotypes

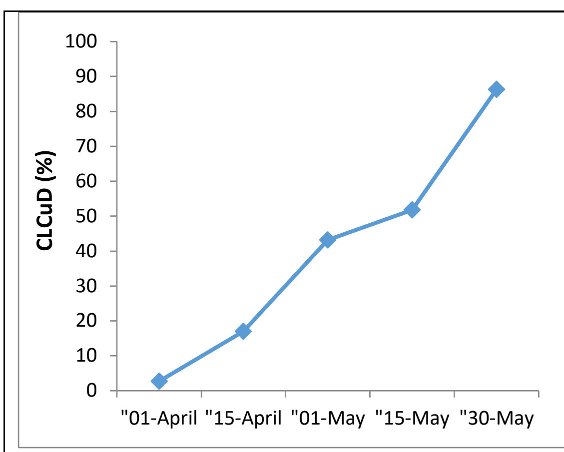

Fig. 5 CLCuD incidence in different sowing dates at 90 DAS

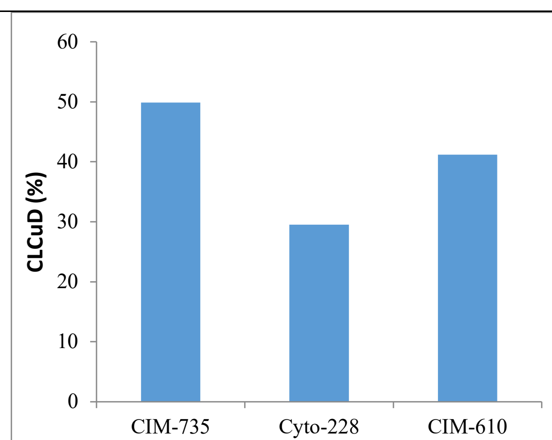

Fig. 6 CLCuD incidence in different genotypes at 90 DAS

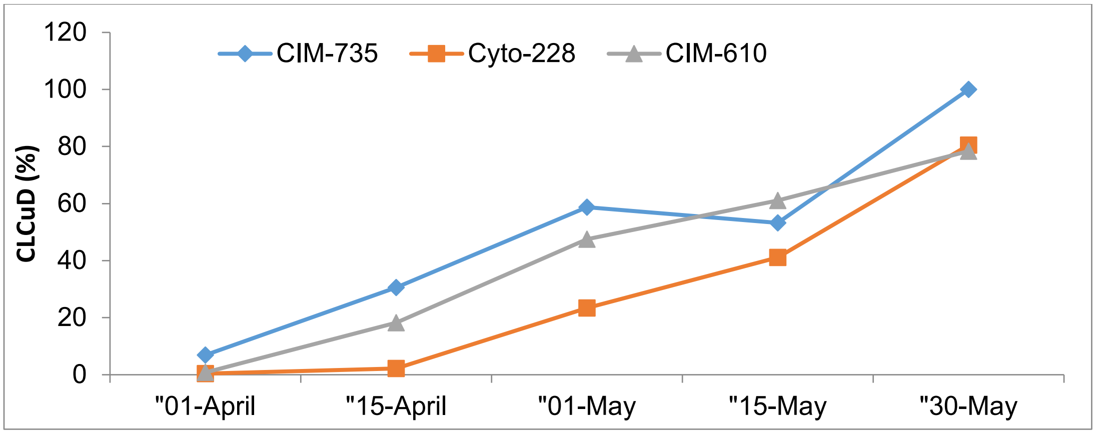

Fig. 7. Interactive affect of sowing dates and genotypes on CLCuD incidence at 90 DAS

The data on CLCuD showed that the disease incidence gradually increased as the sowing was delayed from April 01 up to May 30. The maximum incidence of CLCuD 86.3% at 90 days after sowing was observed in May 30 sown crop. Whereas April 01, April 15, May 01, and May 15 sown crop showed 2.7%, 17%, 43.2% and 51.8% virus infestation, respectively (Fig. 5). On the average basis of sowing dates, genotype Cyto-228 showed 11.7% and 20.4% less CLCuD incidence than CIM-610 and CIM-735, respectively (Fig. 6). The interaction between sowing dates and genotypes is illustrated in Fig. 7.

1.2 Effect of time of sowing on production of transgenic cotton

Five transgenic cotton genotypes i.e. *Bt.*CIM-775, *Bt.*CIM-875, *Bt.*Cyto-535, *Bt.*Cyto-536, *Bt.*Cyto-537 with one standard *Bt.*CIM-663 were evaluated at five different sowing dates starting from April 01 to May 30 at fortnightly interval. Experimental design was split plot, sowing dates were kept in main plot and genotypes in sub plots with four repeats. The net plot size was 20ft x 25ft. Bed-furrows were prepared after land preparation in dry condition. Sowing was done by manual dibbling of seeds at 22.5 cm plant to plant distance followed by irrigation. Dual Gold 960 EC @ 2L per hectare was sprayed after sowing on moist beds. Other cultural practices and plant protection measures were adopted as per need of the crop. The data on plant height, number of bolls and boll weight were recorded before final picking. Five plants were randomly selected for plant height and number of bolls per plant. All the bolls from three randomly selected plants were counted, picked and weighed. The average boll weight was measured by dividing the total seed cotton weight by the total number of bolls. The whole plot was manually picked and seed cotton weight was converted on hectare basis. Data on plant height, boll number, boll weight, seed cotton yield and CLCuD incidence are given in Table 1.2.

The plant height, bolls per plant and seed cotton yield decreased while, boll weight increased with the delay in sowing (Fig. 8, 9, 10 and 11). The maximum plant height (122.8 cm), bolls plant^{-1} (34) and seed cotton yield (3425 kg ha^{-1}) were harvested from April 01 sown crop (Table 1.2). Among all sowing dates maximum boll weight (2.98 g) was produced in May 30 sown crop. On overall average basis of sowing dates,*Bt.*CIM-775 produced 8.4%, 9.3%, 13.0%, 20.3% and 35.2% significantly more seed cotton yield than *Bt.*Cyto-537, *Bt.*Cyto-535, *Bt.*CIM-663, *Bt.*Cyto-536 and *Bt.*CIM-875, respectively.

Table-1.2 Effect of sowing dates on plant height, seed cotton yield, yield components and CLCuD incidence

Sowing dates	Genotypes	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})	CLCuD incidence (%) at 90 DAS
April 01	*Bt*.CIM-775	136.2	35	2.75	3541	0.0
	Bt.CIM-875	155.0	27	2.85	2769	0.0
	Bt.Cyto-535	110.4	38	2.87	3853	0.0
	Bt.Cyto-536	114.3	30	2.73	2999	0.0
	Bt.Cyto-537	99.5	36	2.86	3644	0.0
	Bt.CIM-663	121.2	37	2.83	3746	1.8
April 15	*Bt*.CIM-775	123.4	29	2.78	2929	1.1
	Bt.CIM-875	146.0	22	2.89	2242	0.0
	Bt.Cyto-535	107.3	33	2.92	3414	3.3
	Bt.Cyto-536	105.2	27	2.75	2694	3.1
	Bt.Cyto-537	99.1	33	2.90	3340	4.0
	Bt. CIM -663	119.0	26	2.87	2650	19.7
May 01	*Bt*.CIM-775	120.8	27	2.80	2734	17.8
	Bt.CIM-875	144.2	19	2.93	1933	15.0
	Bt.Cyto-535	104.6	24	2.96	2425	37.7
	Bt.Cyto-536	103.5	23	2.80	2267	43.5
	Bt.Cyto-537	98.0	24	2.95	2415	45.6
	Bt. CIM -663	116.2	20	2.90	1971	31.7
May 15	*Bt*.CIM-775	116.2	22	2.86	2223	53.6
	Bt.CIM-875	137.3	16	2.98	1616	47.1
	Bt.Cyto-535	104.0	15	3.02	1542	95.1
	Bt.Cyto-536	102.0	19	2.85	1890	87.6
	Bt.Cyto-537	96.2	15	3.00	1520	97.0
	Bt. CIM -663	107.0	20	2.93	1982	45.8
May 30	*Bt*.CIM-775	110.2	21	2.92	2068	78.3
	Bt.CIM-875	136.0	14	3.00	1425	92.9
	Bt.Cyto-535	101.0	11	3.06	1112	100.0
	Bt.Cyto-536	94.5	14	2.90	1369	100.0
	Bt.Cyto-537	95.0	15	3.02	1530	100.0
	Bt. CIM -663	103.3	16	2.97	1594	50.0

DAS* =Days after sowing

Sub-effects

Sowing dates	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})	CLCuD incidence (%) at 90 DAS
April 01	122.8	34	2.82	3425	0.3
April 15	116.7	28	2.85	2878	5.2
May 01	114.6	23	2.89	2291	31.9
May 15	110.5	18	2.94	1796	71.0
May 30	106.7	15	2.98	1516	86.9

Genotypes	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})	CLCuD incidence (%) at 90 DAS
Bt.CIM-775	121.4	27	2.82	2699	30.2
Bt.CIM-875	143.7	20	2.93	1997	31.0
Bt.Cyto-535	105.5	24	2.97	2469	47.2
Bt.Cyto-536	103.9	23	2.81	2244	46.8
Bt.Cyto-537	97.6	25	2.95	2490	49.3
Bt.CIM-663	113.3	24	2.90	2389	29.8

C.D 5%

Sowing date (SD)	7.13	3.14	ns	318.58	3.45
Genotype (G)	6.19	1.48	ns	149.68	4.26
SD x G	ns	3.32	ns	334.70	9.53

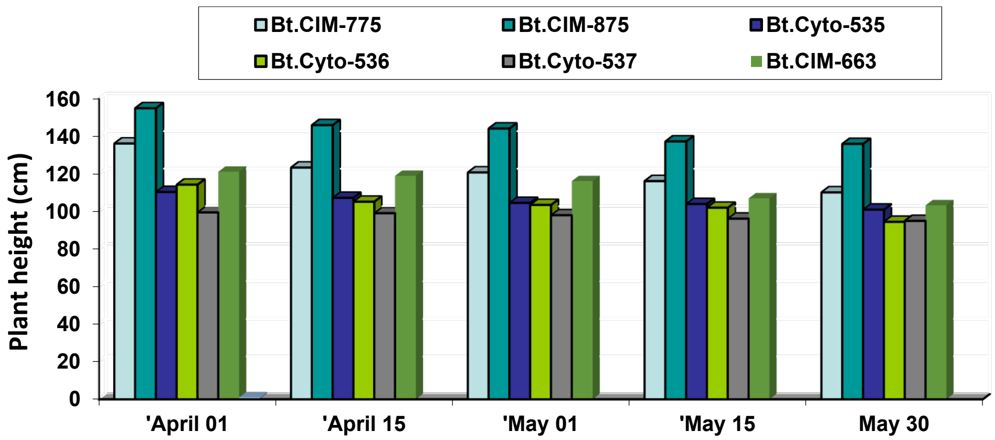

Fig. 8 Plant height as affected by interactive effects of sowing dates and genotypes

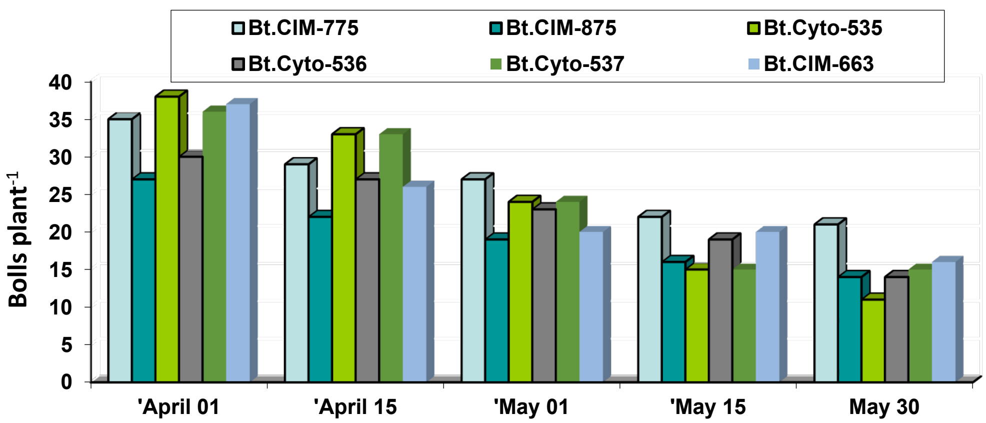

Fig. 9 Bolls plant^{-1} as affected by interactive effects of sowing dates and genotypes

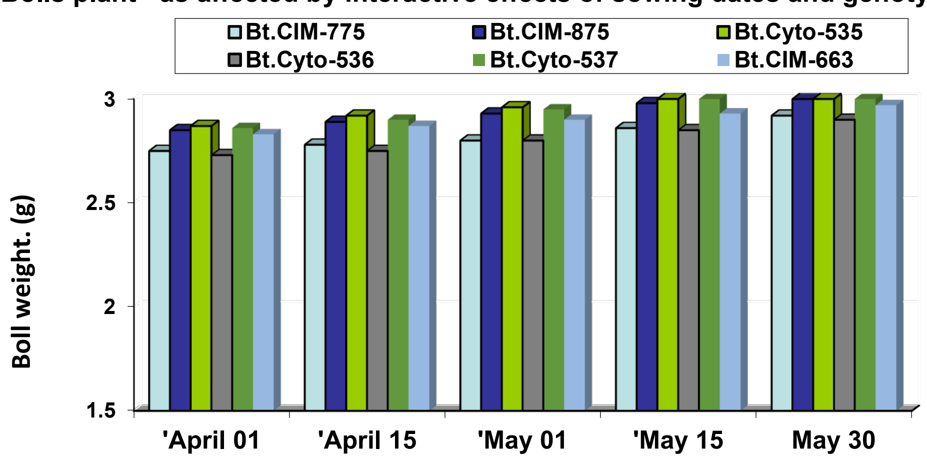

Fig. 10 Boll weight as affected by interactive effects of sowing dates and genotypes

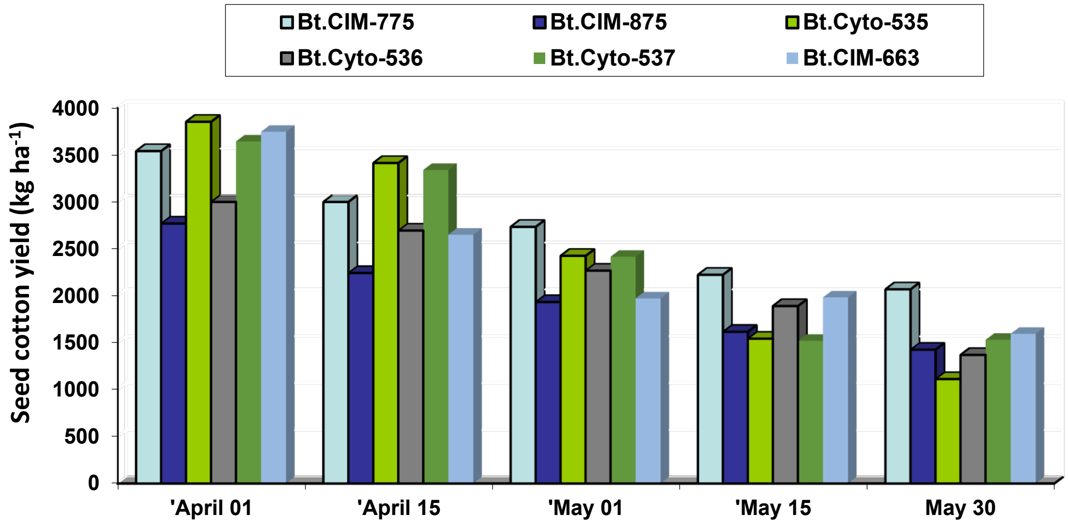

Fig. 11 Seed cotton yield as affected by interactive effects of sowing dates and genotypes

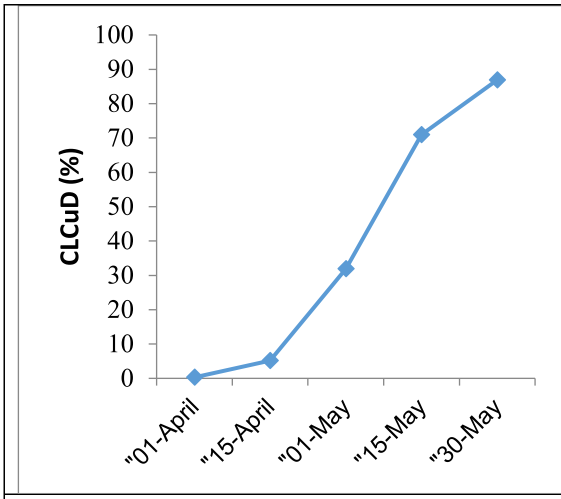

Fig. 12. CLCuD incidence in different sowing dates at 90 DAS

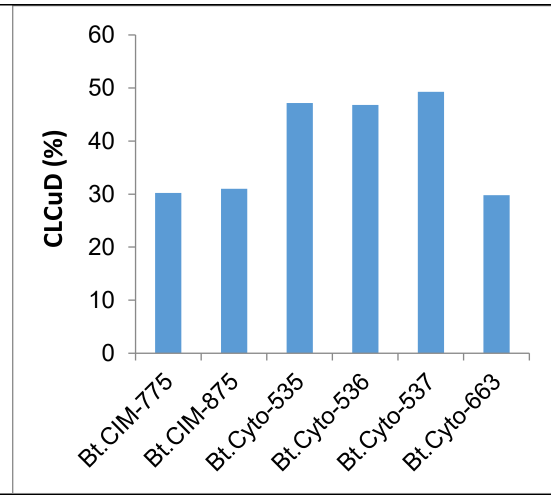

Fig. 13. CLCuD incidence in different genotypes at 90 DAS

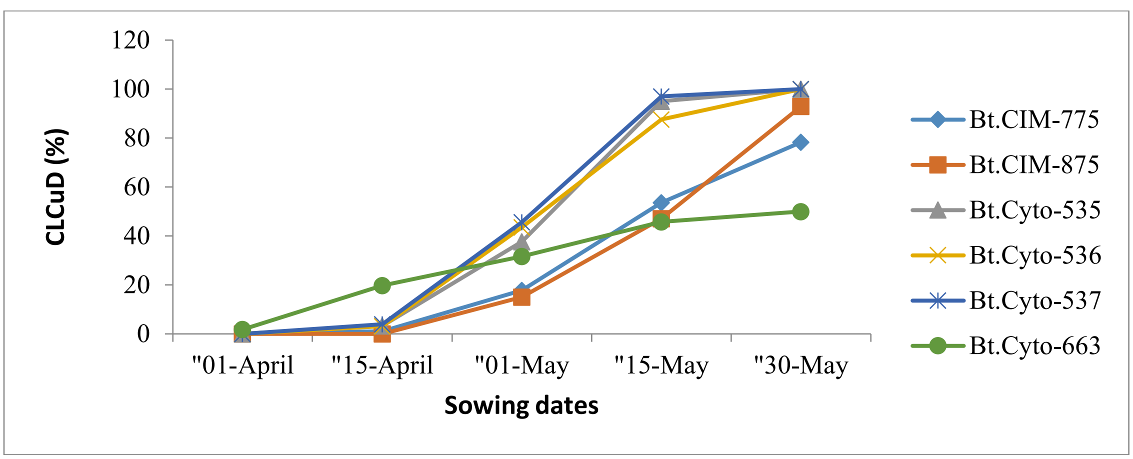

Fig. 14. Interactive effects of sowing dates and genotypes on CLCuD incidence at 90 DAS

The data on CLCuD indicated that the disease incidence increased as the sowing was delayed from April 01 to May 30. The incidence of CLCuD at 90 days old crop was observed 71.0% in May 15 and 86.9% in May 30 sown crop. While April 01, April 15 and May 01 sown crops showed 0.3%, 5.2% and 31.9% virus infestation, respectively at 90 days old crop (Fig.12). On the average basis of sowing dates, genotype *Bt.*CIM-663 showed 0.4%, 1.2%, 17.0%, 17.4% and 19.5% less incidence of CLCuD than *Bt*.CIM-775, *Bt*.CIM-875, *Bt.*Cyto-536, *Bt.*Cyto-535 and *Bt*.Cyto-537, respectively (Fig.13). The interaction between sowing dates and genotypes is illustrated in Fig.14.

1.3 Synchronizing nitrogen application with crop growth

The impact of various application strategies of two levels of nitrogen (150 and 250 kg ha^{-1}) was
The impact of various application strategies of two levels of nitrogen (150 and 250 kg ha^{-1}) was
evaluated on yield performance of *Bt.* CIM-775 and *Bt.* Cyto-535. The application strategies for nitrogen were 10% as basal dose, 25% at squaring, 25% at flowering and 40% at peak flowering (T_1), 25% as basal dose, 25% at squaring, 25% at flowering and 25% at peak flowering (T_2), No basal dose, 25% at squaring, 25% at flowering and 50% at peak flowering (T_3) and No basal dose, 33% at squaring, 33% at flowering and 33% at peak flowering (T_4). The experiment was laid out in randomized complete block design with split-split plot arrangements. The genotypes were allocated to main plots, the nitrogen levels in sub-plot and application strategies were kept in sub-sub plots. The treatments were replicated three times and net plot size was 15 × 64 ft, accommodating six rows in each plot. Recommended crop production and protection practices were performed as per need of the crop. The crop was sown on 31st March, 2021 using seed rate of 15 kg ha^{-1}. The seeds were manually dibbled followed by irrigation, while Dual Gold 960 EC @ 2L per hectare was applied as pre-emergence weedicide on moist beds within 24 hours after sowing. The gap filling was carried out with third irrigation. The fertilizer application at squaring was completed on 25th May 2021 and fertilizer application at flowering was completed on 07th July 2021 and peak flowering was completed on 07th September 2021. All the plots were treated alike except specific treatments application. The data on plant height, number of bolls and boll weight was recorded before final picking. Five plants were randomly selected for plant height and number of bolls per plant. All the bolls from three random selected plants were counted, picked and weighed. The average boll weight was measured by dividing the total seed cotton with the total number of bolls. The whole plot was manually picked and seed cotton weight was converted on hectare basis. The data on plant height, yield and yield components are given in Table 1.3 (d).

The data presented in Table 1.3 (a) demonstrated non-significant interaction between nitrogen dose and genotypes. Similarly, non-significant interaction between genotypes and application strategies was recorded for plant height, yield components and seed cotton yield. The maximum plant height was recorded in *Bt.* CIM-775 when nitrogen was applied according to T_1 and minimum plant height was noticed in *Bt.* Cyto-535 with T_1 application strategies. On the other hand, nitrogen application according to T_4 resulted highest seed cotton yield in *Bt.* Cyto-535. Similarly, the genotype *Bt.* CIM-775 produced the highest seed cotton yield with T_4 (Table 1.3 (b)). The data given in Table 1.3 (c) revealed significant interaction between nitrogen levels and application strategies for seed cotton yield. The nitrogen application at the rate of 150 kg ha^{-1} resulted in highest seed cotton yield when applied according to T_4. Likewise, for 250 kg N ha^{-1}, T_4 resulted in highest seed cotton yield. The three-way interaction between G × N × AS remained non-significant for all recorded observations. The nitrogen means across genotypes and applications strategies showed highest seed cotton yield for 150 kg N ha^{-1}. Except plant height, the highest values for recorded observations were produced from genotype *Bt*. Cyto-535 over *Bt*. CIM-775. The highest seed cotton yield was recorded in T_4 among the application strategies; however, it was statistically non-significant with T_3. Likewise, the differences between T_1 and T_2 were also non-significant with each other.

Table 1.3 (a) Interactive effects of nitrogen rates (N) and genotypes (G) on plant height, bolls per plant, boll weight and seed cotton yield

Genotypes	Nitrogen levels (kg ha^{-1})	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Bt. Cyto-535	150	103.8	28.9	2.94	2974.5
	250	105.4	28.3	2.96	2831.1
Bt. CIM-775	150	124.7	25.7	2.57	2454.9
	250	126.9	24.1	2.56	2304.4

Table 1.3 (b) Interactive effects of genotypes (G) and application strategies (AS) on plant height, bolls per plant, boll weight and seed cotton yield

Genotypes	Application Strategies	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Bt. Cyto-535	T1	99.6	28.9	2.95	2799.7
	T2	102.2	27.5	2.92	2769.6
	T3	107.5	28.4	2.96	2947.9
	T4	109.0	29.6	2.99	3094.0
Bt. CIM-775	T1	130.7	24.4	2.58	2242.6
	T2	124.5	23.1	2.54	2172.2
	T3	127.0	26.6	2.55	2481.1
	T4	121.2	25.6	2.61	2622.6

T1 = 10% at basal, 25% at squaring, 25% at flowering and 40% at peak flowering, **T_2**= 25% at basal, 25% at squaring, 25% at flowering and 25% at peak flowering, **T_3**= No basal, 25% at squaring, 25% at flowering and 50% at peak flowering, **T_4** = No basal, 33% at squaring, 33% at flowering and 33% at peak flowering.

Table 1.3 (c) Interactive effects of nitrogen (N) and application strategies (AS) on plant height, bolls per plant, boll weight and seed cotton yield

Nitrogen levels (kg ha^{-1})	Application strategies	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})
150	T1	113.8	26.7	2.76	2507.6
	T2	112.8	25.2	2.72	2487.4
	T3	116.2	28.3	2.74	2820.1
	T4	114.3	29.0	2.81	3043.7
250	T1	116.5	26.6	2.76	2534.7
	T2	113.9	25.4	2.74	2454.4
	T3	118.3	26.6	2.76	2608.9
	T4	115.9	26.2	2.79	2672.9

Table 1.3 (d) Interactive effects of nitrogen rates, genotypes and application strategies on plant height, bolls per plant, boll weight and seed cotton yield

Genotypes	Nitrogen rates (kg ha^{-1})	Application strategies	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Bt. Cyto-535	150	T1	98.6	28.8	2.93	2803.0
		T2	101.5	26.9	2.90	2798.1
		T3	106.9	28.8	2.95	3023.2
		T4	108.1	31.0	3.0	3273.8
	250	T1	100.5	29.0	2.96	2796.5
		T2	102.9	28.1	2.94	2741.1
		T3	108.1	27.9	2.96	2872.5
		T4	109.9	28.1	2.99	2914.2
Bt. CIM-775	150	T1	128.9	24.6	2.59	2212.2
		T2	124.0	23.4	2.55	2176.7
		T3	125.5	27.9	2.53	2616.9
		T4	120.5	27.0	2.62	2813.6
	250	T1	132.5	24.3	2.56	2273.0
		T2	124.9	22.7	2.53	2167.7
		T3	128.4	25.4	2.57	2345.2
		T4	121.9	24.2	2.59	2431.7

Sub-effects

Nitrogen rates (kg ha^{-1})	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})
150	114.3	27.3 A	2.76	2714.7
250	116.1	26.2 B	2.76	2567.7

Genotypes	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Bt. Cyto-535	104.6	28.6 A	2.95 A	2902.8
Bt. CIM-775	125.8	24.9 B	2.57 B	2379.6

Application strategies	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})
T1 = 10% at basal, 25% at squaring, 25% at flowering and 40% at peak flowering	115.1	26.7 AB	2.76	2521.2
T2 = 25% at basal, 25% at squaring, 25% at flowering and 25% at peak flowering	113.3	25.3 B	2.73	2470.9
T3 = No basal, 25% at squaring, 25% at flowering and 50% at peak flowering	117.2	27.5 A	2.75	2714.5
T4 = No basal, 33% at squaring, 33% at flowering and 33% at peak flowering	115.1	27.6 A	2.80	2858.3

C.D 5%

Variables	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Genotypes (G)	9.6451	1.4630	0.2620	473.38
Nitrogen (N)	ns	0.9637	ns	124.87
Application strategies (AS)	ns	2.1489	ns	179.98
G × N	ns	ns	ns	ns
G × AS	ns	ns	ns	ns
N × AS	ns	ns	ns	305.51
G × N × AS	ns	ns	ns	ns

1.4 Cotton yield response to residues management and tillage systems in cotton-wheat cropping system

The wheat cotton cropping system produces huge amount of residue which is not properly being utilized. In general, wheat straw is burned in the field and cotton sticks are used for cooking in rural areas. These residues contain nutrients which can improve soil health and fertility level. In this experiment, we used various treatments of residues in combination with tillage systems. The treatments included were no residue incorporation (T_1), cotton sticks incorporation (T_2), cotton sticks & wheat straw incorporation (T_3) and wheat straw incorporation (T_4). The cotton genotype *Bt.* CIM-663 were sown on 2ndJune 2021 under normal production practices. The experiment will be continued for five years, starting from 2018-2023. The tillage system was applied following residue incorporation. The post picking left over cotton sticks were incorporated at the rate of 4306 and 4951 kg ha^{-1} for treatments of cotton sticks and wheat straw along with cotton sticks along with chiseling. While in conventional tillage, the residues were incorporated at the rate of 3875 and 4090 kg ha^{-1} for treatments of cotton sticks and wheat-straw along with cotton sticks incorporation, respectively. Prior to incorporation, the soil samples were collected from two cores of soil i.e 0-15 cm and 15-30 cm. The wheat was sown on 26th November, 2021 following the cotton. The plant height and boll numbers were measured from five randomly selected plants from individual plot. The boll weight was worked out by counting all open bolls and picking bolls from three plants. The whole plot was manually picked, weighted and yield was converted on hectare basis.

The data presented in Table 1.4a showed that significant differences occurred only due to residues incorporation. The maximum plant height, bolls per plant, boll weight and seed cotton yield was recorded in plots where both wheat straw and cotton sticks were incorporated. This treatment improved the seed cotton by 9.8%, 19.2% and 25.2%, respectively over cotton sticks incorporation, wheat straw incorporation and control. Similarly, it also improved the plant height, number of bolls, boll weight and seed cotton yield over rest of treatments. The interactive effects of tillage × residue were non-significant for recorded observations. Data on soil analysis are given in Table 1.4b. The results showed that in cotton sticks and wheat straw incorporation plot reduced the EC and pH by 3.7% and 1.3%, respectively. It increased organic matter, available phosphorus and potassium by 0.10%, 4.6% and 9.2%, respectively.

Table 1.4a Effect of various tillage and crop residues management on plant height, yield and yield components of various genotypes

Tillage	Residues	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Chisel and conventional tillage	Cotton sticks	102.1	16.5	2.81	1776
	Cotton sticks and wheat straw	104.1	16.9	2.85	1829
	Wheat straw	99.3	14.6	2.79	1572
	No residue	95.1	14.1	2.75	1480
Conventional tillage	Cotton sticks	98.1	14.2	2.77	1507
	Cotton sticks and wheat straw	100.9	16.5	2.84	1776
	Wheat straw	94.9	14.0	2.75	1453
	No residue	92.0	13.5	2.71	1399

Sub-effects

Tillage	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Chisel and conventional tillage	100.1	15.5	2.80	1664
Conventional tillage	96.5	14.5	2.77	1534

Residues	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Cotton sticks	100.1	15.3	2.79	1642
Cotton sticks and wheat straw	102.5	16.6	2.85	1803
Wheat straw	97.1	14.3	2.77	1512
No residue	93.6	13.8	2.73	1440

C.D. 5%

Variable	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (Kg ha^{-1})
Tillage (T)	ns	ns	ns	ns
Residue (R)	5.35	2.04	0.06	150.92
T × R	ns	ns	ns	ns

Table 1.4b: Soil analysis

Residues incorporation	Texture	Saturation (%)	EC dsm^{-1}	pH	Organic matter (%)	Available phosphorus (mg kg^{-1})	Available potassium (mg kg^{-1})
Cotton sticks	Loam	40.6	5.62	8.12	0.80	8.05	255.0
Cotton sticks and wheat straw	Loam	40.5	5.91	8.10	0.75	8.18	269.2
Wheat straw	Loam	40.0	5.94	8.13	0.71	7.95	251.5
No residue	Loam	39.6	6.14	8.21	0.65	7.82	246.6

1.5 Cotton yield and fiber quality response to high density planting system (HDPS)

The trial was conducted to evaluate the suitability of increased planting densities on yield performance of two cotton genotypes i.e. *Bt.* CIM-663 and *Bt.* Cyto-535. The plant spacings were 15.0, 22.5 and 30.0 cm, while row spacings were 45, 60, 75 and 90 cm. The experimental layout was Randomized Complete Block Design (RCBD) with split-split arrangement with three replications. The genotypes were allocated in main plots, row and plant spaces were allocated in sub and sub-sub plots, respectively. The plot width was variable to adjust the number of rows and plot length was 14 ft. The seeds were sown on 09thApril, 2021 and seed rate was adjusted as per required planting geometry. The beds and furrows were prepared using different bed maker implements. The Dual Gold 960 EC @ 2L per hectare was used on moist beds within 24 hours after planting as pre-emergence herbicide. The crop was grown under normal crop management. The plant population, plant height, number of bolls (m^{-2}) and boll weight was recorded before picking. The whole number of plants in each plot were counted and converted to find out number of plants on hectare basis. The plant height of five plants was measured with measuring scale. The number of bolls (m^{-2}) was recorded by counting all the bolls from all plants in an area of 1 sq. meter. The open bolls from three random selected plants were counted, picked and weighed to get average boll weight. All the plants from each plot were manually picked, weighted and converted on hectare basis. The recorded data are presented in Table 1.5 (d).

The data presented in Table 1.5 (a) showed that interactive effects of genotypes and row spacing were non-significant for all recorded parameters. Similarly, genotypes response was not significantly impacted by plant spacing with respect to various recorded observations (Table 1.5-b). Except plant population, and seed cotton yield none of the variables differed significantly due to interaction between row and plant spacing. The variations in row and plant to plant spacing have direct influence on the number of plants per unit area, therefore significant differences were recorded. Like plant population the seed cotton yield was decreased with increasing either plant spacing or row spacing. This shows its close association with number of plants per unit area. The interaction between genotypes, plant spacing and row spacing remained non-significant in all recorded parameters except seed cotton yield. The highest seed cotton yield was obtained from *Bt.* Cyto-535 with 15-cm plant spacing and 45-cm row spacing. Whereas, genotype *Bt.* CIM-663 produced maximum value for seed cotton yield when planted with 60-cm row spacing and 15-cm plant spacing. The means of genotypes across row and plant spacing showed significant differences only for seed cotton yield where *Bt.*Cyto-535 outperformed the *Bt.* CIM-663. It was due to greater number of bolls (m^{-2}) and higher boll weight. The means of row spacing across genotypes and plant spaces significantly decreased in plant population and seed cotton yield with increasing row spaces. The plant spacing means across the genotypes and row spacing also significantly affected the plant population and seed cotton yield in which these parameters were significantly decreased due to increase in spacing.

Table 1.5 (a): Interactive effects of genotypes and row spacing on plant population, plant height, seed cotton yield and its components

Genotypes	Row spacing (cm)	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Bt. CIM-663	45	97860	109.0	106.9	2.71	2405
	60	73110	116.5	100.9	2.76	2309
	75	57321	114.1	90.5	2.77	2073
	90	45418	117.5	58.0	2.78	1337
Bt. Cyto-535	45	101372	116.0	122.2	2.82	2858
	60	73538	111.3	115.1	2.87	2734
	75	54715	117.4	96.8	2.92	2320
	90	47483	118.3	66.8	2.96	1631

Table 1.5 (b): Interactive effects of genotypes and plant spacing on plant population, plant height, seed cotton yield and its components

Genotypes	Plant spacing (cm)	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Bt. CIM-663	15.0	87882	116.8	103.5	2.70	2314
	22.5	66397	114.3	86.8	2.76	1992
	30.0	51003	111.8	77.0	2.81	1787
Bt. Cyto-535	15.0	89829	118.5	116.1	2.85	2736
	22.5	67017	115.4	95.4	2.89	2269
	30.0	50985	113.5	89.2	2.93	2151

Table 1.5 (c): Interactive effects of row and plant spacing on plant population, plant height, seed cotton yield and its components

Row spacing (cm)	Plant spacing (cm)	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (kg ha^{-1})
45	15.0	134404	115.5	131.1	2.72	2963
	22.5	93114	111.4	114.9	2.77	2646
	30.0	71331	110.7	97.7	2.81	2285
60	15.0	95464	117.4	123.6	2.76	2835
	22.5	70797	114.5	104.4	2.82	2443
	30.0	53712	109.9	96.0	2.87	2287
75	15.0	68426	117.9	110.8	2.80	2554
	22.5	56573	115.7	84.2	2.84	1988
	30.0	43055	113.8	85.9	2.89	2046
90	15.0	57129	119.7	73.7	2.84	1748
	22.5	46344	117.9	60.8	2.87	1446
	30.0	35879	116.2	52.9	2.89	1257

Table 1.5 (d): Interactive effects of genotypes, row and plant spacing on plant population, plant height, seed cotton yield and its components

Genotypes	Row spacing (cm)	Plant spacing (cm)	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Bt. CIM-663	45	15.0	129848	111.2	119.5	2.66	2642
		22.5	92260	108.5	110.6	2.72	2499
		30.0	71473	107.3	90.7	2.76	2075
	60	15.0	94396	120.0	121.7	2.69	2724
		22.5	71331	118.3	93.9	2.76	2156
		30.0	53605	111.2	87.1	2.84	2047
	75	15.0	72399	117.1	109.0	2.72	2440
		22.5	56509	113.0	83.1	2.78	1931
		30.0	43055	112.2	79.4	2.82	1849
	90	15.0	54886	118.7	63.7	2.75	1450
		22.5	45489	117.5	59.6	2.78	1384
		30.0	35879	116.4	50.8	2.81	1176
Bt. Cyto-535	45	15.0	138960	119.8	142.7	2.77	3285
		22.5	93969	114.2	119.2	2.82	2793
		30.0	71188	114.0	104.7	2.85	2495
	60	15.0	96531	114.7	125.5	2.82	2945
		22.5	70263	110.6	115.0	2.87	2729
		30.0	53818	108.5	104.9	2.90	2528
	75	15.0	64454	118.7	112.6	2.87	2669
		22.5	56637	118.3	85.3	2.91	2046
		30.0	43055	115.3	92.4	2.97	2244
	90	15.0	59371	120.7	83.6	2.93	2046
		22.5	47198	118.3	62.0	2.96	1509
		30.0	35879	116.0	54.9	2.98	1338

Sub-effects

Genotypes	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Bt. CIM-663	68427	114.3	89.1	2.76	2031
Bt. Cyto-535	69277	115.8	100.2	2.89	2386

Row spacing (cm)	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (kg ha^{-1})
45	99616	112.5	114.6	2.77	2631
60	73324	113.9	108.0	2.81	2521
75	56018	115.8	93.6	2.84	2196
90	46450	117.9	62.4	2.87	1484

Plant spacing (cm)	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (kg ha^{-1})
15.0	88856	117.6	109.8	2.78	2525
22.5	66707	114.8	91.1	2.82	2131
30.0	50994	112.6	83.1	2.87	1969

C.D 5%

	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Genotypes (G)	ns	ns	ns	ns	100.20
Row spacing (RS)	4010	ns	8.84	ns	162.48
Plant spacing (PS)	2541.6	ns	4.67	ns	82.93
G x RS	ns	ns	ns	ns	ns
G x PS	ns	ns	ns	ns	ns
RS x PS	5083.2	ns	ns	ns	165.86
G x RS x PS	ns	ns	ns	ns	298.96

1.6 Genotypes performance at high density planting system (HDPS)-NCVT trial

The experiment was designed to evaluate the impact of the two plant spacing (15.0 and 22.5 cm) on yield performance of five genotypes coded as PC-2210, PC-2211, PC-2212, PC-2213 and PC-HD. The treatments were laid out in three replications according RCBD split plot by allocating genotypes to main plots and plant spacing in sub plots. The crop was sown on 05th May 2021. The net plot size was 25 × 30 ft, comprising of ten rows. The crop was grown in recommended package of the practices. The crop protection practices were integrated to control various insects and pests. The crop was fertilized with 150 kg N, 50 Kg P_2O_5 and 50 Kg K_2O ha^{-1}. The phosphorous and potassium was applied in one split at 30 days after sowing following the thinning. The nitrogen was applied in three equal splits at squaring, flowering and peak flowering stage. The data on plant population, plant height, bolls (m^{-2}), boll weight and seed cotton yield were recorded. The plant population was calculated by counting the total number of plants in each plot. The plant height was measured with height measuring scale and average plant height was worked out from five plants. The numbers of bolls from all the plants in an area of one square meter were counted. All the open bolls from five plants were picked and average boll weight was recorded by dividing the total seed cotton by number of picked bolls. The seed cotton yield was calculated by weighing the whole seed cotton, picked from each plot. It was further converted to obtain the yield on hectare basis. The data presented in Table 1.6 revealed significant impact of plant spacing on plant population, plant height, bolls and seed cotton yield. These parameters were decreased with increasing plant spaces. While, the boll weight did not vary significantly with plant spacing. The 15.0 cm plant space produced 37.6% higher plant population, 10.8% higher bolls (m^{-2}) and 8.6% higher seed cotton yield. The genotypes had significant impact on plant population, bolls (m^{-2}), boll weight and seed cotton yield. The significant variations among genotypes for plant population were due to differences in germination %age. Among the genotypes, the maximum plant population, bolls (m^{-2}) and seed cotton yield was recorded in PC-2210. Despite the low plant population of PC-2211, it produced higher yield than PC-2212 due to its greater boll size. The interactive effects of genotypes and plant spacing were non-significant for recorded observations.

Table 1.6: Effect of planting density on plant population, plant height, seed cotton yield and its components

Genotypes (code)	Plant spacing	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (Kg ha^{-1})
PC-2210	15.0-cm	78013	132.6	91.4	2.78	2126
	22.5-cm	56139	129.8	86.8	2.80	2049
PC-2211	15.0-cm	69174	116.2	84.6	2.83	1985
	22.5-cm	50039	115.4	75.0	2.86	1789
PC-2212	15.0-cm	74544	125.3	87.0	2.63	1904
	22.5-cm	56150	120.6	77.1	2.66	1717
PC-2213	15.0-cm	36931	118.2	73.9	2.74	1667
	22.5 cm	25642	114.5	65.2	2.78	1546
PC-HD	15.0-cm	39539	124.4	82.7	2.64	1833
	22.5 cm	28715	114.2	74.2	2.67	1660

Sub-effects

Genotypes (code)	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (Kg ha^{-1})
PC-2210	67076	131.2	89.1	2.79	2088
PC-2211	59607	115.8	79.8	2.85	1887
PC-2212	65347	123.0	82.0	2.65	1811
PC-2213	31287	116.4	69.6	2.76	1607
PC-HD	34127	119.3	78.4	2.66	1747

Plant spacing	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (Kg ha^{-1})
15.0-cm	59640	123.3	83.9	2.72	1903
22.5-cm	43337	118.9	75.7	2.75	1752

C.D 5%

Treatments	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (Kg ha^{-1})
Genotypes (G)	3507.9	ns	8.07	0.11	109.24
Plant spacing (PS)	3159.6	3.84	6.25	ns	123.34
G x PS	ns	ns	ns	ns	ns

1.7 Agro-economics feasibility for cotton based intercropping systems.

The cotton genotype *Bt*.Cyto-535 was sown on 22nd April 2021 to evaluate the impact of various intercrops including mung bean (AZRI-06), fodder maize (SG-2002), sesame (T-6) and peanut (BARI-16). The experimental design was randomized complete block design. The net plot size was 20 ft x 100 ft. Bed-furrows were prepared after land preparation in dry condition by employing 75 cm distance in rows. Cotton delinted seeds and intercrops' seed were sown at 22.5 cm and 15.0 cm respectively plant to plant distance by dibbling method followed by irrigation. Dual Gold 960 EC @ 2 L per hectare was sprayed after sowing on moist beds. Nitrogen at the rate of 150 kg ha^{-1} was applied in three split doses. Other cultural practices and plant protection measures were adopted as per need of the crop. The data on plant height, number of bolls and boll weight were recorded before final picking. Five plants were randomly selected for plant height and number of bolls per plant. All the bolls from three randomly selected plants were counted, picked and weighed. The average boll weight was measured by dividing the total seed cotton with the total number of bolls. The whole plot for different intercrops along with cotton and control (cotton alone) was manually harvested and seed cotton & inter crop yield weight was converted on hectare basis. Soon after the harvest of mung bean, corn was planted on 20th July 2021 at the same piece of land along with standing cotton. The data on plant height, number of bolls, boll weight, intercrop yield (biological and economical) and seed cotton yield are given in Table 1.7.

Table 1.7 Impact of different intercroppings on plant height, number of bolls, boll weight, seed cotton yield, intercrops yield and economic returns

Intercrops	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (Kg ha^{-1})	Intercrop yield (Kg ha^{-1})	Income (Rs. ha^{-1})		Total income (Rs. ha^{-1})
						Cotton	Intercrop	
Cotton alone	127.6	28	3.00	2936	-	455080	-	455080
Cotton + Mung bean + Corn	133.0	22	3.02	2230	861 + 2367	345650	172200 + 177525	695375
Cotton + Sesame	130.2	19	2.98	1895	646	293725	129200	422925
Cotton + Peanut	128.7	14	2.96	1395	323	216225	51680	267905
Cotton + Fodder Maize	125.4	16	2.96	1576	19768	244280	74130	318410
C.D.5%	ns	2.73	ns	224.93	-	-	-	-

The data presented in Table 1.7 revealed that among all the treatments, the maximum plant height and boll weight was observed in cotton + mung bean + corn while, the maximum bolls per plant and seed cotton yield was observed in cotton alone. Among the intercrops, cotton + mung bean + corn produced 17.7%, 41.5% and 59.9% higher seed cotton yield as compared to cotton + sesame, cotton + maize and cotton + peanut intercrops, respectively. The cotton alone produced significantly higher seed cotton yield as compared to all other treatments. As far as the economic returns are concerned, fodder maize produced 19768 kg ha^{-1} of green fodder with an income of Rs. 74130/- as compared to 861 kg ha^{-1} of mung bean, 2367 kg ha^{-1} of corn, 323 kg ha^{-1} of peanut and 646 kg ha^{-1} of sesame with monetary returns of Rs.172200/- 177525/-, 51680/- and 129200/- respectively. However, as for as the performance of different intercropping system is concerned, cotton + mung+ corn produced 64.4%, 118.4% and 159.6% high income as compared with cotton + sesame, cotton + fodder maize and cotton + peanut, respectively.

1.8 Cost of production of one acre cotton for the year 2021-22 is given below

Sr. No.	Operations and Inputs	Number/ Quantity	Rate (Rs)	Amount (Rs.)
1.	Seedbed Preparation			**6550**
	a) Cultivation (Ploughing + planking)	4	800/cultivation	3200.00
	b) Leveling	1	700/leveling	700.00
	c) Bed and furrow making	1	1200/acre	1200.00
	d) Pre-emergence Weedicides	800ml	1350/800 ml	1350.00
	e) Bund making	1	100/acre	100.00
2.	Seed			**2126.00**
	a. Cost	8 kg.	10000/40 kg	2000.00
	b. Transportation	-	30/40 kg	6.00
	c. Delinting	-	600/40 kg	120.00
3.	Sowing	2 men day	1378/acre	**1378.00**
4.	Thinning	2 men day	1378/acre	**1378.00**
5.	Interculturing and earthing up	4	800/acre	**3200.00**
6.	Irrigation			**12089.00**
	a. Land preparation (3 hours)	1/3 canal		
	b. *Rouni*(4 hours)	2/3 tubewell	500/hour of tubewell	9333.00
	c. Post planting irrigation (21hours)			
	d. Cleaning of water channel and labour charges for irrigation	4 man day	689/man day	2756.00
7.	*Abiana* (Water rates)	-	125/acre	**125.00**
8.	Fertilizer			**10149.00**
	a. DAP (Di-Amonium Phosphate)	1 bag	3850/bag	3850.00
	b. Urea	3.0 bags	1830/bag	5490.00
	c. Transportation	4.0 bags	30/bag	120.00
	d. Fertilizer Application Charges	1man day	689/day	689.00
9.	Plant Protection			**5000.00**
	a. Sucking	5	850/spray	4250.00
	b. Bollworm	1	750/spray	750.00
10.	Harvesting (Picking charges)	800 Kg	15.0/kg	**12000.00**

11 11a	Stick Cutting Value of cotton sticks	2 men day	689/man day	+1378.00 -1378.00
12.	Managerial Charges for 1 acre	7 months	32000/month/100 acre	**2240.00**
13.	Land Rent	7 months	40,000/acre/annum	**23,333.00**
14.	Unforeseen Expenses	-	3000/acre	**3000.00**
15.	Production Expenditure a. Including Land Rent b. Excluding Land Rent	-	-	 **82568.00** **59235.00**
16.	Mark-up on Investment a. Including Land Rent b. Excluding Land Rent	7 months	12.5% for one year	 **6020.58** **4319.22**
17.	Total Expenditure a. Including Land Rent b. Excluding Land Rent	--		 **88588.58** **63554.22**
18.	Income of Seed Cotton	800 kg	6200/40 kg	**124000. 00**
19.	Market expenses	800 kg	120/40 kg	**2400. 00**
20.	Cost of Production at Farm level a. Including Land Rent b. Excluding Land Rent	-	 Per 40 kg	 **4429.43** **3177.71**
21.	Cost of production at Market Including Land Rent. Excluding Land Rent.	-	 Per 40 kg	 **4549.43** **3297.71**

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2. PLANT BREEDING & GENETICS SECTION

Plant Breeding & Genetics Section develops new cotton varieties or lines with desirable fibre characteristics by utilizing purposeful breeding (crossing) among closely or distantly related genotypes. Plants are crossbred to introduce traits/genes from one variety or line into a new genetic background. The promising *Bt*. and non-*Bt*. strains of all the cotton breeders of the country were evaluated under National Coordinated Variety Trial (NCVT) Program of Pakistan Central Cotton Committee. The commercial varieties (*Bt*. and non-*Bt*.) were also tested for their performance under local conditions in standard varietal trial. The advance breeding materials were tested in Micro-varietal and varietal trials to test their yield potential and other economic parameters. The breeding materials in different filial generations were screened out for advance filial generations. Major emphasis was laid on the selection of material having resistance/tolerance to heat and drought, CLCuV and Pink boll worm along with excellent fibre characteristics. Fresh crosses were also attempted to develop resistance/tolerance to heat, drought and insect-pests along with Glyphosate resistance in *Bt*. & Non-*Bt* breeding material. Pre-basic seed of commercial varieties viz., *Bt*.CIM-678, *Bt*.CIM-785, *Bt*.CIM-663, *Bt*.CIM-632, *Bt.*CIM-602, *Bt.*CIM-600, CIM-620, CIM-610 and CIM-554 were produced for distribution to public and private seed corporations for further multiplication. The genetic stock of World Cotton collections comprising of 6226 cultivars of the four *Gossypium* species is being preserved for short (25 years), medium (50 years) and long (100 years) term as well as for utilization in breeding program by cotton breeders in the country and abroad. Trainings were also imparted to small farmers, progressive growers and students from different colleges and universities. The result of the trials are described as below.

Testing of new strains

2.1.1 Varietal Trial-1

Objective: Testing and evaluation of promising medium long staple *Bt*. strains for the development of commercial varieties

Nine medium long staple promising *Bt*. strains viz., CIM-651, CIM-753, CIM-782, CIM-783, CIM-784, CIM-787, CIM-788, CIM-790, and CIM-791 were evaluated against *Bt*. commercial variety i.e. *Bt*.CIM-663 at CCRI, Multan. Data of seed cotton yield and other parameters are given in **Tables 2.1.**

The data revealed that the strain CIM-782 produced the highest seed cotton yield of 2036 kg ha^{-1} followed by CIM-787 having yield 1932 kg ha^{-1} while the standard variety *Bt*.CIM-663 yielded 1436 kg ha^{-1} **(Table 2.1).**

Table 2.1 Yield Performance of advanced strains in Varietal Trial-1

Sr. #	Strains	Seed Cotton Yield (kg ha^{-1})	Lint Yield (kg ha^{-1})	Lint (%age)	Staple length (mm)	Micronaire value	Fibre strength (g/tex)	Av. Boll Weight (g)	Plant Pop. (ha^{-1})
1.	CIM-651	1478	568	38.4	29.5	4.1	29.5	3.5	40440
2.	CIM-753	1480	591	39.9	28.1	4.1	27.3	2.9	40978
3.	CIM-782	2036	821	40.3	28.1	4.4	27.7	3.1	38467
4.	CIM-783	1533	599	39.1	28.0	4.2	27.7	3.3	38198
5.	CIM-784	1624	567	34.9	27.5	4.5	27.3	2.9	40260
6.	CIM-787	1932	736	38.1	28.4	4.0	27.1	3.7	39274
7.	CIM-788	1096	432	39.4	28.4	4.7	28.3	2.8	40619
8.	CIM-790	1523	579	38.0	28.1	4.0	26.9	3.3	41247
9.	CIM-791	1473	566	38.4	29.0	4.8	28.9	3.0	38646
10.	CIM-663	1469	548	37.3	27.4	4.3	26.3	3.7	39543

Sowing date = 21.04.2021;CD (5%) for seed cotton: Strains = 208.12; CV % = 7.76

The new strain CIM-782 produced the highest lint percentage of 40.3 followed by CIM-753 having lint percentage values of 39.9 as compared with the standard *Bt*.CIM-663 (37.3%) **Table 2.1**). The new strain CIM-651 produced the longest staple of 29.5 mm, followed by CIM-791 with 29.0 mm while the standards *Bt*.CIM-663 produced 27.4 mm staple length **(Table 2.1).**

All the new strains possess desirable micronaire value ranging from 4.0 to 4.8 in comparison to *Bt*.CIM-663 with 4.3.The fiber strength of all new strains and standards are in desirable range **(Table 2.1).**

2.1.2 Varietal Trial-2

Objective: Testing and evaluation of promising medium long staple strains for the development of commercial varieties

Eight new strains with medium-long staple viz., *Bt*.CIM-757, *Bt*.CIM-758, *Bt*.CIM-759, *Bt*.CIM-762, *Bt*.CIM-778, *Bt*.CIM-781, *Bt*.CIM-792, and *Bt*.CIM-663 were tested at CCRI, Multan.

Data presented in **Table 2.2** showed that the new strain *Bt*.CIM-762 produced the highest seed cotton yield of 2192 kg ha^{-1} followed by *Bt*.CIM-792 with 2153 kg ha^{-1} while the standard variety *Bt*.CIM-663 produced 1841 kg ha^{-1}.The strain *Bt*.CIM-762 had the highest lint percentage of 40.1 %, followed by 39.1% of *Bt*.CIM-792 in comparison to the commercial variety *Bt*.CIM-663 that produced 38.0% lint percentage. The strain *Bt*.CIM-759 produced the longest staple of 29.0 mm followed by *Bt*.CIM-778 having 28.8 mm against the 26.4mm of standard of *Bt*.CIM-663 **(Table 2.2).**All the strains possess desirable micronaire values ranging from 3.8 to 4.2**.** The fibre strength of the strains ranged from 26.4 to 28.9 g tex^{-1} **(Table 2.2).**

Table 2.2 Yield Performance of advanced strains in Varietal Trial-2

Strains	Seed cotton yield (kg ha^{-1})	Lint yield (kg ha^{-1})	Lint (%age)	Staple length (mm)	Micronaire value	Fibre strength (g/tex)	Av. boll Wt (g)	Plant Pop. (ha^{-1})
Bt.CIM-757	1953	749	38.4	28.2	4.2	28.7	3.3	41157
Bt.CIM-758	2126	812	38.2	28.4	4.1	28.6	3.1	40709
Bt.CIM-759	1926	733	38.1	29.0	4.2	28.6	3.5	42950
Bt.CIM-762	2192	878	40.1	28.0	4.1	27.6	3.4	42323
Bt.CIM-778	1943	742	38.2	28.8	3.8	28.9	3.5	42909
Bt.CIM-781	2006	772	38.5	27.8	4.2	26.4	3.2	39722
Bt.CIM-792	2153	841	39.1	28.5	4.2	28.7	3.7	41247
Bt.CIM-663	1841	699	38.0	26.4	4.1	26.7	3.6	40798

Sowing date = 21.04.2021;CD (5%) for seed cotton: Strains = 297.03; CV % = 8.41

2.1.3 Varietal Trial-3

Objective: Testing and evaluation of promising medium long staple non *Bt*. strains for the development of commercial varieties

Seven promising *Bt*. strains viz. *Bt*.CIM-741, *Bt*.CIM-743, *Bt*.CIM-744, *Bt*.CIM-746, *Bt*.CIM-768, *Bt*.CIM-769 and *Bt*.CIM-770 were evaluated against cultivar *Bt*.CIM-663 at CCRI, Multan. Data on seed cotton yield and other parameters are given in **Table 2.3**.

Strain *Bt*.CIM-768 produced the highest seed cotton yield of 1838 kg ha^{-1} followed by *Bt*. CIM-746 having yield of 1568 kg ha^{-1} while the standard *Bt*.CIM-663 produced 1323 kg ha^{-1} seed cotton yield **(Table 2.3).**

Table 2.3 Yield Performance of advanced strains in Varietal Trial-3

Strains	Seed cotton yield (kg ha^{-1})	Lint (%age)	Staple length (mm)	Micronaire value	Fibre strength (g/tex)	Av. Boll wt (g)	Plant Pop.(ha^{-1})
Bt.CIM-741	1013	39.3	26.9	4.5	26.3	2.7	40347
Bt.CIM-743	1367	39.0	27.6	4.8	26.0	2.7	33713
Bt.CIM-744	1473	38.7	28.6	4.6	28.0	2.8	35057
Bt.CIM-746	1568	38.9	28.6	3.9	28.6	3.1	36223
Bt.CIM-768	1838	38.2	29.1	4.2	28.5	3.0	34519
Bt.CIM-769	1347	38.0	28.1	4.1	27.2	2.8	32009
Bt.CIM-770	1277	36.0	29.0	3.8	28.8	3.1	28692
Bt.CIM-663	1323	36.7	27.8	4.4	26.0	3.6	38734

Sowing date = 17-04-2021 CD (5%) for seed cotton: Strains = 251.95; CV % = 10.27

Bt.CIM-741 produced the highest lint percentage of 39.3, followed by *Bt*.CIM-743 having lint percentage of 39.0 **(Table 2.3).** *Bt*.CIM-768 produced the longest staple of 29.1 mm, followed by *Bt*.CIM-770 with 29.0 mm while the standard *Bt*.CIM-663 produced 27.8mm **(Table 2.3).**

All the new strains possess desirable micronaire values ranging from 3.8 to 4.8 against the standard *Bt*.CIM-663 with micronaire value of 4.4. The fibre strength of all new strains and standards is in the desirable range, i.e. 26.0 to 28.8 g/tex **(Table 2.3).**

2.1.4 Micro Varietal Trial-1

Objective:-Testing of newly bulked long staple *Bt.* strains to develop Commercial varieties.

Nine newly bulked strains numbering from MV-1/21 to MV-9/21 were tested against commercial variety *Bt*.CIM-663 at CCRI, Multan. The new strain MV-2/21 surpassed all the strains and standard variety in seed cotton yield by producing 2346 kg ha^{-1}, followed by MV-1/21 with 2050 kg ha^{-1} and MV-9/21 having 2023 kg ha^{-1} compared with 1502 kg ha^{-1} of *Bt*.CIM-663 **(Table 2.4).**

The strain MV-5/21 produced the highest lint percentage of 42.1 followed by 40.8 percent lint in MV-1/21 while the commercial variety *Bt*.CIM-663 produced the lint percentage of 37.9. The strain MV-1 produced the longest staple of 29.2 mm, followed by 28.8 mm in MV-6/21 compared with the fibre length of 26.0 mm in commercial variety *Bt*.CIM-663. All the strains have desirable micronaire values. The strain MV-1/21 maintained the maximum fibre strength of 29.1 g/tex, followed by 28.7 g/tex in MV-6 while the standard *Bt.*CIM-663 had 26.1 g/tex.

Table 2.4 Performance of advanced strains in Micro Varietal Trial-1 at CCRI, Multan

Strains	Seed Cotton Yield (kg ha^{-1})	Lint Yield (kg ha^{-1})	Lint (% age)	Staple length (mm)	Micro-naire value	Fibre strength (g/tex)	Av. boll wt. (g)	Plant Pop. (ha^{-1})
MV-1/21	2050	836	40.8	29.2	4.5	29.1	3.8	45013
MV-2/21	2346	922	39.3	28.5	4.0	28.5	3.1	44654
MV-3/21	1248	487	39.0	27.2	4.4	26.8	3.3	41067
MV-4/21	1803	656	36.4	28.3	4.1	28.5	3.0	43937
MV-5/21	1662	700	42.1	28.0	4.1	28.2	3.3	44475
MV-6/21	1592	607	38.1	28.8	4.6	28.7	3.4	44475
MV-7/21	1856	718	38.7	28.3	4.1	28.4	3.5	44654
MV-8/21	1709	627	36.7	26.7	4.0	26.7	3.2	43757
MV-9/21	2023	801	39.6	28.1	3.9	27.8	3.1	42143
CIM-663/ 21	1502	569	37.9	26.0	4.3	26.1	3.4	42143

Sowing date = 21.04.2021;CD (5%) for seed cotton: Strains = 310.24; CV % = 10.17

2.1.5 Micro Varietal Trial-2

Objective:-Testing of newly bulked medium-long staple with high lint percentage *Bt*. strains to develop commercial varieties

Nine newly bulked strains numbering from MV-10 to MV-18 were tested against commercial variety *Bt*.CIM-663 at CCRI, Multan. The new strain MV-10/21 surpassed all the strains and standard variety in seed cotton yield by producing 2434 kg ha^{-1}, followed by MV-11/21 with 2224 kg ha^{-1} and MV-13/21 having 1898 kg ha^{-1} compared with 1444 kg ha^{-1} yield of *Bt.*CIM-663 **(Table 2.5).**The strain MV-14/21 produced the highest lint percentage of 42.0 followed by 41.0 percent lint in MV-16/21 while the commercial variety *Bt*.CIM-663 produced the lint percentage of 39.2. The strain MV-15/21 produced the longest staple of 29.6 mm, followed by 29.0 mm in MV-14/21 compared with the fibre length of 26.8 mm in commercial variety *Bt*.CIM-663. All strains have micronaire values ranging from 3.7 to 4.6. The strain MV-15/21 maintained maximum fibre strength of 29.3 g/tex, followed by 28.2 g/tex in MV-14/21 while standard *Bt.*CIM-663 had 26.4 g/tex.

2.1.6 Micro Varietal Trial-3

Objective:- Testing of newly bulked medium-long staple strains to develop commercial varieties

Nine newly bulked *Bt*. strains numbering from MV-19/21 to MV-27/21 were tested against cultivar *Bt*.CIM-663 at CCRI, Multan. Data presented in **Table 2.6** indicated that the new strain MV-19/21 surpassed all the new strains yielding 2407 kg ha^{-1}, followed by strains MV-23/21 and MV-25/21 which produced 2370 and 2312 kg ha^{-1} seed cotton respectively, while the standard *Bt*.CIM-663 yielded 2079 kg ha^{-1}. The new strain MV-25/21 produced the highest lint percentage of 39.8 followed by 39.3% of both MV-23/21 and MV-21/21 in comparison to *Bt*.CIM-663 having 38.3 lint percentage. The strain MV-19/21 has the longest staple of 28.9 mm followed by MV-22/21 with the staple of 28.5 mm compared with the staple length of 28.1 mm of standard *Bt*.CIM-663. All the genotypes have desirable micronaire value except MV-19/21. All the strains were showing fibre strengths ranging from 25.0 to 29.4 g/tex.

Table 2.5 Performance of advanced strains in Micro-Varietal Trial-2 at CCRI, Multan

Sr. #	Strains	Seed Cotton Yield (kg ha^{-1})	Lint Yield (kg ha^{-1})	Lint (% age)	Staple Length (mm)	Micro-naire value	Fibre Strength (g/tex)	Av. boll wt. (g)	Plant Pop. (ha^{-1})
1.	MV-10/21	2434	959	39.4	28.3	4.3	27.8	3.7	44116
2.	MV-11/21	2224	838	37.7	28.0	4.3	27.5	3.6	44116
3.	MV-12/21	1309	512	39.1	28.4	3.8	27.9	3.0	42143
4.	MV-13/21	1898	748	39.4	28.2	4.1	27.8	2.9	44654
5.	MV-14/21	1572	660	42.0	29.0	4.6	28.2	3.2	40709
6.	MV-15/21	1749	686	39.2	29.6	3.7	29.3	3.3	44833
7.	MV-16/21	1452	595	41.0	27.1	4.6	26.8	3.1	34970
8.	MV-17/21	1266	509	40.2	27.0	4.6	26.9	3.1	42861
9.	MV-18/21	1446	568	39.3	28.8	4.1	28.1	3.4	40888
10.	CIM-663/21	1444	566	39.2	26.8	4.4	26.4	3.5	42143

Sowing date = 21.04.2021; CD (5%) for seed cotton = 269.62; CV. % = 9.14

Table 2.6 Performance of advanced strains in Micro-Varietal Trial-3 at CCRI, Multan

Sr. #	Strains	Seed cotton yield (kg ha^{-1})	Lint Yield (kg ha^{-1})	Lint (% age)	Staple length (mm)	Micro naire value	Fibre Strength (g/tex)	Av. boll weight (g)	Plant Pop. (ha^{-1})
1.	MV-19/21	2407	932	38.7	28.9	3.6	28.8	3.3	41284
2.	MV-20/21	2020	780	38.6	28.1	4.1	27.9	2.9	39690
3.	MV-21/21	2082	819	39.3	28.0	4.5	26.7	3.3	41125
4.	MV-22/21	2221	844	38.0	28.5	4.5	28.0	3.5	42559
5.	MV-23/21	2370	931	39.3	28.4	4.4	29.0	3.3	36183
6.	MV-24/21	1899	739	38.9	28.2	4.3	27.5	3.0	38096
7.	MV-25/21	2312	921	39.8	27.3	4.1	29.4	3.1	39052
8.	MV-26/21	2088	805	38.6	27.9	4.3	26.7	3.0	28692
9.	MV-27/21	2089	806	38.6	28.4	4.3	25.0	2.8	32198
10.	CIM-663	2079	796	38.3	28.1	4.2	27.9	3.9	38255

Sowing date = 14.04.2021;CD (5%) for seed cotton = 170.20; CV. % = 4.60

2.1.7 Micro-Varietal Trial-4

Objective: Testing of medium long staple with yield potential *Bt*. strains to develop commercial varieties

Nine newly bulked elite *Bt*. strains from MV-28/21 to MV-36/21 were tested against commercial variety *Bt.*CIM-663 at CCRI, Multan. Data on yield and other parameters are presented in **Table 2.7**.

The strain MV-33/21 out-yielded all the strains and standard variety by producing 3187 kg ha^{-1} seed cotton, followed by MV-29/21 and MV-36/21 having seed cotton yields of 2794 kg ha^{-1} against commercial variety *Bt.*CIM-663 which produced 2512 kg ha^{-1} seed cotton. The strain MV-35/21 produced the highest lint percentage of 41.2% followed by MV-31/21 with 39.0 and MV-33/21 with 38.8 %.compared with that of 38.7% by *Bt.*CIM-663.The strain MV-36/21 produced the longest staple of 28.5 mm, followed by the 28.3 mm of strain MV-29/21, MV-32/21 and MV-33/21 compared with the 27.8 mm of *Bt.*CIM-663. The maximum micronaire value 4.3 were recorded in MV-35/21 and MV-36/21 while standard has micronaire value of 3.9. The fibre strength of all the new strains were observed within the range i.e. 26.7 to 29.7.g/tex **(Table 2.7).**

Table 2.7 Performance of advanced strains in Micro-Varietal Trial-4 at CCRI, Multan

Sr. #	Strains	Seed Cotton Yield (kg ha^{-1})	Lint Yield (kg ha^{-1})	Lint (% age)	Staple Length (mm)	Micro-naire value	Fibre Strength (g/tex)	Av. boll weight (g)	Plant pop. (ha^{-1})
1.	MV-28/21	2429	904	37.2	27.9	3.8	28.8	3.9	38019
2.	MV-29/21	2794	1056	37.8	28.3	3.8	28.6	3.6	36584
3.	MV-30/21	2512	945	37.6	27.0	3.7	27.2	3.8	38377
4.	MV-31/21	2472	964	39.0	28.2	4.0	28.3	3.4	37122
5.	MV-32/21	2518	972	38.6	28.3	3.7	29.3	3.5	34073
6.	MV-33/21	3187	1237	38.8	28.3	4.0	27.6	3.6	38377
7.	MV-34/21	2452	934	38.1	27.9	4.2	26.7	3.7	36943
8.	MV-35/21	2429	1001	41.2	28.0	4.3	27.5	3.9	38019
9.	MV-36/21	2794	1070	38.3	28.5	4.3	29.7	3.5	36584
10.	CIM-663	2512	972	38.7	27.8	3.9	27.1	3.8	38377

Sowing date = 19-04-2021; CD (5%) for seed cotton = 155.976; CV. % = 6.03

2.2 Coordinated Variety Testing Programme

2.2.2 National Coordinated Varietal Trials (Set-B)

Objective: Testing of promising *Bt.* strains of different cotton breeders of Pakistan

Twenty strains from different cotton breeders of the country were received in coded numbers from Director of Research PCCC for evaluation at CCRI Multan.

The data presented in **Table 2.8** showed that the CIM-600 (Standard) produced the highest seed cotton yield of 2098 kg ha^{-1} followed by TEVC-49 having 2087 kg ha^{-1} seed cotton yield while JSQ-White-Gold produced lowest seed cotton yield of 1086 kg ha^{-1}. Data also revealed that the strain Rawal-222 produced the highest lint percentage of 42.7 followed by PC-2121 with 42.0% while strain TEVC-49 produced the longest staple with 28.8 mm length followed by BAHAR-GTG-155 with 28.5mm.The ranging of micronaire value ranged from 4.1 to 5.5 . Maximum fibre strength was maintained by TEVC-49 having 28.4 g/tex while Suncrop-3 (Diamond-24) had 24.2 g/tex fibre strength.

Table 2.8 Performance of Different of Public Sector in National Coordinated Varietal Trial (Set-B) at CCRI, Multan

Strains	Variety's name	Seed-cotton Yield (kg ha^{-1})	Lint Yield (kg ha^{-1})	Lint (%age)	Staple length (mm)	Micron aire value	Fibre strength (g/tex)	Plant Pop. (ha^{-1})
PC-2111	Sahara-Klean-10	1485	612	41.2	26.5	4.8	25.4	41165
PC-2112	JSQ-White-Gold	1086	420	38.7	26.0	4.4	27.1	37815
PC-2113	Suncrop-3(Diamond-24)	1475	614	41.6	25.5	5.5	24.2	41764
PC-2114	Tara-CKC-333	1510	609	40.3	27.6	4.6	27.0	39969
PC-2115	TEVC-49	2087	839	40.2	28.8	4.2	28.4	37934
PC-2116	Tahafuz-25	1498	616	41.1	27.4	4.7	27.3	38892
PC-2117	FBS-Falcon	1313	527	40.1	26.0	4.8	26.3	40208
PC-2118	CIM-600 (Standard)	2098	755	36.0	27.7	4.1	27.7	40804
PC-2119	Rawal-222	1634	698	42.7	26.9	4.2	27.6	39729
PC-2120	Thakar-76(Uneek-123)	1535	626	40.8	26.8	4.8	26.0	38533
PC-2121	PC-2121	1603	673	42.0	25.7	4.9	24.8	39011
PC-2122	Rawal-111	1909	701	36.7	25.3	4.5	24.3	38293
PC-2123	TEVC-111	1343	524	39.0	27.1	4.8	26.5	37934
PC-2124	YBG-2525	1637	679	41.5	27.0	4.6	25.7	36379
PC-2125	CKC-7	1798	719	40.0	27.2	4.9	26.4	38892
PC-2126	BAHAR-GTG-155	1279	515	40.3	28.5	4.7	26.8	37934
PC-2127	ICS-386	1518	630	41.5	26.0	4.5	26.0	41883
PC-2128	Ghauri-3	1134	451	39.8	26.7	4.3	27.3	36498
PC-2129	Tara-CKC-335	1630	652	40.0	26.4	5.0	25.7	41046
PC-2130	CKC-8	1724	721	41.8	25.9	5.0	25.6	40328

Sowing date 11.05.2021

2.3 Testing of Commercial Varieties

2.3.1 Standard Varietal Trial-1

Objective:- To test the performance of non-*Bt.* commercial varieties under the agro-climatic conditions of Multan

Seven commercial Non *Bt*. varieties were tested at CCRI, Multan. Data recorded on seed cotton yield and other parameters are presented in **Table 2.9**. The results indicated that variety CIM-496 excelled among all varieties by producing seed cotton yield of 1304 kg ha^{-1} followed by the variety CIM-608 with 1270 kg ha^{-1} and CIM-620 with 1173 kg ha^{-1} seed cotton yield. Variety CIM-573 had the highest lint percentage of 40.4, followed by variety Cyto-124 having lint percentage of 39.1. The variety Cyto-124 maintained the longest staple of 28.7 mm, followed by the variety the CIM-573 with 28.3 mm staple length.

Table 2.9 Performance of commercial varieties in Standard Varietal Trial-I at CCRI, Multan

Sr. #	Varieties	Year of release	Seed Cotton Yield (kg ha^{-1})	Lint Yield (kg ha^{-1})	Lint (% age)	Staple length (mm)	Micro-naire value ()	Fibre Strength (g/tex)	Av. Boll wt. (g)	Plant Pop. (ha^{-1})
1.	CIM-482	2000	1084	411	38.0	27.3	4.1	28.0	3.4	39657
2.	CIM-496	2005	1304	477	36.6	27.4	3.9	28.2	3.6	38222
3.	CIM-573	2012	1167	472	40.4	28.3	4.1	30.6	3.3	41272
4.	CIM-608	2013	1270	493	38.8	27.8	4.1	29.0	3.3	38222
5.	Cyto-124	2015	1127	441	39.1	28.7	4.0	30.4	3.4	39119
6.	CIM-620	2016	1173	441	37.5	27.8	4.1	28.4	3.3	35709
7.	CIM-610	2018	1107	401	36.2	27.7	3.9	29.2	3.5	39837

Sowing date: 19.04.2021; C.D. (5%) for seed cotton 224.54 CV% = 10.72

Micronaire values of all the varieties were according to the permissible range. Fibre strength of all the genotypes was in the desirable range.

2.3.2 Standard Varietal Trial-2

Objective:-To test the performance of commercial *Bt*. varieties under the agro-climatic conditions of Multan

Seven *Bt*. commercial varieties were tested for seed cotton yield and fiber characteristics at CCRI, Multan. Data recorded on seed cotton yield and other parameters are presented in **Table 2.10**. The results indicated that variety *Bt*.CIM-663 excelled among all varieties by producing seed cotton yield of 2512 kg ha^{-1}, followed by the variety *Bt*.CIM-600 with 2146 kg ha^{-1} while *Bt*.CIM-602 produced lowest (1883 kg ha^{-1}) seed cotton yield. *Bt*.CIM-632 had the highest lint percentage of 39.1 followed by CIM-598 (38.3%) while *Bt*.CIM-602 had the lowest (36.8%) lint percentage. Staple lengths of all the varieties ranged from 27.5 to 29.6mm. Micronaire value of all the varieties were in desirable range. Fibre strength range from 26.3 to 28.8 g/tex.

Table 2.10 Performance of commercial varieties in Standard Varietal Trial-2 at CCRI, Multan

Sr. #	Varieties	Year of release	Seed Cotton Yield (kg ha^{-1})	Lint Yield (kg ha^{-1})	Lint (% age)	Staple length (mm)	Micro-naire value	Fibre Strength (g/tex)	Av. Boll wt. (g)	Plant Pop. (ha^{-1})
1.	*Bt*.CIM-598	2012	2011	770	38.3	27.8	3.8	26.9	3.3	40407
2.	*Bt*.CIM-602	2013	1883	693	36.8	28.2	4.0	28.5	3.1	41125
3.	*Bt*.CIM-600	2016	2146	811	37.8	27.9	4.1	28.8	3.2	37897
4.	*Bt*.Cyto-179	2017	2042	780	38.2	27.5	3.8	27.3	3.7	40288
5.	*Bt*.CIM-632	2018	1626	636	39.1	29.6	4.1	28.2	2.9	41483
6.	*Bt*.CIM-663	2021	2512	954	38.0	28.0	4.3	26.3	3.9	40766
7.	*Bt*.CIM-343	2021	1969	750	38.1	28.2	4.4	27.8	3.3	41722

Sowing date: 14.04.2021; C.D.(5%) for Seed Cotton Yield=185.23; CV% = 5.14

2.4. Yield comparison of Local vs. Exotic cotton genotypes

Objective: To test the performance of local genotypes against exotic under the agro-climatic conditions of Multan

Six local and five exotic genotypes were tested for seed cotton yield at CCRI, Multan. Data recorded on seed cotton yield and other parameters are presented in **Table 2.11**. The results indicated that SLH-Chandi surpassed all genotypes by producing seed cotton yield of 3228 kg ha^{-1}, followed by the variety *Bt*.CIM-663 with 2654 kg ha^{-1} while exotic genotypes produced seed cotton yield ranges from 502 to 1435 kg ha^{-1}. Boll weight of local genotypes ranges from 2.1 to 3.2 g while that of exotic genotypes range from 2.1 to 2.3 g.

Table 2.11 Performance of local and exotic genotypes at CCRI, Multan

Sr. #	Varieties	Origin	Seed Cotton Yield (kg ha^{-1})	Av. Boll wt. (g)
1.	MNH-1035	CRI, Multan, Pakistan	2439	2.7
2.	DIK	CRS, DI Khan, Pakistan	2367	2.2
3.	CIM-663	CCRI, Multan, Pakistan	2654	3.2
4.	SLH-Chandi	CRS, Sahiwal, Pakistan	3228	2.9
5.	Sindh-1	ARI, Tandojam, Pakistan	1793	2.1
6.	GH-Sultan	CRS, Ghotki, Pakistan	2511	2.6
7.	Acala-5-918	USA	502	2.1
8.	SA-71	USSR	1076	2.1
9.	Carolina Queen	Turkey	1435	2.3
10.	BPA	Brazil	1004	2.2
11.	BJA-HC-27-B/163	France	1076	2.2

Sowing date: 14.04.2021

2.5 Breeding Material

2.5.1 Selection from Breeding Material

Single plant selections were made from the breeding material in different segregating generations for further testing and screening against biotic and a biotic stresses. The detail of breeding material planted and number of plants selected during 2021-22 is given in **Table 2.12**.

Table 2.12 Detail of single plants selected from breeding material

Generation/Trial	No. of plants Selected	Range	
		Lint (%age)	Staple length (mm)
VT	337	37.9 - 43.4	27.9 - 30.1
MVT	329	39.5 - 43.2	28.0 - 30.4
F_7 single lines	96	39.4 - 43.8	28.1 - 30.4
F_6 single lines	478	39.3 - 43.3	28.3 - 30.2
F_5 single lines	809	38.4 - 42.3	28.1 - 30.1
F_4 generation	1004	39.0 - 42.8	28.5 - 30.7
F_3 generation	773	37.7 - 42.8	27.8 - 29.8
F_2 generation	912	37.5 - 41.9	27.4 - 31.3
Others	64	37.5 - 44.4	27.2 - 32.5
EGS Production	781	38.0 - 40.1	28.0 - 29.5

2.6 Maintenance of Genetic Stock of World Cotton Collection

2.6.1 Maintenance/Preservation of Cotton Genetic Stock at CCRI Multan

With the induction of 83 new genotypes of different cotton breeders, now six thousand two hundred and twenty six genotypes are being maintained at CCRI Multan for Long (100 years), medium (50 years) and short term (25 years) duration. One third of the seed was planted in the field for production of fresh seed as well as to utilize in the hybridization programme. Detail of genetic stock is given in **Table 2.13.** The seed of genetic stock were also supplied, locally and abroad, to different scientists, cotton growers, academia and different institutes/research stations for their research/breeding programs. The detail is given in **Table 2.14.**

Table 2.13 Detail of Genetic Stock of World Cotton Collection

Local genotypes	1293
Exotic genotypes	4933
Total	**6226**
Species-Wise Detail	
Gossypium herbaceum L.	556
Gossypium arboreum L.	1025
Gossypium hirsutum L.	4536
Gossypium barbadense L.	109

Table 2.14. Beneficiaries (Scientists/Researchers) received the cotton germplasm 2021-22

Sr. No.	Name of Scientist / Research Institute	No. of stock
1.	Dr. Mazhar Din Keerio, Principal Scientist/Director Cotton Research Institute, Tandojam.	46
2.	Mrs. Sanober Gul (Lec.), Ghazi University Dera Ghazi Khan.	26
3.	Mr. Ali, Assistant Professor, University of Agriculture, Faisalabad.	34
4.	Associate Professor,University of Agriculture, Faisalabad.	39
5.	Chandni Zafar M. Phil Scholar The Women University, Multan.	01
6.	Cotton Botanist, Cotton Research Station, Sahiwal.	05
7.	Officer Incharge, Cotton Research Station, Sahiwal.	04
8.	Dr. Sanaullah Yasin Officer Incharge, Cotton Research Station, Ghotki.	04
9.	Ms. Faiza Khan, Ph.D Scholar (PBG), University of Agriculture, Faisalabad.	99
10.	Dr. Irfan Ali, Scientist FB Genetics Lab, Four Brothers Group, Lahore.	02
11.	Dr. Qaiser Rashid, Managing Director.	03
12.	Mr. Nauman Bin Mustafa, M.Sc. (Hons.) Entomology University of Agriculture Faisalabad Sub Campus, Depalpur Okara.	21
13.	Dr. Zaheer Ahmad Deho, Principal Scientist, Cotton Group Nuclear Institute of Agriculture, Tandojam.	02
14.	Mr. Hafiz Faisal Maqbool, M.Sc. (Hons.) Plant Pathology University of Agriculture Faisalabad Sub Campus, Depalpur Okara.	21
15.	Cotton Botanist, Cotton Research Station, Sahiwal.	38
16.	Dr. Syed Bilal Hussain, Associate Professor, Institute of Molecular Biology & Biotechnology, BZU, Multan.	100
17.	Professor Dr. Rashida Atiq, Chairperson, Department of Plant Pathology BZU, Multan.	28
18.	Dr. Tariq Mahmud Shah Director NIAB Jhang Road, Faisalabad.	15
19.	Dr. Tariq Mahmud Shah Director NIAB Jhang Road, Faisalabad.	30
20.	Dr. Sanaullah Yasin Officer Incharge, Cotton Research Station, Ghotki.	06
21.	Dr. Muhammad Kamran Qureshi, Assistant Professor, Department of Plant Breeding & Genetics, Faculty of Agricultural Science & Technology Bahauddin Zakariya University, Multan.	12
22.	Mr. Muhammad Kashif Shehzad Sarwar, Ph.D Scholar Institute of Plant Breeding & Biotechnology MNS, University of Agriculture, Multan.	100
23.	Dr. Professor Bushra Rashid, Centre of excellence in Molecular Biology University of Punjab, 87-West Canal Bank Road, Thokar Niaz Baig, Lahore.	05
24.	Dr. Rao Sohail Ahmad Khan Assistant Professor Centre of Agriculture Biochemistry and Biotechnology (CABB), University of Agriculture Faisalabad.	28
25.	Mr. Nabeel-ur-Rehman, Ph.D Scholar Department of Environmental Sciences Quaid I Azam University Islamabad.	04
26.	Mr. Muhammad Saad Khalil, Department of Plant Breeding & Genetics, Faculty of Agricultural Science & Technology Bahauddin Zakariya University, Multan.	02
27.	Professor Dr. Zulfiqar Ali, Director, Office of Research Innovation of Commercialization, MNS, University of Agriculture, Multan.	24
28.	Dr. Khalid Abdullah, Cotton Commissioner Ministry of National Food Security & Research Islamabad.	40
	Total Accessions	**739**

2.6.2 Early Generation Seed production of commercial varieties

Single lines of *Bt and non Bt* approved varieties were sown in the fields. All the agronomic practices were made sure throughout the cropping season. Single plants were selected from pure and uniform families. These single plants were ginned for further fibre traits testing and multiplication. The detail is given in **Table 2.15**.

Table 2.15 Detail of pre-basic seed produced during 2021-22

Sr. #	Variety	Family No	No. of Single plant selected	Basic Seed produced (Kg)
1	*Bt*.CIM-663	40	80	172
2	*Bt*.CIM-632	40	75	222
3	*Bt*.CIM-678	60	178	132
4	*Bt*.CIM-785	40	60	109
5	CIM-554	30	50	15
6	CIM-610	20	30	15

2.7 Ratoon of Pak-US ICARDA Cotton Project materials

2.7.1 Use of USA cotton germplasm for the evolution of CLCV resistant/tolerant varieties.

A total of 40 accessions showing resistance against CLCuV is being ratooned at CCRI Multan from the last 4 years. Out of the 40, square formation and flower induction were recorded in 17 accessions during the months of December 2021 as detailed in **Table 2.16**.. All the flowers were analyzed for their pollens fertility and it was found that the pollens of the majority flowers were found unfertile.

Table 2.16 Ratoon crop of resistant accessions of 2013 & 2014 having bud and flower formation

Sr. No.	Set No.	Year	Total Accessions	CLCuV Resistant accessions	Accessions with buds and flower formation
1.	C	2013	200	3	USG-881
2.	D	2013	200	3	USG-1028, USG-1087
3.	K	2014	200	2	USG-1446, USG-1448
4	N	2014	600	32	USG-2131, USG-2135, USG-2210, USG-2225, USG-2231, USG-2235, USG-2269, USG-2285, USG-2288, USG-2472, USG-2476, USG-2480
		Total	**1200**	**40**	**17**

The above accessions were properly maintained for proper squares and flowers formation. Efforts were made to get fertile flowers which will be used in our breeding programs. In 17 accessions squares and flowers formation were noted. Crossing between these resistant accessions and standard varieties sown (in pots) in glass house are in process.

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3. CYTOGENETICS SECTION

Pakistan observed the lowest production level (5.56 million bales) in 2020/21 and is estimated to reach 9.0 million bales by 2021/22. But the consumption is 15.0 million bales. There is a huge gap between production and consumption; Pakistan would have to depend on the imported cotton. So, there is need to define the clear-cut policies for cotton breeding Programme to enhance the cotton production. We have to determine that whether traditional cotton breeding without use of biotechnology is enough to improve cotton status in Pakistan or the development of transgenic cotton varieties will solve the cotton production problem. Keeping in view, Cytogenetics section has also made special emphasis on cotton Biotechnology with interspecific hybridization to combat diverse upcoming biotic and abiotic intimidation. Wild *Gossypium* germplasm are source of novel alleles that can be exploited to expand desirable trait performance in upland cotton. Crossing of wild species with cultivated cotton is first step in exploiting the genetic variability and broadening the genetic base of existing cultivars.

Interspecific germplasm introgression enables unique opportunities for genetic analysis and improvement of domesticated plants but is commonly impeded by barriers to transmission and recombination, insufficient genetic resolution, and the difficulty of deriving economically suitable products. However, intensive selection that accompanies contemporary breeding strategies has also introduced a very high degree of genetic uniformity in the field, making crops vulnerable to emerging challenges. Cytogenetic Section is working on creation of novel genetic variation into the gene pool of cultivated cotton that can buffer the crop against agro-environmental challenges brought about by shifts in climate. The main objective of cytogenetic section is

- Maintenance of wild *Gossypium* germplasm
- Transferring desirable genes of the wild species to the cultivated cotton for commercial exploitation.
- Chromosomal study of developed inter and intra-specific hybrids.
- Development of biotech and abiotic resistant varieties through conventional and molecular approaches

3.1 Maintenance of *Gossypium* Germplasm

Thirty species of *Gossypium* (cultivated and wild) are being maintained in living herbarium at CCRI, Multan for exploitation in hybridization program. List is given below.

Table. 3.1. List of wild species maintained at CCRI, Multan during 2021-22

Species Name	Genome	Habit
G. hirsutum L.	AD1	Cultivated
G. barbadense L.	AD2	Cultivated
G. tomentosum	AD3	Wild
G. darwinii	AD5	Wild
G. herbaceum L.	A1	Cultivated
G. arboreum L.	A2	Cultivated
G. anomalum	B1	Wild
G. capitis-viridis	B4	Wild
G. sturtianum	C1	Wild
G. nandewarense	C1-n	Wild
G. australe	C3	Wild
G. thurberi	D1	Wild
G. harknessii	D2-2	Wild
G. davidsonii	D3-d	Wild
G. klotzschianum	D3-k	Wild
G. aridum	D4	Wild
G. raimondii	D5	Wild
G. gossypioides	D6	Wild
G. lobatum	D7	Wild
G. trilobum	D9	Wild
G. laxum	D8	Wild
G. stocksii	E1	Wild
G. somalense	E2	Wild
G. areysianum	E3	Wild
G. incanum	E4	Wild

G. longicalyx	F1	Wild
G. bickii	G1	Wild
G. australe	G2	Wild
G. nelsonii	G3	Wild
G. lenceolatum	2AD?	Wild

In addition; twenty-eight interspecific hybrids (5 diploids, 7 triploids, 5 tetraploids, 2 pentaploids and 4 hexaploid interspecific hybrids) and 5 tri species combinations are also maintained (Table 3.2).

Table.3.2. List of Interspecific hybrids maintained at CCRI, Multan.

Sr. No	Interspecific Hybrids	No
1	Diploid hybrids	5
2	Triploid	7
3	Tetraploid	5
4	Pentaploid	2
5	Hexaploid	4
6	Tri-species combinations	5
Total		**28**

A. Through Seed

For the strengthening of *Gossypium* species in living herbarium at CCRI, Multan seeds of twenty-three wild species were germinated in an incubator at 28 $\pm$ 2ºC and then shifted in earthen pots in glass house. List of species is given in (Table-3.3).

Table 3.3. List of wild species planted in glass house through seed

Name of Species	No. of seeds planted	No. of seeds germinated
G. arboreum	10	4
G. anomalum	15	8
G. capitis-viridis	8	4
G. thurberi	22	8
G. harknessii	11	2
G. davidsonii	10	3
G. klotzschianum	7	5
G. aridum	12	3
G. raimondii	29	2
G. gossypioides	22	4
G. laxum	19	2
G. stocksii	30	9
G. somalense	13	4
G. areysianum	24	4
G. incanum	17	2
G. longicalyx	16	2
G. bickii	24	5
G. herbaceum (Red)	15	3
G. herbaceum (Green)	15	5
G. darwinii	13	6
G. nelsonii	26	5
G. raimondii	10	3
G. barbadense	10	4
	378	97

B. Through Approach Grafting

Approach grafting has been utilized to maintain the already existing wild species. The detail is given below:

Table 3.4. List of wild Species and interspecific hybrids maintained through approach grafting

Sr. No.	Name of species	No. of grafts
1	*G. herbaceum (red)*	7
2	*G.capitis veridis*	6
3	*G. lobatum*	4
4	*G. laxum*	4
5	*G. gossipoides*	7
6	*G. longicalyx*	3
7	*G. bickii*	7
8	*G. incanum*	5
9	*G. somalense*	4
10	*G. tomentosum*	3
11	*G. stocksii*	9
12	*G. anomalum*	9
13	*G. tomentosum*	4
14	*G. areysianum*	5
15	*G. nelsonii*	5
16	*2(G. arbo. X G. somalense)* 2n	8
17	*(G. hirs. X G. arbo.)* 3n	7
18	*2(G. hirs. X G. ano.)* X *G. barba.4*n	9
19	*G. barba* X *2(G. arbo. X G. stockii) 5*n	6
20	*G. barba* X *2(G. arbo. X G. stockii) 6*n	4
Total		**116**

C. Through Cutting

Cuttings of wild species and interspecific hybrids were planted in the field and earthen pots in glass house to maintain the precious material. The detail is given in below.

Table 3.5. List of species /hybrids maintained through cuttings

Sr. No.	Name of species	No. of Cuttings
1	*G. laxum*	22
2	G. stocksii	28
3	G. laxum	30
4	G. lanceolatum	12
5	G. areysianum	11
6	G. lobatum	12
7	*G. tomentosum*	20
8	*G. anomalum*	22
9	*G. harknessii*	10
10	*G. klotzschianum*	11
11	*2(G.hirsutum* x *G.anomalum)*	15
12	*2(G.hirsutum* x *G.anomalum)* x *G.barbadense* (5n)	20
13	*2(G.arbo.* x *G.anomalum)* x *G.hirsutum* (5n)	20
14	*2(G.hir.* x *G.stocksii) (*6n)	18
15	*2(G.arbo.* x *G.anomalum)* x *G.hirsutum* (4n)	11
16	*2(G.arbo.* x *G.somalense)* (4n)	18
17	*2(G.hir.* x *G.anomalum)* (3n)	14
18	*2(G.hir.* x *G.anom.)* x *G.hir.* (5n)	11
19	*2(G.arbo.* x *G.anomalum)* (2n)	20
20	*(G. arboreum* x *G.australe)* (2n)	24
21	2(*G.hir.x G. stocksii*) x *G. hirsutum* (5n)	20
22	2(*G.hir.x G. anomalum*) (3n)	14
23	*(G.arborerum* x *G.capitis veridis)* x *G. arbo.*	14
24	*(G. arboreum* x *G.herbaceum)* (2n)	14
25	*2(G.arbo.* x *G.anomalum)* x *G. hirsutum* (4n)	15
26	2(*G. hirsutum* x *G. bickii*) x *G. barba.* (6n)	17
27	2(*G.arboreum .x G. stocksii*) (4n)	10
28	*(G.arboreum* x *G.thurberii*) (2n)	10
29	*G.hirsutum* x *G.herkensii* (3n)	10
30	*2(G.hirsutum* x *G.stockii)* (4n)	16
31	*G.hirsutum* x *G.gossypiodes* (3n)	20
32	*G.hirsutum*	20
33	*G.barbadense*	13
Total		**542**









Fig.3.1. Maintenance of wild species during 2021

3.2 Development of Auto-tetraploids

Seeds of *G. arboreum* were treated with 0.01, 0.02 and 0.05% colchicine to obtain autotetraploid. Seed treatment was done for 24, 48 and 72 hours. Plants are under observation. Cytologically will be checked on availability of buds.

Table. 3.6: Detail of treated plants

No of treatments	Colchicine concentration (%)	No of Seeds treated	No of plants germinated	Results
1	0.05 (24 hrs)	20	16	Plants under observation
2	0.02 (48 hrs)	20	13	Plants under observation
3	0.01(72 hrs)	20	12	Plants under observation
4	control	25	3	-

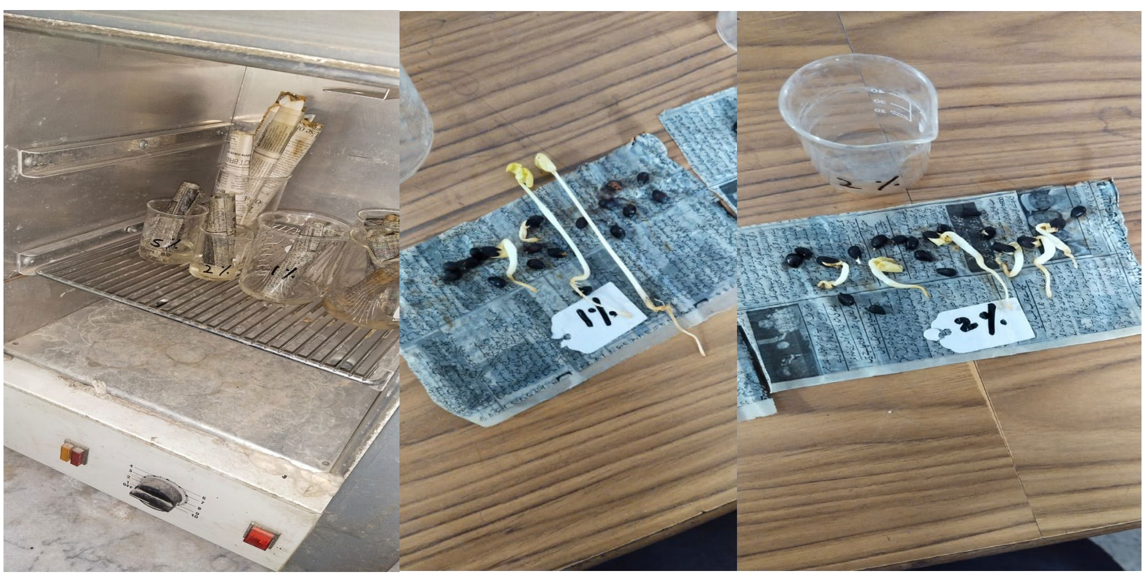

Fig-3.2. Colchicine Seed treatment in *G. arboreum*

(*G. hirs* ×*G. stocksii*) hybrid developed during 2019 is maintained in glass house for shoot treatment (0.1%). The chromosomal studies carried out at metaphase-1. Plant was triploid. This triploid plant will be used for doubling of chromosomes through shoot treatment. Plants are being maintained in glass house.

Fig.3.3. Triploid plant of *G. hirsutum* x *G. stocksii.* (Shoot treatment)

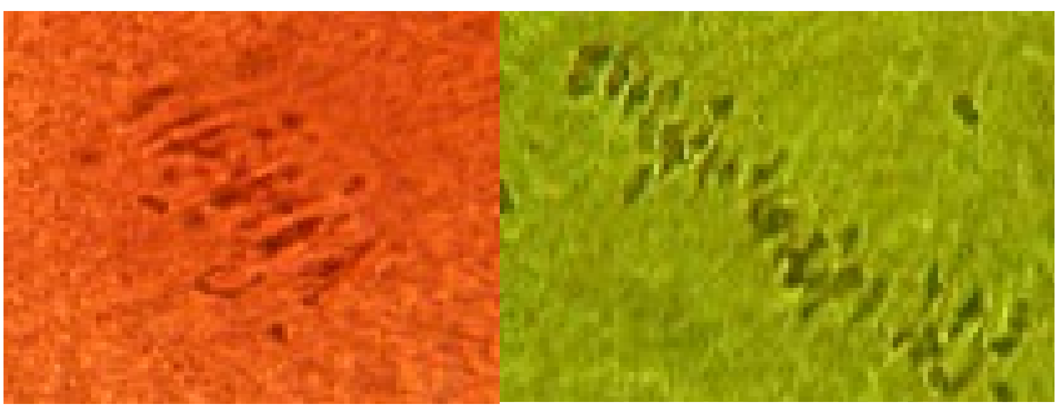

Fig.-3.4 Chromosomes pairing at M-1 in triploid plant (*G. hirsutum* x *G. stocksii*) (Chromosome=39)

Buds of *G. arboreum* x *G. australe* were checked cytologically. Plant is tetrploid. 52 chromosomes were present at Metaphase-1. Boll setting is not started yet.

Fig.-3.5 Tetraploid plant (*G. arboreum* x *G. australe*) maintained at wild block.

3.3. Hybridization

Interspecific hybridizations for incorporation of valuable wild species genes for stress resistance into the cultivated cottons were undertaken according to availability of flowers during the season. For intraspecific hybridization, large number of pollinations (4035) were attempted in 81 combinations including interspecific and intraspecific crosses. The boll setting was present in 75 combinations. Boll setting could not be obtained in other combinations either due to incompatibility among different species or sterility barriers existing at pre- and post- fertilization stages in hybridization. The hormones i.e Gibberallic Acid (GA) and Nephthaline acetic acid (NAA) were exogenously applied at the rate of 50 and 100mg $L^{-1}$of water respectively, after 24 hours of pollination. The application continued till 72 hours to retain the crossed bolls.

Table-3.7 Detail of Hybridization

Hybridization	No of cross combination	No of crosses attempted
Intera-specific hybridization	75	3913
Inter-specific hybridization	6	122

3.4. Selection from Breeding Material

Single plant selections were made from the Cyto breeding material in different interspecific and intraspecific segregating generations for further testing and screening against biotic and abiotic stress. The detail of breeding material planted and number of plants selected during 2021 is given in **Table 3.8**.

Table 3.8 Detail of single plants selected from breeding material

Generation/Trial	No. of plants Selected	Range	
		Lint (%age)	Staple length (mm)
VT	205	39.8-43.1	28.2-31.9
MVT	135	37.8-43.3	28.3-32.0
F_6 single lines	61	39.2-44.6	28.7-33.4
F_5 single lines	519	38.5-42.2	27.9-31.1
F_4 generation	2377	37.5-43.5	27.2-31.2
F_3 generation	387	37.1-42.3	28.1-32.2
F_2 generation	892	33.5-44.2	27.5-32.4

3.5 Performance of New Cyto-strains in Micro Varietal Trials

3.5.1. Micro Varietal Trial-1

Objective: Testing of Long staple material for economic and fibre quality traits

Six Bt. strains having tolerance against cotton leaf curl virus (CLCuD) viz., MV1, MV2, MV3, MV4, MV5 and MV6 were tested in replicated micro-varietal trial on a plot size of 12′ x 15′’ along with Cyto-179 as standard. The performance of this material is shown in Table 3.9.

Table 3.9 showed that maximum seed cotton yield was produced by MV-5 (3246 kg ha^{-1}) followed by MV-2 (3126 kg ha^{-1}) and MV-1 (3108 kg ha^{-1}) compared with standard Cyto-179 (2449 kg ha^{-1}). The line MV-4 was found to have highest lint%(41.4%) followed by MV-6 (40.8%) compared with standard Cyto-179 (38.1%).

Table 3.9 Performance of Cyto-strains in Micro Varietal Trial -1 during 2021-22

Strain	Yield (kg ha-1)	Plant Pop.(ha-1)	Boll weight (g)	Lint (%)	Length (mm)	Micronaire (µg inch-1)	Strength (g tex-1)
MV-1	3108	44974	2.9	37.2	28.4	3.8	30.3
MV-2	3126	43581	2.6	38.9	29.8	4.1	33.0
MV-3	2570	43979	2.8	39.8	28.3	3.8	29.9
MV-4	2151	38407	2.5	41.4	28.1	4.1	29.7
MV-5	3246	41591	3.2	39.3	28.9	4.2	29.1
MV-6	2570	42387	2.8	40.8	28.6	3.9	30.3
Cyto-179	2449	36218	3	38.1	28.1	3.8	28.8

The line MV-2 produced the medium long staple of 29.8 mm followed by MV-5 & MV-6 (28.9 & 28.6mm) respectively compared with 28.1 mm of Cyto-179. All the strains have desirable micronaire values ranging from 3.8 to 4.2 µg inch^{-1}. The maximum fibre strength (33.0 g tex^{-1})) was produced in MV-2 followed by MV-6 (30.3 g tex^{-1}) compared with 28.8 g tex^{-1} of standard Cyto-179.

3.5.2. Micro Varietal Trial-2

Objective: Testing of newly bulked white fly resistant strains against commercial varieties

Six *Bt*. strains viz., MV-7, MV-8, MV-9, MV-10, MV-11& MV-12 were tested in replicated micro-varietal trial on a plot size of 12/ x 15/ along with Cyto-179 as standard. Data presented in Table-3.10 exhibited that maximum seed cotton yield was produced by MV-7 (3287 kg ha^{-1}) followed by MV-11 (3266 kg ha^{-1}) compared with Cyto-179 (2254 kg ha^{-1}). Maximum lint % was produced by MV-7 (43.6%) followed by MV-12 (40.0%) compared with standard Cyto-179 (37.7%). The line MV-7 produced the medium long staple of 29.7 mm followed by MV-9 29.1 mm compared with 27.7 mm of Cyto-179. All the strains have desirable micronaire values ranging from 3.7 to 4.1 µg inch^{-1}. The maximum fibre strength (31.2 g tex^{-1})) produced in MV9 followed by MV-11 (31.0 g tex^{-1}) compared with 28.8 g tex^{-1} of standard Cyto-179.

Table 3.10 Performance of advanced strains in Micro Varietal Trial-2 during 2021-22

Strain	Yield (kg ha^{-1})	Plant Population (ha^{-1})	Boll weight (g)	Lint (%)	Fiber Length (mm)	Micronaire (µg inch^{-1})	Strength (g tex^{-1})
MV-7	3287	41392	2.8	43.6	29.7	4.0	30.3
MV-8	3108	42586	2.7	37.5	29.0	3.8	31.2
MV-9	3068	42586	2.5	38.6	29.1	4.0	31.0
MV-10	3168	29054	2.7	39.0	28.1	4.1	30.0
MV-11	3266	40795	2.4	37.5	28.6	3.9	30.1
MV-12	2271	36019	2.6	40.0	28.5	3.8	30.7
Cyto-179	2254	43183	2.9	37.7	27.7	3.7	28.8

3.5.3. Micro Varietal Trial-3

Objective: Testing of newly bulked heat resistant strains against commercial varieties

Six new Bt strains having heat tolerance viz., MV-13, MV-14, MV-15, MV-16, MV-17 and MV-18 were tested in replicated micro-varietal trial on a plot size of 12/ x 15/ along with Cyto-179 as standard. Data presented in Table-3.11 exhibited that maximum seed cotton yield was produced by MV-14 (2869 kg ha^{-1}) followed by MV-13 (2809 kg ha^{-1}) compared with Cyto-179 (2009 kg ha^{-1}). Maximum lint % produced by MV-18 (41.8%) followed by MV-16 (40.9%) compared with standard Cyto-179 (37.7%). The line MV-18 produced the medium long staple of 30.8 mm followed by MV-15 (30.1 mm) compared with 26.8 mm of Cyto-179. All the strains have desirable micronaire values ranging from 3.7 to 4.1 µg inch^{-1}. The maximum fibre strength was produced in MV-14 (30.1g tex^{-1}) followed by MV-15 (29.8 g tex^{-1}) compared with 28.5 g tex^{-1} of standard Cyto-179.

Table 3.11 Performance of Cyto-strains in Micro Varietal Trial -3 during 2021-22

Strain	Yield (kg ha^{-1})	Plant Population (ha^{-1})	Boll weight (g)	Lint (%)	Fiber Length (mm)	Micronaire (µg inch^{-1})	Strength (g tex^{-1})
MV-13	2809	35820	3.4	38.0	28.5	3.7	28.8
MV-14	2869	44775	2.9	39.6	29.9	3.9	30.1
MV-15	2689	40795	2.8	39.9	30.1	3.9	29.8
MV-16	2032	34228	3.2	40.9	28.6	4.0	29.2
MV-17	2749	40994	3.5	39.6	28.8	3.9	29.2
MV-18	1972	35820	2.5	41.8	30.8	4.1	29.6
Cyto-179	2009	42785	2.9	37.7	26.8	3.8	28.5

3.5.4. Micro Varietal Trial-4

Objective: Testing of newly bulked heat resistant strains against commercial varieties

Four new Bt strains MV-19, MV-20, MV-21, MV-22 were tested in replicated micro-varietal trial on a plot size of 20' ×12.5' along with Cyto-179 as standard. Data presented in Table-3.11 exhibited that maximum seed cotton yield was produced by MV-21 (1845 kg ha^{-1}) followed by MV-22 (1763 kg ha^{-1}) compared with Cyto-179 (1595 kg ha^{-1}). Maximum lint % produced by MV-20 (40.5%) followed by MV-21 (40.1%) compared with standard Cyto-179 (36.9%). The line MV-22 produced the medium long staple of 29.8 mm followed by MV-20,21 (28.5mm) compared with 27.4 mm of Cyto-179. All the strains have desirable micronaire values ranging from 3.7 to 4.1 µg $inch^{-1}$. The maximum fibre strength was produced in MV-20 & MV-21 (30.8 g tex^{-1}) followed by MV-19 (30.3 g tex^{-1}) compared with 27.4 g tex^{-1} of standard Cyto-179.

Table 3.11 Performance of Cyto-strains in Micro Varietal Trial -4 during 2021-22

Strain	Yield (kg ha^{-1})	Plant Population (ha^{-1})	Boll weight (g)	Lint (%)	Fiber Length (mm)	Micronaire (µg $inch^{-1}$)	Strength (g tex^{-1})
MV-19	1742	38728	3	39.6	28.0	3.9	30.3
MV-20	1591	40880	2.8	40.5	28.5	3.7	30.8
MV-21	1845	40163	2.7	40.1	28.5	3.7	30.8
MV-22	1763	40163	2.4	37.4	29.8	3.9	29.3
Cyto-179	1595	39446	2.9	36.9	27.4	4.1	27.4

3.5.5. Micro Varietal Trial-5

Objective: Testing of newly bulked heat resistant strains against commercial varieties

Five new Bt strains having heat tolerance viz., MV-23, MV-24, MV-25, MV-26, MV-27 were tested in replicated micro-varietal trial on a plot size of 10' ×20' along with Cyto-179 as standard. Data presented in Table-3.12 exhibited that maximum seed cotton yield was produced by MV-24 (1940 kg ha^{-1}) followed by MV-27 (1842 kg ha^{-1}) compared with Cyto-179 (1563 kg ha^{-1}). Maximum lint % was produced by MV-25 (40.0%) followed by MV-24,26 (39.9%) compared with standard Cyto-179 (35.2%). The line MV-26 produced the medium long staple of 29.3 mm followed by MV-23 (28.7 mm) compared with 27.5 mm of Cyto-179. All the strains have desirable micronaire values ranging from 3.8 to 4.4 µg $inch^{-1}$. The maximum fibre strength was produced by MV-27 (30.1 g tex^{-1}) followed by MV-24 (29.7 g tex^{-1}) compared with 27.9 g tex^{-1} of standard Cyto-179.

Table 3.12 Performance of Cyto-strains in Micro Varietal Trial -5 during 2021-22

Strain	Yield (kg ha^{-1})	Plant Population (ha^{-1})	Boll weight (g)	Lint (%)	Fiber Length (mm)	Micronaire (µg $inch^{-1}$)	Strength (g tex^{-1})
MV-23	1717	38728	2.5	39.3	28.7	4.4	29.3
MV-24	1940	41597	2.6	39.9	28.4	4.1	29.7
MV-25	1724	42314	2.3	40.0	28.3	3.8	29.2
MV-26	1563	40880	2.2	39.9	29.3	3.9	29.6
MV-27	1842	39446	2.1	39.8	28.1	3.9	30.1
Cyto-179	1563	42314	2.8	35.2	27.5	4.0	27.9

Performance of New Cyto-strains in Varietal Trials

3.5.6. Varietal Trial-1

Objective: Testing of new advance Bt strains against commercial varieties

Six *Bt*. strains having tolerance against cotton leaf curl virus (CLCuD) viz., V1, V2, V3, V4, V5 and V6 were tested in replicated varietal trial on plot size 12’ x 15’ along with Cyto-179 as standard. The performance of this material is given in Table 3.13.

Data presented in Table 3.13 exhibited that maximum seed cotton yield was produced by V-4 (3385 kg ha^{-1}) followed by V-1 (3177 kg ha^{-1}) compared with standard Cyto-179 (2014 kg ha^{-1}). Maximum lint % was produced by V-3 (40.1%) and V-6 (39.5%) compared with Cyto-179 (37.4%).

The strain V-4 produced the medium long staple of 29.4 mm followed by 29.0 mm of V-5 compared with Cyto-179 (26.4 mm). All the strains have desirable micronaire values ranging from 3.8 to 4.3 µg $inch^{-1}$. The maximum fibre strength (31.4 g tex^{-1}) produced by V-4 followed by V-5 (30.9 g tex^{-1}) compared with 28.4 g $tex^{-1}$of standard Cyto-179.

Table 3.13 Performance of Cyto-strains in VT-1during 2021-22

Strain	Yield (kg ha^{-1})	Plant population (ha^{-1})	Boll wt. (g)	Lint (%)	Fiber Length (mm)	Micronaire (µg $inch^{-2}$)	Strength (g tex^{-1})
V-1	3177	44756	2.7	38	28.1	4.0	29.8
V-2	2958	41392	3.4	38.7	28.4	4.1	29.9
V-3	2923	35024	2.6	40.1	27.9	4.1	30.3
V-4	3385	44775	2.5	38.9	29.4	4.3	31.4
V-5	2870	42984	2.3	38.0	29.0	4.3	30.9
V-6	2271	31243	2.4	39.5	27.7	3.8	30
Cyto-179	2014	42387	3	37.4	26.4	3.8	28.4

3.5.7 Varietal Trial-2

Objective: Testing of Long staple new advance *Bt* strains against commercial varieties

Seven *Bt* strains viz., V-7 to V-13 were screened in a replicated varietal trial on plot size 30' ×12.5' along with Cyto-179 as standard. The performance of this material is given in Table 3.14. Data showed that maximum seed cotton yield was produced by V-11 (2130 kg ha^{-1}) followed by V-10 (2105 kg ha^{-1}) and V-13 (1914 kg ha^{-1}) compared with standard Cyto-179 (1631kg ha^{-1}). Maximum lint % was produced by V-9 (40.4%) followed by V-13 (40.2%) compared with standard Cyto-179 (37.9%).

Table 3.14 Performance of Cyto-strains in VT-2 during 2020-21

Strain	Yield (kg ha^{-1})	Plant population (ha^{-1})	Boll wt. (g)	Lint (%)	Fiber Length (mm)	Micronaire (µg $inch^{-1}$)	Strength (g tex^{-1})
V-7	1674	39018	2.7	38.0	29.3	3.6	29.9
V-8	1560	36723	2.8	39.2	28.1	3.8	30.1
V-9	1722	36532	3.0	40.4	29.1	3.7	29.7
V-10	2105	38827	2.9	38.7	30.3	4.1	29.4
V-11	2130	36054	2.7	38.0	29.1	3.9	29.2
V-12	1770	35193	2.7	38.7	29.4	3.9	29.0
V-13	1914	38253	2.8	40.2	28.5	3.9	30.9
Cyto-179	1631	35289	2.8	37.9	26.0	4.6	27.7

V-10 produced medium longest staple of 30.3 mm followed by V-12 (29.4 mm) compared with Cyto-179 (26.0 mm). All the strains have desirable micronaire values ranging from 3.6 to 4.1 µg $inch^{-1}$. The maximum fibre strength (30.9 g/tex) was produced by V-13 followed by V-8 (30.1 g tex^{-1}) in contrast to standard Cyto-179 (27.7 g tex^{-1}).

3.5.8. Varietal Trial-3

Objective: Testing of newly bulked medium staple strains against commercial varieties

Seven new *Bt* strains having tolerance against cotton leaf curl virus (CLCuD) viz., V-14 to V-17 with medium-long staple were tested along with Cyto-179 as standard. The performance of this material is given in Table 3.15. It showed that maximum seed cotton yield was produced by V-19 (3402 kg ha^{-1}) followed by V-17 (3362 kg ha^{-1}) compared with standard Cyto-179 (2019 kg ha^{-1}). Maximum boll weight (4.0 g) was produced by V-17 followed by V-20 (3.6g) compared with 2.8 g of standard Cyto-179. Maximum lint % was produced by V-18 (41.0%) followed by V-14 (40.5%) compared with standard Cyto-179 (38.4%).

Table 3.15 Performance of Cyto-strains in Varietal Trial-3 during 2021-22

Strain	Yield (kg ha^{-1})	Plant Population (ha^{-1})	Boll weight (g)	Lint (%)	Fiber Length (mm)	Micronaire (µg $inch^{-1}$)	Strength (g tex^{-1})
V-14	2900	40163	2.9	40.5	28.4	4.0	30.1
V-15	3012	43247	3.2	39.5	28.6	4.2	29.5
V-16	2811	38948	3.3	38.4	29.1	3.9	31.2
V-17	3362	38446	4.0	37.9	28.7	3.8	30.5
V-18	2505	37514	3.5	41.0	29.3	4.5	29.5
V-19	3402	41817	3.5	40.3	28.6	4.2	30.8
V-20	3081	42750	3.6	39.6	29.7	3.9	31.4
Cyto-179	2019	40383	2.8	38.4	27.6	4.1	30.2

The strains V-20 and V-18 produced the medium staple length of 29.7 and 29.3 mm, respectively compared with 27.6 mm of Cyto-179. All strains have desirable micronaire values ranging from 3.8 to 4.5 µg inch^{-1}. The maximum fibre strength (31.4 g tex^{-1}) was produced by V-20 followed by V-16 (31.2 g tex^{-1}) compared with 30.2 g tex^{-1} of Cyto-179.

Coordinated Variety Testing Programme

3.5.9 National Coordinated Varietal Trial (Set-C)

Objective: - Testing of promising *Bt*. Strains of different cotton breeders of Pakistan

The cotton seed of twenty 26 strains under coded numbers was received from Director Research (PCCC) for evaluation. Data on seed cotton production and other parameters are presented in **Table 3.16**. The results indicated that the strain PC-2151 produced maximum yield of 2532 kg ha^{-1} followed by PC-2165 with 2272 kg ha^{-1} seed cotton yield. PC-2148 produced lowest yield that is 1555 kg ha^{-1}. The strain PC-2143 produced the highest lint percentage of 40.7%, followed by PC-2149 & PC-2151 with 40.1 & & 39.7% respectively. The strain PC-2144 produced the highest value of staple length 28.5 mm, followed by PC-2151 which has staple length of 28.3 mm. Most of the strains had the desirable micronaire value. Most of the strains have values of fibre strength according to required standard.

Table 3.16 Performance of Cotton Strains in National Coordinated Varietal Trial at CCRI Multan (Set-C)

Strains	Seed-cotton Yield (kg ha^{-1})	Lint (%age)	Staple length (mm)	Micronaire value	Fibre strength (g/tex)	Boll Weight	Plant Pop. (ha^{-1})
CIM-975	1970	38.2	26.9	4.1	27.9	2.7	33965
ICS-286	1734	37.9	27.5	4.0	28.4	3.0	43412
MNH-1045	1914	35.4	27.4	4.4	28.5	2.8	41971
SAS-1	1973	40.7	26.3	4.4	27.1	2.3	43173
MNH-1090	1914	33.8	28.5	3.9	29.0	3.0	40781
BS-025	1973	38.1	24.9	4.3	25.3	2.3	42097
NIAB-868	1794	37.4	27.0	4.3	27.6	2.1	42336
Tara-CII-222	1973	39.1	25.3	4.6	25.8	2.7	41499
FH-189	1555	37.9	25.6	4.7	25.1	2.6	39705
SAS-2	2212	40.1	25.4	4.7	25.7	3.1	39227
Sahara-500	1674	39.2	25.6	4.5	26.7	2.1	42456
Cyto-541	2532	39.7	28.3	4.3	29.4	3.2	41858
NIAB-484	1854	39.4	26.3	4.3	27.4	2.2	41260
PC-2153	1854	36.9	25.0	4.7	25.5	2.7	43293
NIAB-989	1854	36.3	26.3	4.6	25.7	2.0	43293
CIM-600 (Std)	1854	34.7	26.9	4.0	28.1	2.5	43173
FH-938	1854	36.4	25.7	4.6	27.8	2.1	40542
UAM-20	1854	38.8	26.2	3.9	27.1	2.5	41260
FH-414	1854	36.4	26.2	4.5	26.6	2.8	42934
PC-2159	1854	36.9	25.6	4.8	26.1	2.5	41738
FH-498	1854	38.1	28.0	4.5	29.0	3.1	41977
ZAR-21	1854	37.7	25.9	4.6	26.9	2.5	43532
VH-418	1854	38.9	25.2	4.7	26.1	2.6	41977
FH-416	1854	39.1	25.4	4.9	25.5	2.7	42934
FH-415	2093	36.4	25.8	4.8	26.2	2.7	44010
FH-494	2272	38.3	24.6	4.9	25.5	2.5	44010

C.D Value 5% 344.31
Sowing date = 11.05.2021

3.6 Early Generation Seed (EGS) System

40 single plants from approved varieties of Cyto Section (Cyto-179, Cyto-533, Cyto-535, CIM-608, Cyto-226 and Cyto-124) were sown in the field at maturity. At maturity, single plants were selected which will be used for the production of pre-basic seed.

Table-3.17. No of families selected in EGS

Variety	No of families selected
Cyto-179	05
Cyto-533	07
Cyto-535	15
Cyto-226	04
Cyto-124	05
CIM-608	03

3.7 Cotton Biotechnology

The Biotechnology lab. has been established to develop local cultivars with export quality yield and also resistance to drought stress and bollworms. Apart from lab work, the impact of Abiotic & Biotic stresses on cotton fiber quality is studied. The lab is equipped with basic instruments that are necessary to carry out genetic transformation and GMO testing of cotton genotypes. The genes of different traits are synthesized for transformation in local cotton cultivars. (Table 3.18):

Table 3.18: Genes and function

Sr # No	Name of Gene	Function
1	Cry2A	Pink Bollworm Resistance
2	DREB2	Abiotic stresses including drought tolerance
3	MYB (Fmaily gene)	Fiber Improvement

Milestones achieved till the date are below.

Genetic transformation of Cry2A, DREB2, and Gt-genes was achieved for bollworms, abiotic stress (drought resistance) and glyphosate resistance respectively, into commercial cultivar, and now under evaluation for gene stability and other molecular analysis to develop resistance against bollworms abiotic stresses and herbicides.

MYB (family Gene) gene transformation in the local cotton cultivars
Codon optimisation and chemical synthesis of insecticidal gene.

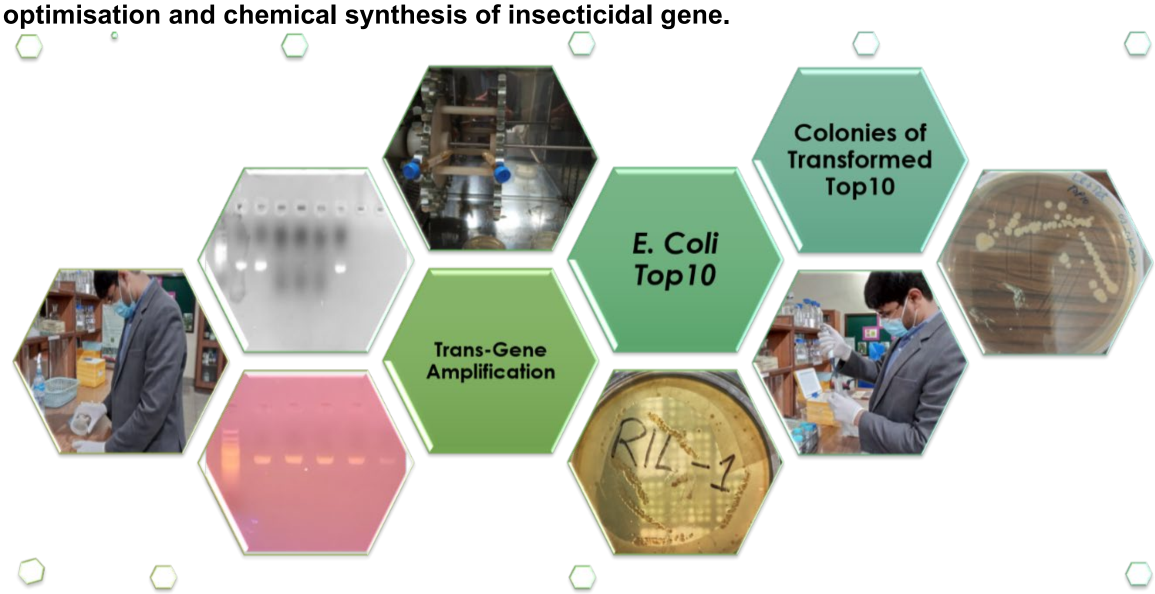

Fig: 3.6: Gene Cloning and Transformation

Full length nucleotide sequence of above-mentioned gene was retrieved from Gene Bank, and checked for complete open reading frames (ORFs) by using online tool available on Expert Protein Analysis System (ExPASy). The codon usage was optimised according to cotton (Gossypium hirsutum) to get high transgene expression through a web-based tool freely available on integrated DNA Technology (IDT) website. Each gene was attached with CaMV 35S promoter and NOS terminator for gene expression.

Next Strategy

Working on challenging issues of the cotton crop. Genetic manipulation of the cotton crop to improve stress tolerance abilities such as water scarcity and sucking insect (whitefly) is the major factor that affects the cotton yield. In the given scenario, the biotechnology lab is currently working on genetic transformation of synthetically developed drought resistance and sucking pest resistance-conferring genes in the commercial cultivar. Agrobacterium-mediated genetic transformation method will be used to transform the above-mentioned synthetic gene construct to develop transgenic local cotton cultivars. CaMV 35S promoter and NOS terminator was used for gene expression in the synthetic cassette. The reason behind the use of constitutive promoter is that it gives maximum gene expression in Plants. Synthesized gene cassette was cloned into pCAMBIA1301 Plasmid vector, then this construct was transformed to Agrobacterium.

Gene Description

Dehydration responsive element binding proteins (DREB) are members of a larger family of transcription factors, many of which have been reported to contribute to plant responses to abiotic stresses in several species. A sequence of 438bp transcribes the mRNA that translates 146 amino acids. The other one (Cry2A) transcribed insecticidal proteins. The gene sequence got from NCBI, the origin of this protein is from *Bacillus thuringiensis* that constitutes the active ingredient in many biological insecticides and biotech crops expressing *B. thuringiensis* genes (Bt crops). For the control of lepidopteran pests, *B. thuringiensis* Cry1 and Cry2 class proteins are being used either in sprayable products or in transgenic plants. A sequence of 1905bp transcribes the mRNA that translates 1635 amino acids.

Table-3.19. Equipment that was purchased for Molecular analysis and experimental purpose.

Sr# No	Name of Equipment	Function
1	qPCR	Quantification of gene expression level
2	Temp Controlled Centrifuge	Separation of solid liquids on density basis
3	Nano-drop Spectrophotometer	Quantification of nucleic acid
4	PCR	Gene Amplification
5	Gel Electrophoresis	DNA visualization

3.8. Mapping population development for Fiber Quality

Objectives: Development of mapping population for Fiber Quality

F_3 population was sown in the field. Agronomic and plant protection measures were applied. DNA extraction was performed from young leaves using CTAB. DNA quantification was checked using 1% gel electrophoresis and Nano-drop Spectrophotometer.

Fig-3.7. DNA isolation

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ENVIRONMENTAL SCIENCES SECTION

Environmental science is a branch of science that deals with the study of atmosphere. The changing global environmental conditions concern the society to a common agenda of sustainable development. The environmental science broadens the insight of the people in identifying principle based solutions to the pinching and emerging issues of society. Environmental science promotes the study and understanding of natural and human caused processes in our natural environment .By researching and investigating complex environmental issues we can enhance essential issues and problem solving thinking. To understand current environmental problems we need to consider physical, biological and chemical processes that are the basis of those problems.

Objectives

- How the natural world works
- How human interact with the environment
- To find ways to deal with environmental problems and live more sustainably
- Promote awareness in regard to environmental issues including water, air, energy and its conservation, waste pollution and other climatic issues.

Artificial Rain Technology

Objective:

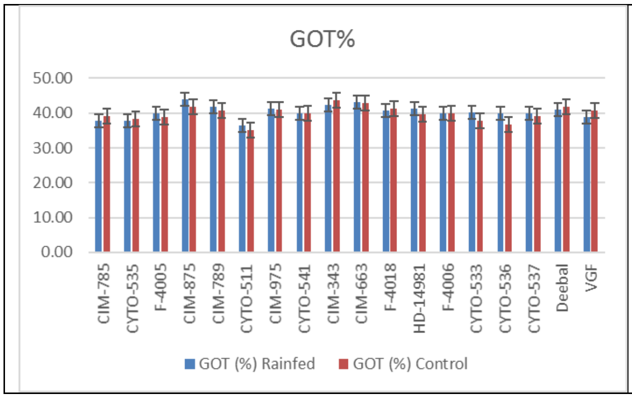
This technology is introduced to check the effects of rain on cotton crop. By doing this trial we can find out the solution of many problems that are due to off the schedule rain in the Pakistan.

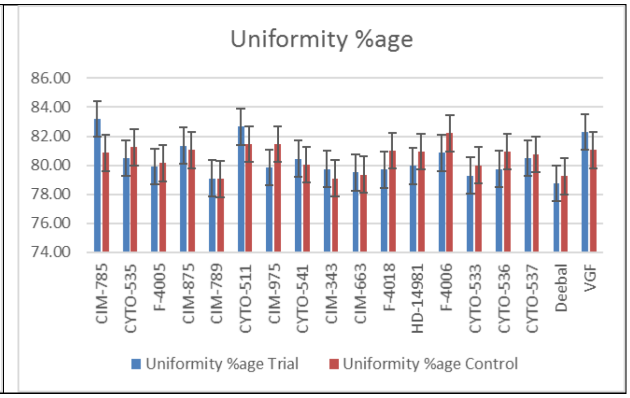
Year of Experiment	:	2021 (1st year)
Instrument	:	Rain nozzle
Rain	:	7 days interval
Timing	:	Morning and Evening
Total varieties	:	18
Each variety area	:	15 sq ft
Rows per entry	:	5

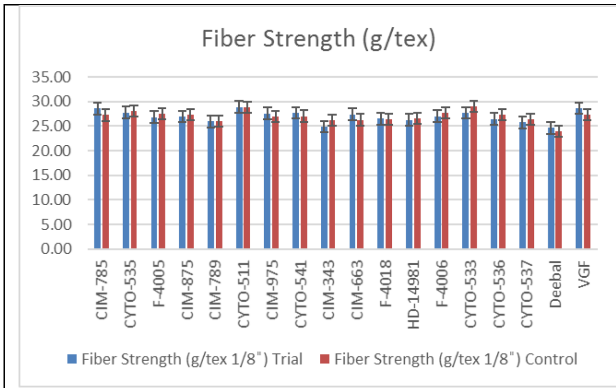
Results

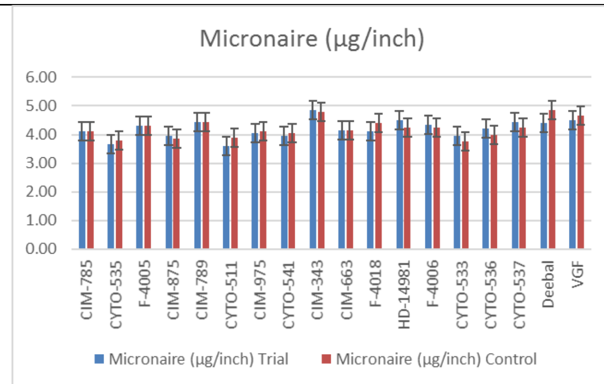
- Improvement in the vegetative growth of the plant
- Pest attack is less than that of the control
- Long stature varieties leaves become red
- Attack of whitefly, jassid and mealy bug quite lesser
- Attack of dusky bug and Pink bollworm witnessed higher
- Hence concluded that rain has both negative and positive effects
- There is more attack of pink bollworm and dusky after rain
- Other sucking pest is less on the rainy area than the control one.

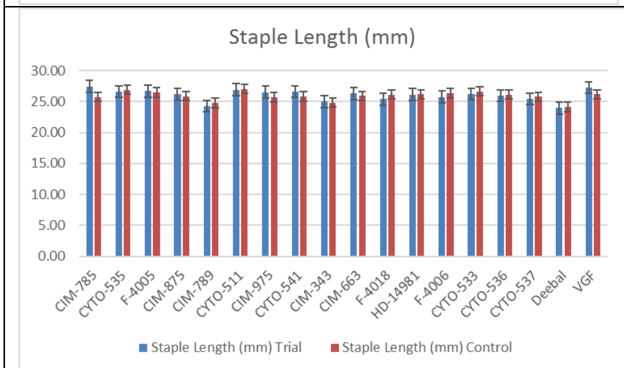
Comparison of Fibre Characteristics, Seed Index and Uniformity %age of Rainfed and Controlled Plot

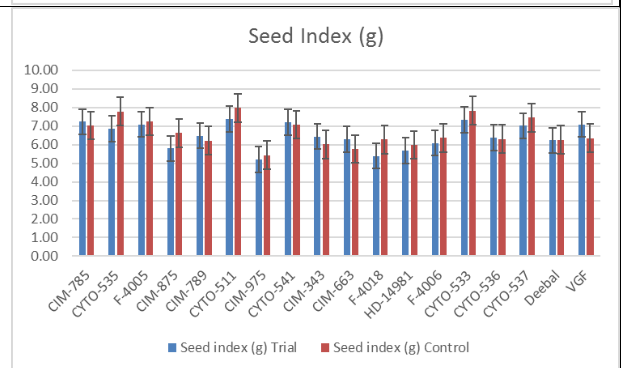




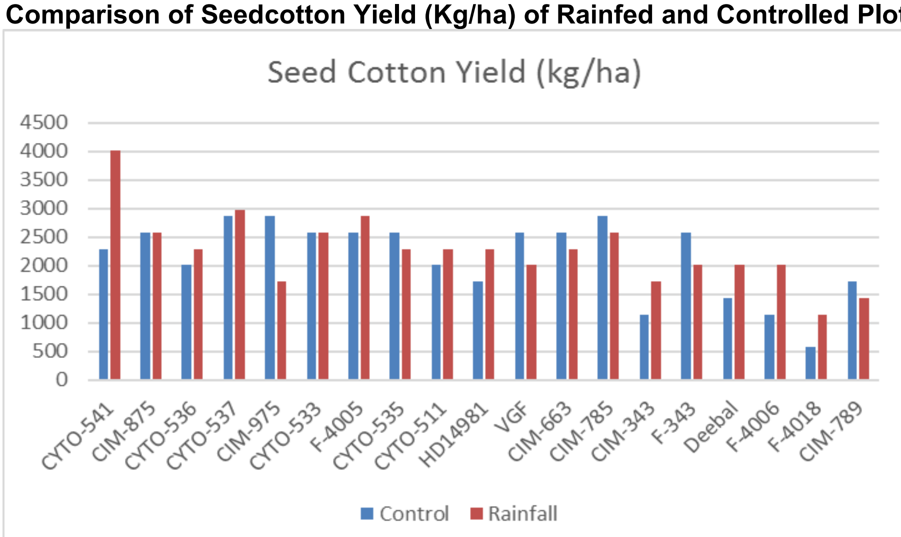








Comparison of Seedcotton Yield (Kg/ha) of Rainfed and Controlled Plot



4. ENTOMOLOGY SECTION

Studies were conducted on various aspects under field and laboratory conditions including

- Surveys of cotton growing areas for pink bollworm infestation.
- Eco-friendly management of pink bollworm using bio-control agents.
- Management of pink bollworm using attractants and different colored adhesive-cloths sheets.
- Monitoring of Lepidopterous pests with sex pheromone traps, 4) National Coordinated Varietal Trials on *Bt.* & non-*Bt.* strains.
- Sowing date impact on the development of dusky cotton bug.
- Incidence of arthropods on light and normal green cotton leaves.
- Impact of pesticides on the crop physiology/shape/canopy.
- Monitoring of insecticide resistance in cotton pests.
- Evaluation of foliar insecticides against sucking insect pests & bollworms.

Efforts were continued to develop mass rearing techniques of pink bollworm along with rearing and maintaining natural enemies of cotton pests for usage in the lab. and field. Internship facilities were provided to students of various Universities. The section actively participated in online and face to face training programmes, organized by the Institute for the farmers and staff of Agriculture Extension and Pest Warning & Quality Control (PW&QC) Department and pesticide companies. Scientists also recorded IPM programs for broadcasting on electronic media.

4.1 Studies on Pink Bollworm

4.1.1 Pink bollworm infestation in green bolls in major cotton growing area

Cotton fields in Muzaffargarh, Dera Ghazi Khan and Rajanpur districts of Punjab were surveyed from August to October, 2021 for the damage assessment of pink bollworm and infestation levels of sucking insect pests complex.

Among bollworms, pink bollworm was reported to be the most serious pest in all the visited localities. Insecticidal proteins from *Bacillus thuringiensis* (*Bt*) are widely used to control chewing insect pests, but their efficacy is reduced when pests evolve resistance. Same is the case with pink bollworm which confers resistance to *Bt* toxin Cry1Ac.

Fig. 4.1 Devastating outbreak of mealybugs in Rajanpur District.

Among the sucking insect pests, the sporadic population of mealybug has been continuously reported every year on cotton crop, however, this year a devastating outbreak of the mealybug was noticed especially in Rajanpur district **(Fig. 4.1),** resulting in serious economic damage to cotton crop like that of whitefly in 2020 in major cotton growing districts of Punjab.

As mentioned earlier, bollworm can be controlled effectively with *Bacillus thuringiensis* (transgenic cotton), which is being adopted worldwide. However, its insecticidal efficacy is not stable. The core objective of this recently conducted survey was to monitor the effectiveness of *Bt* gene against cotton bollworms, especially the damage percentage of pink bollworm **(Table-4.1).** For this purpose, twenty mature bolls were picked from each monitored field for laboratory observations, while for sucking insect pests, twenty leaves were randomly selected from (top, middle and bottom) of cotton plants.

Table-4.1 Pink bollworm damage and live larvae recorded from Muzaffargarh, Dera Ghazi Khan and Rajanpur districts of Punjab

District	August		September		October		Average	
	% Boll damage	% Larvae	% Boll damage	% Larvae	% Boll damage	% Larvae	% Boll damage	% Larvae
Muzaffargarh	8.39	50.0	23.0	76.0	53.0	125.0	28.0	84.0
D G Khan	11.0	26.0	32.0	53.0	46.0	71.0	30.0	50.0
Rajanpur	18.0	55.0	27.0	83.0	37.0	71.0	27.0	70.0

The highest mean damage of pink bollworm (30%) was reported in Dera Ghazi Khan district followed by Muzaffargarh (28%) and Rajanpur (27%). However, in the Rajanpur district, most of the cotton fields were intentionally terminated by farmers before October due to a severe outbreak of mealybug.

Table-4.2 Mean number (August-October) of sucking insect pests per leaf and CCRI reported varieties collectively from Muzaffargarh, Dera Ghazi Khan and Rajanpur districts of Punjab

District	Mean Number of Sucking Insect Pests per leaf			CCR Varieties
	Jassid	Whitefly	Thrips	
Muzaffargarh	0.89	6.67	7.37	CIM-663, CIM-543, CIM-456, CIM-496, CIM-620, CIM-678, CIM-717, CIM-343, CIM-446 & CIM-707
Dera Ghazi Khan	3.10	5.58	6.55	
Rajanpur	1.10	7.89	5.10	

Among the sucking insect pests, the highest mean population of whitefly (7.89/leaf) was recorded in Rajanpur district followed by Muzaffargarh (6.67/leaf). Likewise, mean jassid population was also recorded above ETL in Dera Ghazi Khan (3.10/leaf) and Rajanpur (1.10/leaf), however, mean thrips infestations were reported below ETL in all visited localities of Muzaffargarh, DGK and Rajanpur districts. The tabulated varieties of CCRI in **(Table-4.2)** were reported at farmers' fields in Muzaffargarh, Dera Ghazi Khan and Rajanpur.

Field Survey reports-2021

Multan District:

A total of 26 cotton fields in the direct were observed and mature bolls for pink damage were picked for laboratory observation. Among the sucking insect pest mean population of jassid and whitefly were reccorded above not ETL, whereas thrips were found below the not ETL. Mealbug were reported in patches with medium to a high level of population, while the dusk cotton bug was partially mostly in open bolls.

Khanewal District:

A total 24 cotton fields for pink bollworm were observed and mature bolls were picked kfor laboratory observation. The sucking pest insect pests population patterns were slightly observed different compared with the other district, as jassid, whitefly inculding thrips sere recorded above the not ETL. In most of the fields, Mealybug and mite infestion were also increasing to alarming levels.

Vehari District:

T total 32 cotton fields for pink bollworm damage were observed and mautre bolls picked for laboratory observaion. After laboratory observation, the medium % damage of pink bollworm was recorded in Vehari district followed by Bahawalpur in comparsion with the overall visited district.

Bahawalpur:

A total 16 cotton fields were observed and mautre bolls for pink bollworm damage assesment were picked for laboratory observation. Likewis, in the Vehari district, the damage intensity of pink bollworm and the mean population of sucking insect pests were recorded in Bahawalpur district. Among the new threat for cotton crop, population of mearlybug was also found medium to a high level of intensity.

Lodhran:

A total 15 cotton fields wetre inspected and monitoring of bolls for pink bollworms damage was picked for laboratory observation. In the same pattern of Vehari and Bahawalpur district, susceptibility of pink bollworm and sucking insect in cotton varieties were also recorded in Lodhran district., however %damage of pink bollworm was recorded to (10.4) and (7.03) in Multan and Lodhran District.

4.1.2 Studies on Eco-friendly Management of Pink Bollworm

Biocontrol agents against cotton insect pests, especially the pink bollworm were explored to mitigate economic losses and discouraging indiscriminate use of insecticides. For the purpose mentioned above, natural enemies belonging to *Antilochus* spp., subfamily Harpactorinae and *Acanthaspis* genus of Hemiptera order were collected and presently are being reared in the newly established bio-control lab. on their hosts i.e. cotton stainer, Sitotroga cerealella, pink bollworm and armyworm. Augmentative field releases followed by assessing their development and population levels are the priority for fulfilling the core objectives **(Fig. 4.2).**

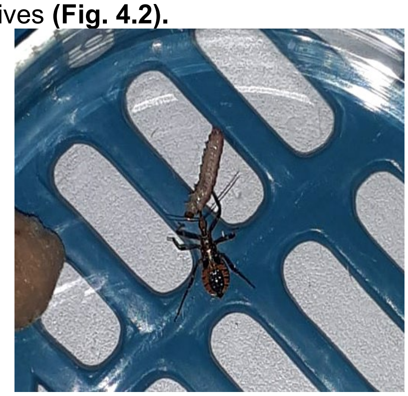


Fig. 4.2 Newly reported bio-agents feeding on pink bollworm larvae

4.1.3 Management of pink bollworm using attractants and different colored adhesive-cloths sheets

Attraction of pink bollworm moths (both sexes) to navy-blue, malasia and white adhesive-cloths and male moths to pheromone/sex traps was evaluated in the field during cotton season 2021-22. The adhesive cloth sheets measuring (91.44 x 91.44 cm) of the above-mentioned colors, each stretched with the help of 2 bamboo sticks fixed in soil keeping sheet at about 3feet above from the ground. Data of moth catches were recorded at 24 hours intervals from all the traps. Sex lures in traps were replaced with fresh ones fortnightly and adhesive material on cloth sheets was refreshed at about one-month intervals. The highest mean moth catches were found on navy-blue adhesive-cloth sheets (31.8/trap) followed by malasia (19.9/trap) whereas, the lowest catches were on white adhasive-cloth sheets (1.2/trap) followed by sex trap (14.0/trap). The most favorable month for moths population establishment was November based both on sticky cloths as well as sex traps **(Fig.4.3).**

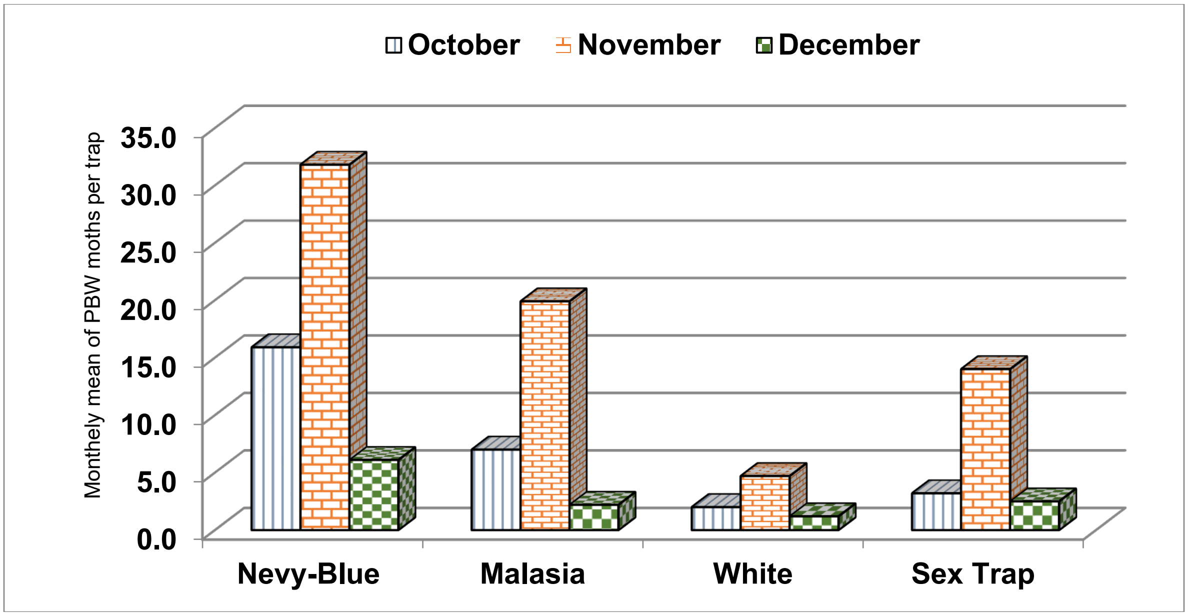


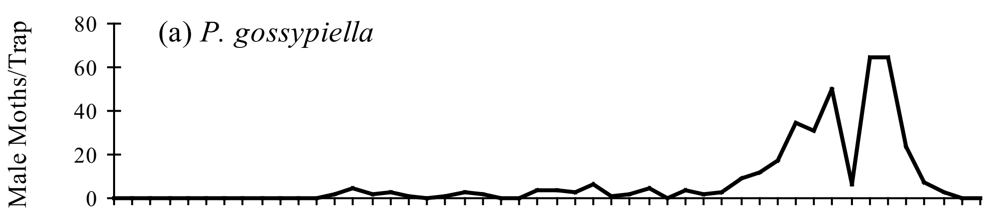
Fig. 4.3 Mean moth catches in different adhesive-cloths and sex traps

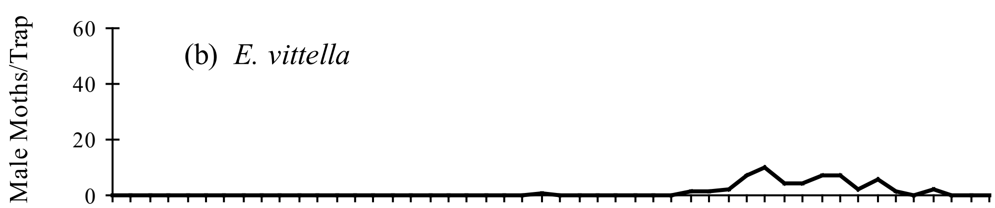
4.2 Monitoring of Lepidopterous pests with sex pheromone traps

Male moth activity of lepidopterous pests viz. *Pectinophora gossypiella*, *Earias insulana, Earias vittella, Spodoptera litura, Spodoptera exigua* and *Helicoverpa armigera,* was monitored with sex pheromone baited traps throughout the year at CCRI, Multan. Overall, declining trend was observed in *P. gossypiella*, *Earias* spp.*, S. exigua* and *H. armigera* except *S. litura* as compared to last year **(Table-4.3).** Moth catches on weekly basis are given in **Fig. 4.4 (a-f).**

4.2.1 *Pectinophora gossypiella* (Pink bollworm)

Male Moth's activity started in in 1st week of April and reached at peak in 3rd week of November at CCRI, Multan. Moth's activity was not consistent and showed fluctuating trend throughout the season **(Fig. 4.4a).** Overall, male moth catches were 13.0% lower as compared to last year **(Table-4.4).**





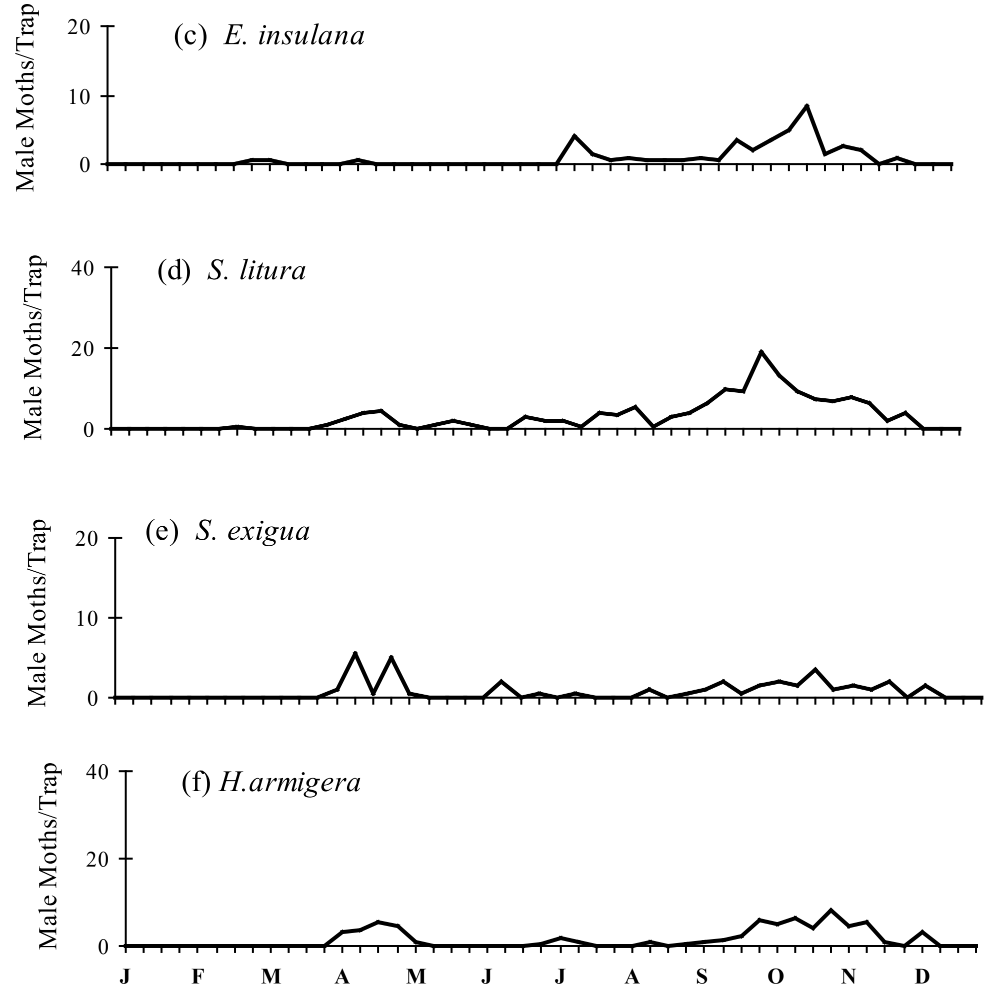


Fig.4.4 Weekly male moth catches of Lepidopterous pests in sex pheromone traps at CCRI, Multan

4.2.2 *Earias vittella* (Spotted bollworm)

Male Moth's catches were zero up to 3rd week of August. Afterwards population increased with fluctuating trend and reached to its peak in 4th week of September **(Fig. 4.4b).** Total number of moth catches was 48.0% lower than last year **(Table-4.4).**

4.2.3 *Earias insulana* (Spiny bollworm)

Moth's activity of *E. insulana* remained zero from January to 4th week of February. Population was inconsistent throughout the season and reached to its maximum in 4th week of October **(Fig. 4.4c).** Overall number of moth catches was 87.3% lower as compared to last year **(Table-4.4).**

4.2.4 *Spodoptera litura* (Armyworm)

Moth's activity started in 4th week of February with inconsistent trend and its peak was observed during 1st week of October **(Fig. 4.4d)**. Overall, moth catches were 32.1 higher than last year **(Table-4.3).**

4.2.5 *Spodoptera exigua* (Beet armyworm)

Moth's catches appeared in 1st week of April and reached to its peak in 2nd week of April **(Fig. 4.4e)**. Overall, moth catches were 75.6% lower to that of last year **(Table-4.3).**

4.2.6 *Helicoverpa armigera* (American bollworm)

Moth's activity remained zero up to 4th week of March with fluctuating trend throughout the season and its peak intensity was detected in 4th week of October **(Fig. 4.4f)**. Total number of moth catches was 18.4% lower than the last year **(Table-4.3).**

Table-4.3 Comparison of male moth catches of lepidopterous pests in sex pheromone traps

Insect pest	CCRI, Multan		
	2020	**2021**	**± %age**
P. gossypiella	425.9	370.5	**-13.0**
E. vittella	110.5	57.5	**-48.0**
E. insulana	324.0	41.0	**-87.3**
S. litura	112.0	148.0	**32.1**
S. exigua	147.5	36.0	**-75.6**
H. armigera	87.0	71.0	**-18.4**

4.3. Efficacy of different insecticides at different infestation levels of whitefly

Decision to initiate the spray application for sucking insect pest is very important because certain groups of insecticides induce pressure on other insect pests. For this purpose, the experiment was laid out in a Randomized Complete Block Design in the farm area of the CCRI, Multan. Cotton variety Cyto-537 was sown on 1st June 2021. The net plot size for each treatment was 40x40 feet and was replicated three times. Three infestation levels i.e 1-3 per leaf, 3-5 per leaf, and above 5 per leaf were used to check the efficacy of the following insecticides. Fertilizers were applied at recommended doses. There were seven treatments including a control. Six insecticides namely, Movento 240 SC, Olala 50% WG, Polo 500 SC, Diafenthiuron 50% SC, Acetamiprid 20 Sp and Pyriproxyfen 10.8% EC. Spray was initiated when whitefly infestation reached 1-3per leaf. Pretreatment data were recorded one day before spray application. The second spray of the same treatments on the same plots were applied after I week. Two consecutive applications of insecticides were applied at each infestation level of whitefly.

Olala 50% WG, proved more effective and gave more than 80% mortality followed by Polo 500SC, Diafenthiuron and Movento 240 SC. Moreover, Acetamiprid and Pyriproxyfen 10.8% EC gave more than 50% mortality 72h after 1st spray application. Efficacy percentage was observed below 60% 1 week after 1st spray keeping the 1-3 infestation level of whitefly,. In the second spray, maximum efficacy percentage was observed in Olala (84.52 %) followed by Movento (79.76 %) & Polo (75.00 %) in treated plots 72h after spray while Olala was proved more effective than the other tested insecticides after I week spray application at above mentioned level of whitefly (Table 1).

Table-4.3.1 Efficacy of different insecticides against whitefly at infestation level 1-3

Treatment	Common name	Dose acre^{-1}	Mortality %age (after 1st spray)		Mortality %age (after 2nd spray)	
			72 hours	**1 week**	**72 hours**	**1 week**
Movento 240 SC	Spirotetramat+ Adjuvant	125 ml + 250 ml	65.33	48.81	79.76	66.67
Olala 50% WG	Flonicamid	80g	81.33	54.76	84.52	71.43
Polo 500 SC	Diafenthiuron	200 ml	77.33	50.00	75.00	63.10
Diafenthiuron 50% SC	Diafenthiuron	200ml	73.33	47.62	70.24	54.76
Acetamiprid	Acetamiprid	125ml	61.33	48.81	60.71	40.48
Pyriproxyfen 10.8% EC	Pyriproxyfen	400 ml	58.67	46.43	60.71	45.24
Untreated Check	-	-	0.00	0.00	0.00	0.00
CD at 5%	**-**	**-**	**6.91**	**6.30**	**7.57**	**6.74**

Pretreatment data = 2.5 / leaf

Maximum mortality percentage was observed in Olala (68.06 %) & (64.58 %) 72h and one week after 2nd spray at 3-5 infestation level of whitefly and efficacy percentage of Polo and Movento were much better than other tested insecticides 72h after 1st spray. While, efficacy of all tested insecticides were below 60 except Olala after one week spray application. In the second spray, Olala proved to be more effective as it showed 73.61 % & 60.42 % efficacy while, efficacy of all other tested insecticides was observed below 60% 72h and one week after application respectively (Table 2).

Table-2 Efficacy of different insecticides against whitefly at infestation level 3-5

Treatment	Common name	Dose acre^{-1}	Mortality %age (after 1st spray)		Mortality %age (after 2nd spray)	
			72 hours	1 week	72 hours	1 week
Movento 240 SC	Spirotetramat+ Adjuvant	125 ml + 250 ml	60.42	56.25	66.67	49.31
Olala 50% WG	Flonicamid	80g	68.06	64.58	73.61	60.42
Polo 500 SC	Diafenthiuron	200 ml	62.50	59.03	56.25	55.56
Diafenthiuron 50% SC	Diafenthiuron	200ml	59.03	57.64	52.08	52.08
Acetamiprid	Acetamiprid	125 ml	56.25	48.61	44.44	45.14
Pyriproxyfen 10.8% EC	Pyriproxyfen	400 ml	59.72	55.56	50.69	45.83
Untreated Check	-	-	0.00	0.00	0.00	0.00
CD at 5%	**-**	**-**	**3.37**	**3.89**	4.00	3.79

Pretreatment data = 4.8 / leaf

Pyriproxyfen gave 58.60% mortality followed by Olala (53.23%), Polo (48.92%) and Movento (48.39 %) 72h after 1st spray application keeping the above 5 infestation level of whitefly. While efficacy of all tested insecticides were recorded below 50% one week after 1st spray application (Table 3).

Table-3 Efficacy of different insecticides against whitefly at infestation level above 5

Treatment	Common name	Dose acre^{-1}	Mortality %age (after 1st spray)	
			72 hours	1 week
Movento 240 SC	Spirotetramat+ Adjuvant	125 ml + 250 ml	48.39	33.87
Olala 50% WG	Flonicamid	80g	53.23	41.94
Polo 500 SC	Diafenthiuron	200 ml	48.92	37.10
Diafenthiuron 50% SC	Diafenthiuron	200 ml	46.77	36.56
Acetamiprid	Acetamiprid	125ml	45.16	33.33
Pyriproxyfen 10.8% EC	Pyriproxyfen	400 ml	58.60	41.40
Untreated Check	-	-	0.00	0.00
CD at 5%	**-**	**-**	**3.01**	**9.97**

Pretreatment data = 6.2 / leaf

4.4 National Coordinated Varietal Trials (NCVT)

4.4.1 Pest situation in Set-B

In this set-B, 20 cotton strains were tested for their tolerance/susceptibility to insect pest complex. During the month of June, jassid population was above ETL while whitefly and thrips populations were below ETL on all tested varieties. Jassid population was below ETL except on Sahara-Klean-10, Suncrop-3 (Diamond 24), Rawal-222, Thakar-76 (Uneek-123) while whitefly was below ETL whereas thrips was above ETL on all tested varieties during the month of July. During the month of August in Set-B, jassid, whitefly and thrip populations were below ETL on all tested varieties. Whitefly was highest on CIM-600 whereas jassid was lowest on JSQ-White-Gold and CKC-7 respectively **(Table-4.5)**. Bollworms population remained zero on all the tested strains **(Table-4.6)**.

Table-4.5 Seasonal population of sucking insect pests in Set-B

Strains	Number of sucking insect pests per leaf								
	Jassid			Whitefly			Thrips		
	June	July	August	June	July	August	June	July	August
Sahara-Klean-10	2.7	0.9	0.4	0.8	1.4	1.9	3.0	13.3	2.5
JSQ-White-Gold	2.9	1.1	0.1	0.5	1.4	3.1	1.6	12.6	3.5
Suncrop-3(Diamond-24)	3.5	0.4	0.7	0.4	1.6	1.2	2.4	12.1	1.5
Tara-CKC-333	4.2	1.5	0.5	0.1	1.1	1.3	2.0	15.8	3.0
TEVC-49	6.0	1.6	0.3	0.4	1.4	1.5	2.4	25.4	7.7
Tahafuz-25	4.9	1.4	0.2	0.4	1.1	2.3	2.0	28.0	2.5
FBS-Falcon	5.4	1.0	0.3	0.4	1.3	2.9	1.6	27.4	2.7
CIM-600 (Standard)	4.9	1.1	0.6	0.5	1.4	3.4	2.0	24.8	5.3
Rawal-222	6.1	0.9	0.2	0.5	1.3	1.7	3.1	14.5	1.6
Thakar-76(Uneek-123)	4.9	0.6	0.3	0.3	1.2	1.6	1.7	15.3	3.4
PC-2121	4.2	0.5	0.6	0.4	1.6	1.8	1.8	25.0	3.0
Rawal-111	3.5	1.4	0.5	0.3	1.7	2.1	1.7	13.0	4.4
TEVC-111	6.6	1.7	0.4	0.4	1.0	2.2	0.9	14.2	2.6
YBG-2525	5.3	1.2	0.3	0.4	1.1	1.8	1.7	13.5	2.7
CKC-7	6.2	1.2	0.1	0.4	1.2	3.3	2.3	12.7	3.3
BAHAR-GTG-155	5.0	1.0	0.4	0.4	2.1	2.0	1.7	23.2	1.9
ICS-386	4.7	1.2	0.4	0.4	1.6	1.7	2.9	24.3	3.3
Ghauri-3	3.5	1.4	0.2	0.9	1.5	1.7	3.5	23.1	2.5
Tara-CKC-335	5.4	1.2	0.4	0.8	2.3	2.6	1.8	24.9	2.4
CKC-8	4.8	2.0	0.5	1.0	0.6	2.3	3.4	26.6	2.4

Table-4.6 Bollworms damage and larval population on different *Bt* strains in set-B

Strains	Bollworm damage % age		larvae/ 25 plants
	September		September
	Immature bolls	Mature bolls	
Sahara-Klean-10	0.00	0.00	0.00
JSQ-White-Gold	0.00	0.00	0.00
Suncrop-3(Diamond-24)	0.00	0.00	0.00
Tara-CKC-333	0.00	0.00	0.00
TEVC-49	0.00	0.00	0.00
Tahafuz-25	0.00	0.00	0.00
FBS-Falcon	0.00	0.00	0.00
CIM-600 (Standard)	0.00	0.00	0.00
Rawal-222	0.00	0.00	0.00
Thakar-76(Uneek-123)	0.00	0.00	0.00
PC-2121	0.00	0.00	0.00
Rawal-111	0.00	0.00	0.00
TEVC-111	0.00	0.00	0.00
YBG-2525	0.00	0.00	0.00
CKC-7	0.00	0.00	0.00
BAHAR-GTG-155	0.00	0.00	0.00
ICS-386	0.00	0.00	0.00
Ghauri-3	0.00	0.00	0.00
Tara-CKC-335	0.00	0.00	0.00
CKC-8	0.00	0.00	0.00

4.4.2 Pest situation in Set-C

In this set 26 cotton strains were tested for their tolerance/susceptibility to insect pest complex. Jassid population was above ETL while whitefly and thrips were below ETL during the month of June. During the month of July, jassid population was fluctuating on all tested varieties and was above ETL on following tested varieties SAS-2, Sahara-500, NIAB-989, CIM-600 (Bt Standard), FH-938, VAM-20, FH-414, FH-498, Zar-21, VH-418, FH-415, FH-416, FH-494 while whitefly was below ETL whereas thrips population was above ETL on all tested varieties. Jassid, whitefly and thrips populations were below ETL on all tested varieties during the month of August. While, thrips population was highest on FH-498 (Table-4.7). Bollworms population remained zero on all the tested strains (Table-4.8).

Table-4.7 Seasonal population of sucking insect pests in Set-C

Strains	Number of sucking insect pests per leaf								
	Jassid			Whitefly			Thrips		
	June	July	August	June	July	August	June	July	August
CIM-975	3.5	0.5	0.1	0.6	0.4	2.4	2.5	21.8	1.8
ICS-286	6.0	0.3	0.0	0.5	0.4	2.7	4.3	21.2	3.0
MNH-1045	3.1	0.6	0.3	0.8	0.3	1.9	0.8	11.0	3.1
SAS-1	3.4	0.3	0.3	0.3	0.4	1.7	0.5	31.1	4.3
MNH-1090	5.0	0.3	0.2	1.0	0.4	1.7	2.8	13.0	2.0
BS-025	4.8	0.8	0.5	1.1	0.1	2.1	1.4	12.0	3.1
NIAB-868	3.7	0.4	0.6	0.3	0.3	2.3	3.8	13.7	4.0
Tara-CII-222	3.8	0.7	0.5	0.9	0.5	1.3	1.7	22.3	4.8
FH-189	4.0	0.2	0.6	0.4	0.9	1.7	1.6	11.4	4.1
SAS-2	4.1	1.6	0.2	0.5	0.4	2.6	0.9	21.8	2.4
Sahara-500	2.9	1.4	0.2	0.7	0.9	2.3	1.1	13.4	2.3
Cyto-541	2.7	0.3	0.4	0.6	1.4	1.6	1.7	25.1	2.8
NIAB-484	3.1	0.5	0.1	0.4	0.9	1.3	1.1	11.9	2.7
PC-2153	2.7	0.4	0.5	0.7	1.4	2.0	2.3	12.0	2.2
NIAB-989	2.4	1.6	0.3	0.7	1.1	2.4	1.7	23.3	1.3
CIM-600 (Std)	1.7	1.7	0.4	0.9	0.9	2.7	2.8	23.2	5.5
FH-938	3.3	1.8	0.1	0.6	1.6	2.3	2.3	13.2	2.0
UAM-20	1.5	1.9	0.5	0.4	1.0	1.7	2.2	14.5	3.5
FH-414	4.2	1.4	0.3	0.5	0.8	1.7	1.9	14.0	2.7
PC-2159	2.2	0.8	0.2	0.7	1.7	3.1	3.1	24.5	2.6
FH-498	2.8	1.6	0.0	0.3	0.8	3.7	4.2	23.7	5.6
ZAR-21	1.7	1.5	0.2	0.2	1.1	2.9	3.1	24.8	3.4
VH-418	3.1	1.7	0.3	0.6	1.4	2.2	1.6	14.9	2.5
FH-416	5.1	1.8	0.2	0.7	1.2	2.4	3.1	15.7	2.5
FH-415	4.9	1.2	0.2	0.4	1.1	2.4	2.8	25.6	2.4
FH-494	3.8	1.9	0.0	0.6	0.8	2.5	5.1	14.8	2.1

Table-4.8 Bollworms damage and larval population on different *Bt* strains in set-C

Strains	Bollworm damage % age		larvae/ 25 plants
	September		September
	Immature bolls	Mature bolls	
CIM-975	0.00	0.00	0.00
ICS-286	0.00	0.00	0.00
MNH-1045	0.00	0.00	0.00
SAS-1	0.00	0.00	0.00
MNH-1090	0.00	0.00	0.00
BS-025	0.00	0.00	0.00
NIAB-868	0.00	0.00	0.00
Tara-CII-222	0.00	0.00	0.00
FH-189	0.00	0.00	0.00
SAS-2	0.00	0.00	0.00
Sahara-500	0.00	0.00	0.00
Cyto-541	0.00	0.00	0.00
NIAB-484	0.00	0.00	0.00
PC-2153	0.00	0.00	0.00
NIAB-989	0.00	0.00	0.00
CIM-600 (Std)	0.00	0.00	0.00
FH-938	0.00	0.00	0.00
UAM-20	0.00	0.00	0.00

FH-414	0.00	0.00	0.00
PC-2159	0.00	0.00	0.00
FH-498	0.00	0.00	0.00
ZAR-21	0.00	0.00	0.00
VH-418	0.00	0.00	0.00
FH-416	0.00	0.00	0.00
FH-415	0.00	0.00	0.00
FH-494	0.00	0.00	0.00

4.4 Impact of sowing period on the Dusky cotton bug infestation

The trial was conducted to assess the impact of dusky cotton bug (DCB) infestation on early and normal sown cotton. Early sown cotton (Mid-April) was planted on 14th April and normal sown cotton (Mid-May) on 16th May. Two Bt varieties (Cyto-179 & CIM-632) and two non Bt varieties (CIM-717 & CIM-620) were planted in split-plot design with three replicates. Main plots were sowing dates whereas varieties were in subplots.

In both early and normal sown cotton, DCB appeared in July with fluctuating trend throughout the season and its peak intensity was noticed in October **(Fig. 4.5 & 4.6)**. Among fruiting parts, DCB preferably harboured and multiplied in open bolls where its maximum population was observed in Mid-April sown cotton as compared to Mid-May sown cotton **(Fig. 4.5)**.

Maximum DCB population in Mid-April planted cotton was recorded on CIM-620 followed by Cyto-179. While, in Mid-May planted cotton DCB was higher on Cyto-179 followed by CIM-717. On the whole, DCB was higher on Cyto-179 and lower on CIM-620 & CIM-632 as compared to other tested varieties **(Table-4.4).** Overall, population of DCB was higher on early sown crop as compared to normal sown cotton **(Fig.4.7)**.

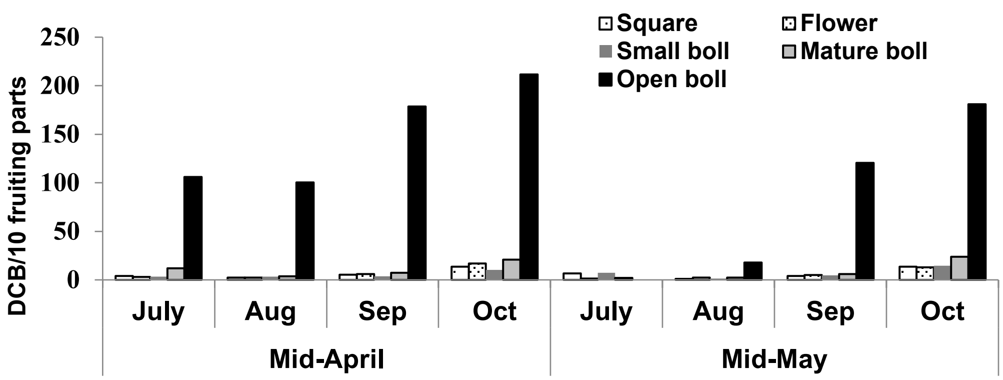


Fig. 4.5 Seasonal incidence of dusky cotton bug on different fruiting parts

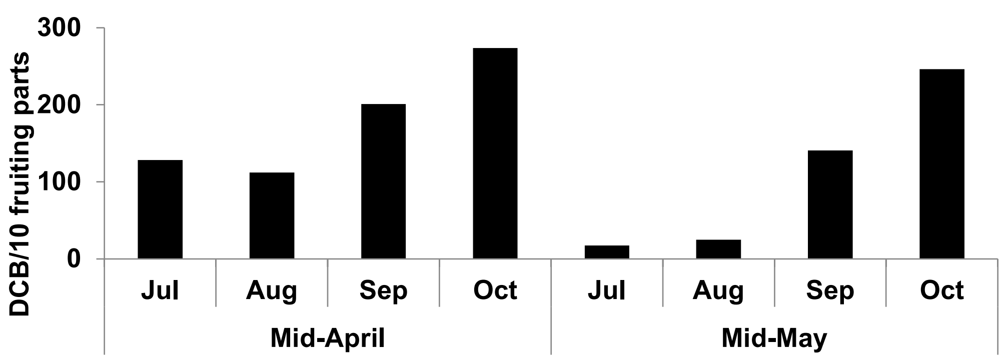


Fig. 4.6 Population dynamics of dusky cotton bug on Mid-April and Mid May sown cotton

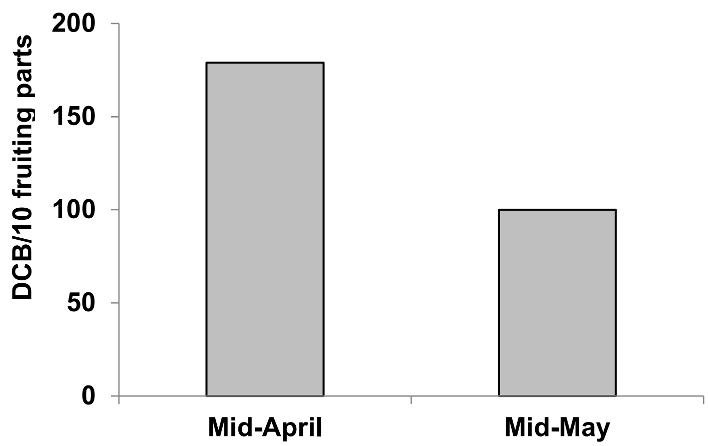


Fig. 4.7 Comparative impact of sowing dates on dusky cotton bug

Table-4.4 Integrated impact of sowing date and varieties on dusky cotton bug infestation

Sowing Date	Month	Dusky cotton bug/ 10 fruiting parts			
		Cyto-179	**CIM-717**	**CIM-632**	**CIM-620**
Mid-April	June	4.1	5.0	4.1	10.0
	July	103.9	171.9	84.9	152.5
	August	116.2	96.8	115.8	120.2
	September	195.0	207.0	211.0	190.4
	October	312.2	228.1	288.4	265.3
Mid-May	July	12.4	13.1	24.4	20.9
	August	30.1	25.3	12.2	31.4
	September	144.6	142.2	130.5	73.3
	October	290.3	210.5	219.5	221.4

4.5 Incidence of arthropods on light and normal green cotton leaves

Comparison of light-green (CIM-775 & CIM-875) with normal-green (CIM-785 & CIM-678) advanced cotton genotypes under sprayed and unsprayed conditions was done regarding the incidence of sucking insect pests, the buildup of beneficial arthropods fauna, damage percentage of pink bollworm and seed cotton yield. Plant protection was carried out when the pests pressure reached ETL. Data on sucking insect pests were recorded from randomly selected twenty leaves (top, middle and bottom) whereas, for bio-agents, five whole plant samples and for pink bollworm damage assessment, thirty green bolls were collected randomly for laboratory observation. Standard agronomic practices were employed in both sprayed and unsprayed sets of the experiments.

Among the sucking insect pests, the highest mean number of whitefly (5.4/leaf) at sprayed set was recorded on CIM-875 followed by CIM-785 (4.6/leaf), whereas the lowest mean number of whitefly (3.8/leaf) was recorded on CIM-775. Overall, population of jassid and thrips remained below ETL on sprayed set **(Fig.4.8).** The same trend of sucking insect pests infestation was observed in the unsprayed set as that of sprayed. The most susceptible strain against the pink bollworm was recorded to be CIM-785 both in sprayed (35%) and unsprayed (40%) sets while, less susceptible strain in sprayed set CIM-775 (25%) and in unsprayed set CIM-678 (25%).

Table-4.5 Mean number of sucking insect pests per leaf, % damage of pink bollworm and seed cotton Yield kg ha^{-1} under sprayed and unsprayed conditions.

Strain	Treated Set					Untreated Set				
	Mean Number of Sucking Insects/Leaf			PBW %Dam.	Yield kg ha^{-1}	Mean Number of Sucking Insects/Leaf			PBW %Dam.	Yield kg ha^{-1}
	Jassid	Whitefly	Thrips			Jassid	Whitefly	Thrips		
CIM-775	0.6	3.8	2.6	25.0	1408.9	0.9	3.6	2.6	28.3	1485.8
CIM-875	0.8	5.4	2.9	31.7	1024.7	1.1	5.8	2.9	35.0	896.58
CIM-785	0.9	4.6	2.1	35.0	973.5	1.0	5.5	2.0	40.0	768.51
CIM-678	0.6	4.0	2.7	28.3	896.6	0.9	4.1	2.0	25.0	742.9

***Dam.** Damage

Due to suppression caused by insecticides, overall, predators population was lower in sprayed set as compared to the unsprayed set. The higher population of spiders seemed due to its potential resistance against insecticides as well as naturally prevailing adverse conditions as compared to other predators **(Fig.4.8),** however, lower population of ladybird beetles might be due to its being more prone to insecticides and natural climate conditions.

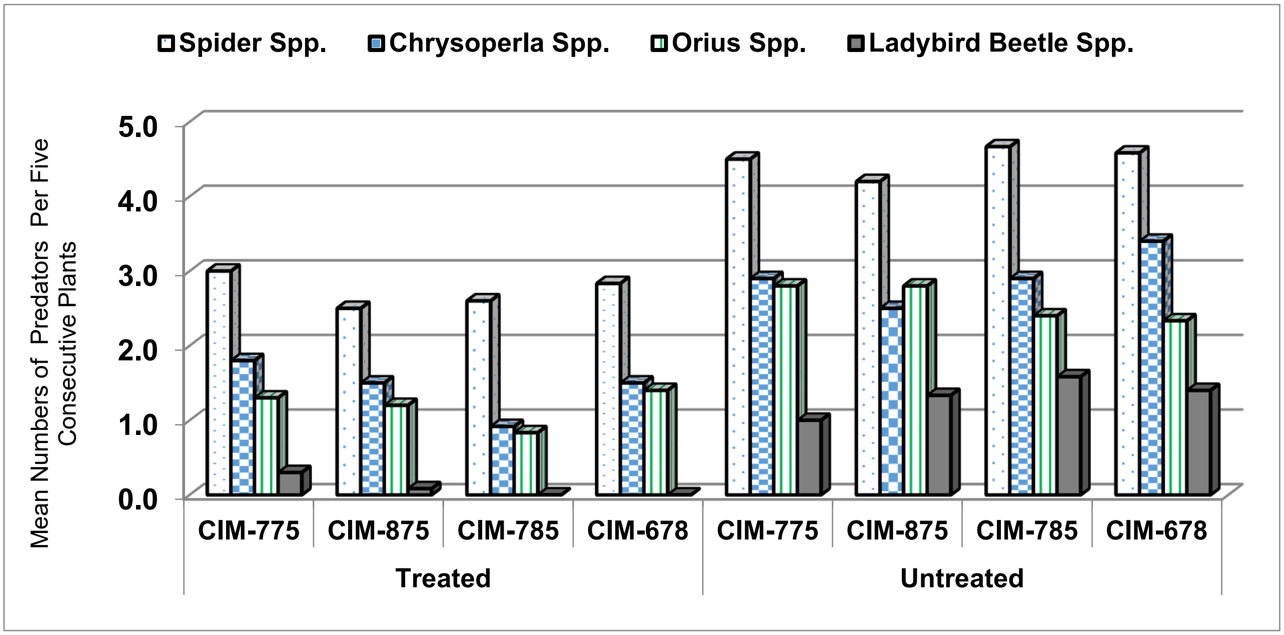


Fig.4.8 Mean number of predator per five consecutive plants under sprayed and unsprayed conditions.

4.6 Impact of pesticides on the crop physiology/shape/canopy

The trial was conducted to evaluate non-phytotoxic potential insecticides for the management of whitefly. Cotton crop was sown in 2nd week of April and was kept unsprayed, to allow whitefly population to reach at or above ETL level (5nymph or adult or both/leaf) for spray application. Efficacy and phytotoxic impact of different commercially available insecticides viz. pyriproxyfen, buprofezin, acetamiprid, spirotetramate, diafenthiuron, flonicamid and bifenthrin were recorded. Each insecticide was tested at three dose rates i.e. recommended field dose (RFD), double dose (DD) and half dose (HD). In RFD, buprofezin gave highest nymphal mortality followed by diafenthiuron, whereas, highest adult mortality was given by flonicamid followed by diafenthiuron one week after second spray. In DD, spirotetramate proved to be the most effective against whitefly nymphs followed by pyriproxyfen and diafenthiuron. Adult mortality was higher where flonicamid was applied followed by diafenthiuron. In both RFD and DD, lowest efficacy was shown by flonicamid and acetamiprid against nymphs while bifenthrin proved weaker against adults. In HD, most of the insecticides led to resurgence/ increased nymphal population. Population of both nymph and adult whitefly was increased where bifenthrin was applied at half dose rate **(Table-4.6).** Though, all the insecticides showed slightly higher nymphal and adult mortality at DD as compared to RFD and HD but none of the insecticide gave > 75% mortality of whitefly nymph and adults at either of the doses **(Table-4.6).** Moreover, lowest number of fruiting bodies was observed when diafenthiuron was applied at DD. Furthermore, plant height was reduced when insecticides applied at DD as compared to RFD **(Fig.4.9).**

Table-4.6 Efficacy of insecticides against whitefly

Insecticides	Mortality (%) 1 week after second spray					
	RFD		DD		HD	
	Nymph	Adult	Nymph	Adult	Nymph	Adult
Pyriproxyfen	41.7	46.8	63.2	58.2	12.1	39.8
Buprofezin	51.1	41.8	61.3	59.6	-15.0	25.9
Acetamiprid	33.3	56.5	33.3	69.1	-16.7	41.5
Spirotetramate	41.7	55.2	69.4	68.8	11.1	18.6
Diafenthiuron	44.8	62.0	62.2	72.0	-8.3	33.1
Flonicamid	16.7	66.1	38.9	74.9	-5.0	25.0
Bifenthrin	44.4	22.8	46.6	36.2	-14.0	-10.0

RFD= Recommended field dose
DD= Double dose
HD= Half dose

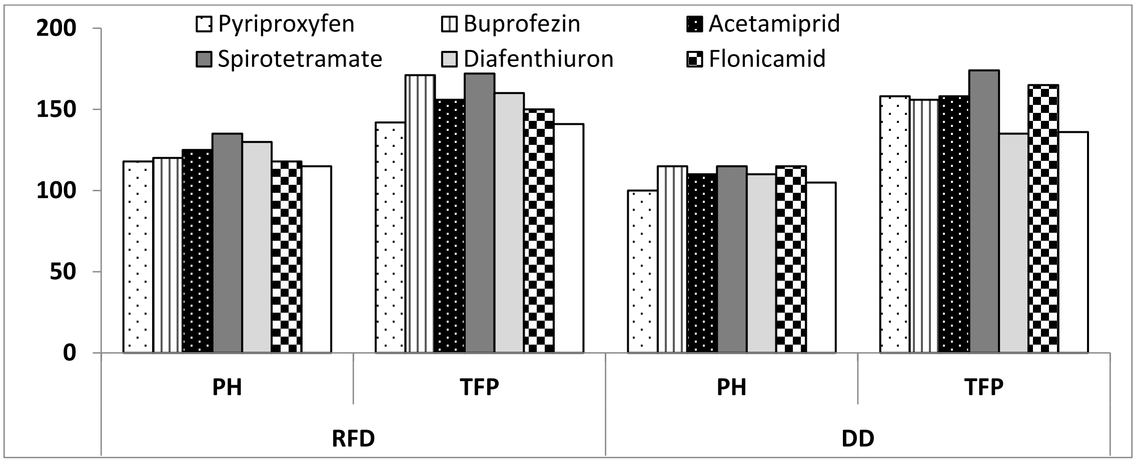


Fig.4.9 Impact of different insecticides on plant height (cm) and total fruiting parts at dose rates; RFD= recommended field dose, DD= double dose, PH= plant height and TFP= total fruiting parts

4.7 Insecticide resistance monitoring

4.7.1 Army worm *(Spodoptera litura)*

Adults of *Spodoptera litura* collected from light trap at CCRI, Multan were kept in the laboratory on artificial diet in 8 lbs glass jars covered with muslin cloth. Nappy liner strips were hanged in the jar for oviposition and the eggs laid were removed daily and kept in glass jars of 800 ml capacity each. Newly emerged larvae were fed on artificial diet. Second instar larvae were exposed to insecticides viz. profenofos, triazophos, chlorpyriphos, indoxacarb, emmamectin benzoate, flubendamide, leufenoron and cypermethrin using leaf dip method. Larval mortality was observed 48 hours after treatment for conventional insecticides and 72 h after treatment for new chemistry insecticides. Results indicated very high LC50 values for Cypermethrin followed by Triazophos as compared to other insecticides **(Table-4.7).**

Table-4.7 Response of *Spodoptera litura* to different insecticides

Insecticide	Slope ± SE	95% fiducial limits	LC50 (ppm)
Profenofos	1.46±0.162	25.54-42.33	33.01
Triazophos	0.99±0.134	134.85-306.79	207.48
Chlorpyrifos	1.78±0.276	4.08-7.67	5.86
Indaxacarb	0.96±0.175	2.80-6.85	4.67
Emamectin benzoate	1.108±0.144	0.227-0.425	0.313
Flubendamide	1.43±0.16	3.95-6.57	5.11
Lufenuron	0.88±0.11	1.37-2.91	2.04
Cypermethrin	2.23±0.525	832.36-1441.53	1118.78

4.7.2 Dusky cotton bug *(Oxycarenus hyalinipennis)*

Oxycarenus hyalinipennis, dusky cotton bug collected from cotton fields at Multan, Vehari, Khanewal and Rahim Yar Khan (RYK) were exposed to five insecticides viz. cypermethrin, deltamethrin, triazophos, fipronil and clothianidin using leaf dip method. Adults of *O. hyalinipennis* were exposed and observations on mortality were taken 48 h after treatment for conventional insecticides and 72 h after treatment for new chemistry insecticides. Resistance ratio (RR) was calculated by dividing LC^{50} of field population with LC^{50} of susceptible population (Lab-Sus).

Moderate to very high level of resistance to cypermethrin was detected in tested populations of four different locations as compared to the Lab-Sus population. Very low to low levels of resistance were observed for deltamethrin in the *O. hyalinipennis* from tested locations. *O. hyalinipennis* showed moderate to high level of resistance to clothianidin as compared to the Lab-Sus. While no to very low levels of resistance to triazophos and fipronil were observed in all the tested field populations. Among the locations, *O. hyalinipennis* collected from Vehari and Khanewal were the most resistant to cypermethrin and clothianidin, respectively **(Table-4.8)**.

Table-4.8 Response of *Oxycarenus hyalinipennis* to different insecticides

Insecticide	Location	Slope ± SE	LC50 (ppm)	95% fiducial limits	RR
Cypermethrin	Lab-CCRI	1.76 ± 0.30	10.72	7.92–15.71	1
	Multan	1.48 ± 0.27	471.52	337.67–687.88	44.0
	Vehari	132 ± 0.28	1873.26	1202.75–3863.26	174.7
	Khanewal	1.07± 0.22	601.58	392.81 – 1008.17	56.1
	RYK	1.68± 0.27	584.29	434.14 – 813.24	54.5
Deltamethrin	Lab-CCRI	1.36 ± 0.26	11.73	8.06–19.79	1
	Multan	0.93 ± 015	204.42	131.27–356.13	17.4
	Vehari	1.29 ± 0.24	111.92	74.22–161.05	9.5
	Khanewal	1.97± 0.30	103.33	77.82 – 134.94	8.8
	RYK	1.45 ± 0.25	127.94	89.90–178.92	10.9
Triazophos	Lab-CCRI	1.90 ± 0.29	5.77	4.39–7.72	1
	Multan	2.03 ± 0.31	37.19	28.65–49.10	6.4
	Vehari	2.89 ± 0.44	16.04	12.96–20.06	2.8
	Khanewal	2.54± 0.37	10.77	8.49 – 13.50	1.9
	RYK	1.99 ± 0.30	31.97	24.53–42.13	5.5
Fipronil	Lab-CCRI	1.78 ± 0.28	0.48	0.31–0.74	1
	Multan	2.24 ± 0.34	0.93	0.72–1.19	1.9
	Vehari	1.35 ± 0.30	1.14	0.68–1.78	2.4
	Khanewal	1.04± 0.22	2.16	0.90 – 1.10	4.5
	RYK	2.17 ± 0.43	0.78	0.55–1.08	1.6
Clothianidin	Lab-CCRI	1.72 ± 0.39	7.70	5.39–13.78	1
	Multan	1.37 ± 0.20	286.61	205.56–404.41	37.2
	Vehari	1.33 ± 0.31	178.77	95.47–281.11	23.2
	Khanewal	1.19± 0.23	589.65	399.51 – 927.88	76.6
	RYK	1.86 ± 0.35	357.76	250.37–512.82	46.5

4.8 Screening of new and commercially available insecticides

Efficacy of different insecticides against Jassid during-2021

Common Name	Dose (ml/g)	Mortality %	
		72 hour	1-Week
Flonicamid 50 % DF	60	81.2	84.3
Nitenpyram 10 SL	200	73.8	78.4
Abamectin + Dinotifuron 30 WP	75	74.4	79.6
Dinotifuron 80% WDG	100	73.1	78.3
Flonicamid + Abamectin 10.7 WG	400	74.8	80.5
Diafenthiuron 50 SC	200	72.9	76.1
Chlorfenapyr + Nitenpyram 50 WDG	150 g	86.4	91.7
Bifenthrin 30% SC	50	73.0	77.2
Dinotifuron + Spirotatramat 17 % WDG	250g	80.1	87.8
Abamectin + Thiamethoxam 108 SC	300	71.5	76.2
Imidacloprid + Fipronil 80 WDG	50	64.8	77.7
Nitenpyram 50% WDG	40	79.4	88.6

Nitenpyram + Acephate 48% SP	300	78.9	82.0
Dimathoate 40 SC	400	79.6	70.5
CD 5%	-	9.69	10.34

Pre-treatment data-2.63 per leaf

Effcacy of different insecticides against Whitefly during-2021

Common Name	**Dose (ml/g)**	**Mortality %**	
		72 hour	**1-Week**
Acetamiprid 20 SL	150	53.2	41.6
Difenthiuron 50 SC	200	64.1	54.8
Diafenthiuron 80 WDG	150	58.6	47.3
Abamectin + Thiamethoxam 108 SC	300	55.9	34.5
Pyriproxifen 10.8 EC	400	48.7	37.6
Pyriproxifen + Diafenthiuron 50 SC	400 + 150	62.0	66.8
Pyriproxifen + Acetamiprid 41.6 EC	250	71.4	39.9
Spiortatramat 240 SC	125 + 250	62.2	49.8
Pyriproxifen 20%WDG	250	68.3	52.7
Metrin 0.5 SC	500	62.0	50.6
Buprofezin 35% WP	600 g	49.5	41.2
Acetamiprid + Thiocylam hydrogen Oxilate 28 WP	200	61.8	56.9
Flonicamid 50% DF	80 g	83.4	87.2
Imidacloprid 25 WP	250	29.6	38.4
CD 5%	-	7.04	8.20

Pre-treatment data-8.50 per leaf

Pink bollworm damage and live larvae recorded from major cotton growing districs-2021

Districts	**2021**						**2020**	
	September		**October**		**November**			
	% Boll damage	**% Larvae**	**% Boll damage**	**% Larvae**	**% Boll damage**	**% Larvae**	**% Boll damage**	**% Larvae**
Vehari	52.95	421	19.93	103	22.57	84	66.7	71.5
Khanewal	40.20	101	20.30	100	18.20	77	64.6	74.7
Bahawalpur	50.67	131	16.40	77	21.06	81	50.3	53.4
Lodhran	46.67	119	28.13	181	17.57	70	50.0	50.9
Multan	26.36	78	41.0	101	26.43	104	57.6	72.4

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5. PLANT PATHOLOGY SECTION

Plant pathology is the science that studies the causes of plant diseases, the mechanisms by which diseases develop in individual plants and in plant populations, and the ways and means by which plant diseases can be managed or controlled, it ameliorates the disease-management approaches to attain cotton yield security and safety for the country. Therefore with the understanding of the dynamic nature of the plant diseases, the outsmart management approach must be in line with the environmental-acceptability and circumstances prevailing in the agriculture field and markets. The approaches of sustainable intensification with modern technical advancements offered new opportunities in the form of an integrated systems-based viewpoint for disease management.

Experiments were conducted under greenhouse and field conditions. The promising strains in National Coordinated Varietal Trial (NCVT) and Punjab Government Trial i.e. Provincial Cotton Coordinated Trial (PCCT), for Bt. and non-Bt. Varieties were screened for their reaction to various diseases.

The section participated in training programs, organized by the Institute for the farmers and staff of the Agriculture Extension. The section also provided internship facilities to students from different universities..

5.1 Screening of Breeding Material against CLCuD

The advanced strains/genotypes of this Institute included in varietal, micro varietal trials and various national coordinated varietal trials were screened for their reaction to CLCuD under field conditions. One hundred and thirty families were screened during the year. Data present in **Table-5.1** revealed that all families of breeding material, showed symptoms of the CLCuD under filed conditions except eleven families, which exhibited resistance against CLCuD in VT-3,MVT-1,MVT-2 and MVT-3 and two families showed high tolerance against CLCuD, in VT-1, NCVT-B.

Table 5.1 CLCuD status in Breeding Material under field condition

Experiment	No. of Families Screened	No. of Families showing Res. to CLCuD	Disease index Range	Name of strain Resistance or Tolerance
VT-1	10	0	1.07~ 81.98	
VT-2	8	2	0.00 ~78.56	CM10,CM-11
VT-3	8		1.46~ 78.48	
MVT-1	9	3	0.00~50.19	CM5,CM8,CM9
MVT-2	9	3	0.00~ 17.21	CM14,CM17,CM18
MVT-3	9	3	0.00~ 28.25	CM23,CM26,CM27
MVT-4	10	0	25.93~77.28	
NCVT-C	30	0	79.49~82.12	
NCVT-D	25	0	27.22~81.30	
SVT-I	7	0	28.68~79.55	
SVT-II	6	0	52.60~79.68	
Total	130	11		

VT = Varietal Trial MVT = Micro-Varietal Trial NCVT = National Coordinated Varietal Trial
SVT = Standard Varietal Trail

5.2 Evaluation of National Coordinated Varietal Trial against Different Diseases

National coordinated Varietal Trial were planted in two sets.In Set-B thirty strains and Set-C twenty five strains were tested against stunting, boll rot and Cotton Leaf Curl Disease under field conditions.

NCVT-Set-B

In set-B, all the NCVT strains were found highly susceptible to cotton leaf curl disease. Except one that showed tolerance(2116) Minimum disease incidence (2.11%), disease index (1.06) and disease severity (1.33) was recorded in 2116 Two genotypes were free from boll rot incidence. While rest of strains had boll rot incidence less than 2 % (Table 5.2).

NCVT-Set-C

In set-C, all the NCVT strains were observed to be highly susceptible to cotton leaf curl disease. Disease severity ranged from 2.87-3.24% and disease index that ranged from 71.86%-81.10.% was recorded in all strains (Table-5.3).

5.3 Epidemiological Studies on CLCuD

5.3.1 Incidence of Cotton Leaf Curl Disease (CLCuD) in Sowing Date Trial

(A) *Bt*-Strains

Six Bt strains viz Bt.CIM-775, Bt.CIM-875, Bt.Cyto-535, Bt.Cyto-536,Bt. Cyto-537, Bt.CIM-663 were tested at five different sowing dates from 1stApril to 1stJune at 15 days' interval to observe the response to CLCuD.. The experimental design was split-plot (main plots: Sowing time; sub-plot: genotype). Data on CLCuD incidence were recorded fortnightly on day 30 after each planting date during the season. The results are given in Fig-5.1. Averaged across cultivars, the infection level was 0.00 at day 30 disease which increased to (1.3%) at day 60 after planting with the advancement of age, the incidence increased up to 22.1% at 135 days on that crop planted on 15th April, The infection level was 0.1 % at day 45 and reached to its maximum (72.2%) at 120 days after planting on crop seeded on 1st May. However, incidence of CLCuD was 3.3% at day 45 and reached to its maximum level of 74.6% at 105th day of planting for crop sown on 15th May. The incidence of disease started from 0.5% at day 30 and reached up to 81.6% at day 90 after planting for crop planted on 1st June.

Early sowing i.e. 1stApril revealed less CLCuD incidence The rise in CLCuD incidence could be attributed to gradual increase in relative humidity as the growing season advanced. Whereas at 60 days after sowing (DAS), more CLCuD incidence in May sowing can be due to comparatively higher rainfall and relative humidity. The incidence of CLCu disease increased as sowing was delayed.. The intensity of the disease varied from variety to variety. (Fig-5.2). Use of greater amounts of nitrogenous fertilizer, more severe insect attacks, and late sowing of the cotton crop significantly increase the incidence of the CLCuD disease. Averaged across planting dates, there was a significant varietal difference in all sowing dates. CIM-775 and CIM-875 performed better against CLCuD even in May Planting.(Fig-5.3).

(B) Non Bt.Strains

Non-Bt cotton genotypes i-e Cyto-228 and CIM-735 along with one standard variety CIM-610 were sown on five different sowing dates from 1st April to 1st June at 15 days interval. to observe the response to CLCuD with the collaboration of the Agronomy Section. The experiment design was split-plot (main plots: sowing time: subplots genotypes). Data on CLCuD incidence were recorded fortnightly at day 30 from each sowing date during the season. Results are given in Fig-5.1. Results reveal that expression of CLCuD and its progression during the season differed greatly with planting dates. Averaged across varieties minimum incidence of disease (0.15 %) was recorded at day 75 after planting and increased up to 7.60% at day 105 after planting. The disease boosted up to 41.28% at day 150 after planting on the crop planted on 1st April of the year. The infection level was 0.41 % at day 45 and attained its maximum (66.06%) at day 135 after planting on crop planted on 15th April of the year. However, incidence of CLCuD was (10.32%) at day 45 and reached to its maximum level (84.16%) at day 120 after planting on crop planted on 1st May of the year. The incidence of the disease was 12.93% at day 45 and reached to maximum (93.64%) at day 105 after planting on crop planted on 15th May of the year. Furthermore crops planted on 1st June of the year fell prey to CLCuD to 45.22% within 75 days after planting and to its maximal (93.93%) with in next 15 days (Table 2). Data revealed that the incidence of disease increased and period decreased (days after planting) as the planting time was delayed (Table 2). Average across sowing dates. Comparison among the varieties revealed that CIM-228 perform well as compared to other genotypes. Although in June sowing all varieties showed maximum CLCuD infestation at 90,DAP (Fig-5.3).

Data on incidence and severity were recorded during the end of September from each sowing date and computed for disease index In Bt strains; Averaged across cultivars, in non Bt the minimum disease index of 4.62 % was recorded on the crop planted on 1st April as compared to other planting dates. Average across planting dates, significant differences were found in all genotypes. The minimum disease index of 8.45 % followed by 13.15 % was recorded CIM-775 and CIM-875 (Table-5.4) Average across cultivars, the minimum disease index 24.0 % was recorded on the crop planted on 1st April as compared to other planting dates. Averaged across planting dates, a minimum disease index (43.41%) was recorded on genotype CIM-610 (Table-5.5). On an average basis of sowing dates, a maximum fortnightly increase in disease in Bt strains was recorded during mid-August. Among environmental parameters, the maximum temperature range was 35.8~38.5°C while the minimum temperature 29.6~31.3°C with the relative humidity of 84.6~ 89.1 %. It has been observed that if the difference between maximum temperature and minimum temperature isthe less incidence of cotton leaf curl disease is more and vice-versa. Rainfall also plays an important role in disease epidemiology (fig.5.4).

On an average basis of sowing dates, a maximum fortnightly increase in disease in non Bt-strains was recorded during mid-August. Among environmental parameters, the maximum temperature range was 35.8~38.5°C while the minimum temperature 30.3~31.3°C with the relative humidity of 73~ 89.1 %. It has been observed that if the difference between maximum temperature and minimum temperature is less the incidence of cotton leaf curl disease is more and vice-versa. Rainfall also plays an important role in disease epidemiology. It was also noted that early sown crops were less affected by CLCuD than late sown crops due to attainment of early plant vigor (fig5.5).

Table-5.2 Stunting, Cotton Leaf Curl Disease Incidence, Severity, Disease Index and Boll Rot of Cotton on NCVT Set-B

NCVT Set B Strain	Stunting %age	Cotton Leaf Curl Disease			Boll Rot (%)
		Disease % age	Disease Severity	Disease Index	
Sahara-Klean-10	0.00	100.00	2.10	52.48	0.82
JSQ-White-Gold	0.00	100.00	2.05	51.37	1.01
Suncrop-3(Diamond-24)	0.00	100.00	2.09	52.23	0.00
Tara-CKC-333	0.00	100.00	2.01	50.30	0.00
TEVC-49	0.00	44.39	1.77	21.14	0.72
Tahafuz-25	0.00	2.11	1.33	1.06	0.00
FBS-Falcon	0.00	100.00	2.11	52.68	0.00
CIM-600 (Standard)	0.00	100.00	2.17	54.27	1.52
Rawal-222	0.00	100.00	2.08	52.08	0.72
Thakar -76(Uneek-123)	0.00	100.00	2.05	51.29	0.45
Rawal-111	0.00	100.00	2.14	53.53	1.47
TEVC-111	0.00	100.00	2.12	52.91	0.48
YBG-2525	0.00	100.00	2.07	51.74	0.43
CKC-7	0.00	98.18	1.98	48.01	1.36
BAHAR-GTG-155	0.00	100.00	2.11	52.76	0.57
ICS-386	0.00	100.00	2.14	53.42	1.00
Ghauri-3	0.00	100.00	2.11	52.77	0.80
Tara-CKC-335	0.00	100.00	2.08	51.93	0.43
CKC-8	0.00	100.00	2.08	52.11	0.39

Disease Index= Disease percentage x Disease severity/maximum severity value (4).

Table-5.3 Stunting, Cotton Leaf Curl Disease Incidence, Severity, Disease Index and Boll Rot of Cotton on NCVT Set-C

NCVT Set C Strain	Stunting %age	Cotton Leaf Curl Disease			Boll Rot (%)
		Disease % age	Disease Severity	Disease Index	
CIM-975	0.00	100.00	2.87	71.86	0.33
ICS-286	0.00	97.56	3.05	74.34	0.00
MNH-1045	0.00	96.67	3.09	74.74	0.00
SAS-1	0.00	98.79	3.10	76.54	0.00
MNH-1090	0.00	99.28	3.07	76.16	1.63
BS-025	0.00	100.00	3.14	78.39	1.16
NIAB-868	0.00	100.00	3.02	75.53	0.00
Tara-CII-222	0.00	100.00	3.10	77.55	0.81
FH-189	0.00	100.00	3.15	78.74	1.21
SAS-2	0.00	100.00	3.04	75.95	0.37

Sahara-500	0.00	100.00	2.99	74.85	1.06
Cyto-541	0.00	100.00	3.17	79.21	0.37
NIAB-484	0.00	100.00	3.09	77.18	0.00
NIAB-989	0.00	100.00	3.08	77.09	0.00
CIM-600 (Standard)	0.00	100.00	3.24	81.10	0.00
FH-938	0.00	100.00	3.09	77.34	1.95
UAM-20	0.00	100.00	3.16	79.05	0.00
FH-414	0.00	100.00	3.07	76.82	0.40
FH-498	0.00	100.00	3.18	79.59	0.00
ZAR-21	0.00	100.00	3.05	76.13	0.41
VH-418	0.00	100.00	3.02	75.38	1.23
FH-416	0.00	100.00	3.08	76.92	0.00
FH-415	0.00	100.00	3.17	79.23	0.78
FH-494	0.00	100.00	3.05	76.25	1.18

Disease Index= Disease percentage x Disease severity/maximum severity value (4)

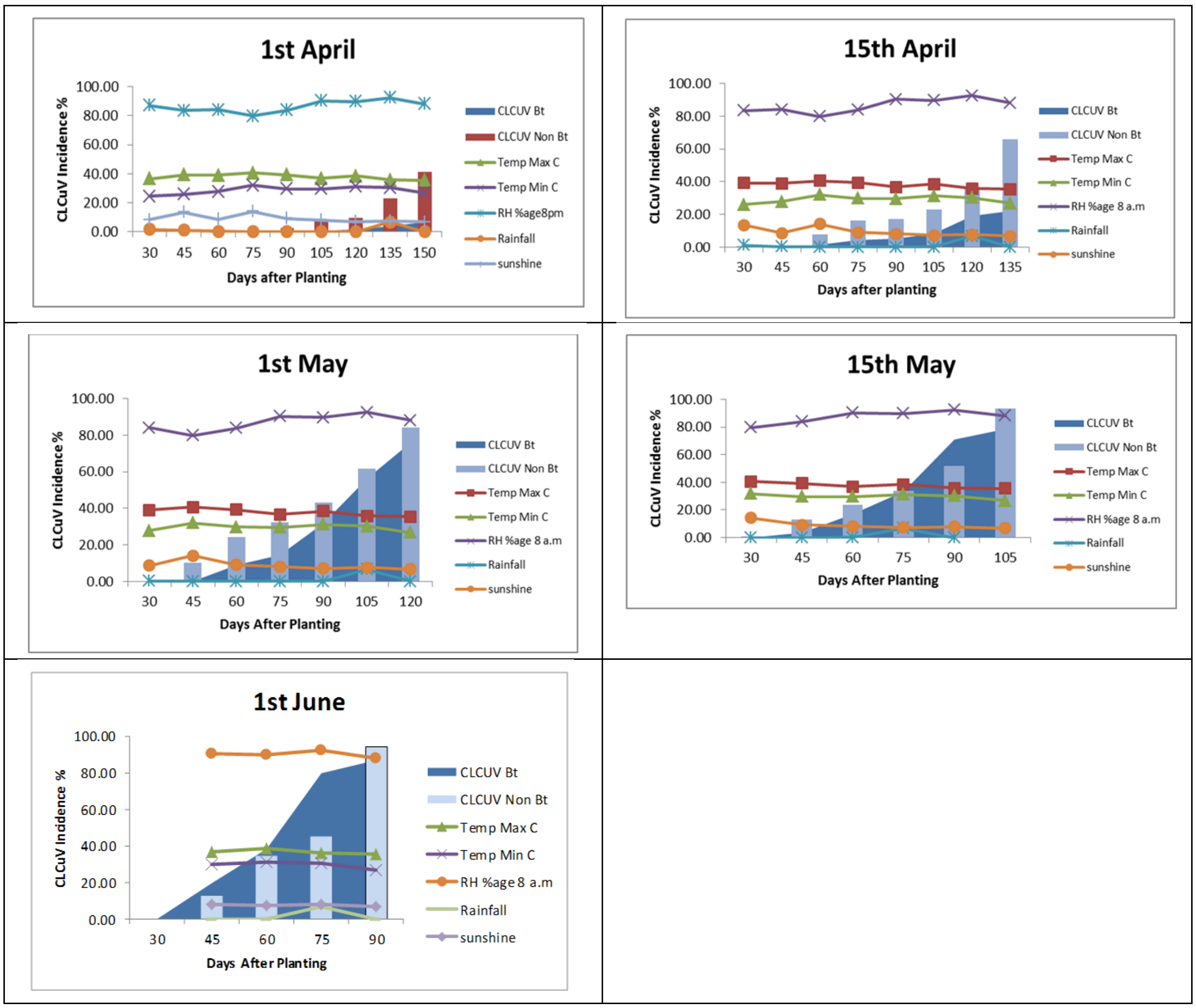

Fig-5.1 CLCuD incidence in different as influenced by days after planting

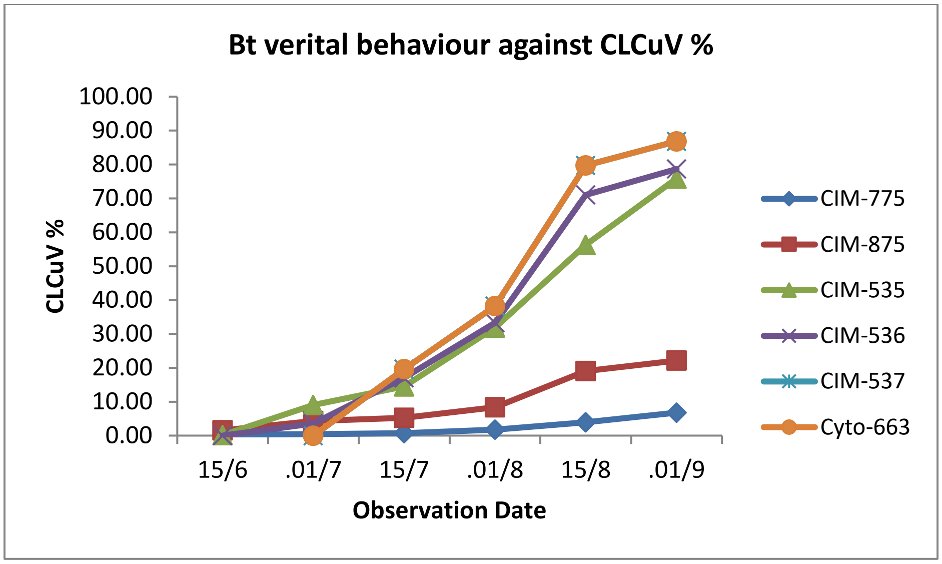

Fig-5.2 incidence of CLCuD in Bt-cotton strains

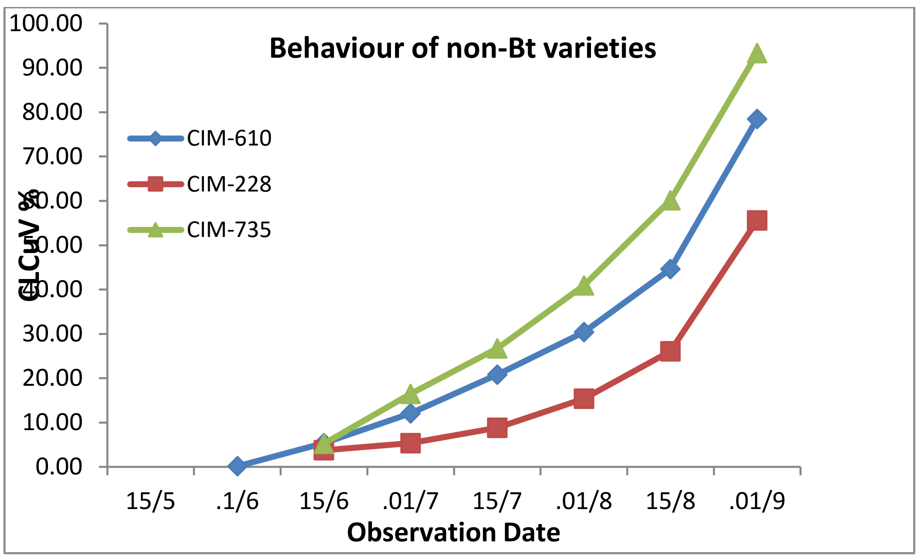

Fig-5.3 incidence of CLCuD % trend in Non Bt-cotton strains

Data on incidence and severity were recorded during the end of September from each treatment and computed for disease index. Average across cultivars, the minimum disease index 24.0 % was recorded on the crop planted on 1st April as compared to other planting dates. Averaged across planting dates, a minimum disease index (43.41%) was recorded on genotype CIM-610 (Table-5.5).

Table 5.4 Disease Index of CLCuD (%)on Bt sowing date trial

	01/4	15/4	,1/5	,15/5/2021	,1/6/2021	Average
CIM-775	0.00	1.06	2.78	6.87	31.52	8.45
CIM-875	0.63	0.53	6.22	15.73	42.62	13.15
CIM--535	5.80	19.00	74.10	81.79	88.36	53.81
Cyto-536	3.18	15.89	58.55	80.29	76.85	46.95
Cyto-537	3.32	12.68	52.56	86.67	72.58	45.56
CIM-663	14.78	68.06	79.82	86.05	87.38	67.22
Average	4.62	19.54	45.67	59.57	66.55	

D.I = Disease Index, Disease incidence x Severity/ maximum severity value (4)

CD 5% Sowing Dates = 12.6 Varieties = 41.3

Table-5.5 Disease Index of CLCuD (%)on Non Bt sowing date trial

Cultivars	*1st April*	*15th April*	1st May	15th May	1st June	Average
CIM-610	14.13	53.80	49.16	50.21	49.75	43.41
CIM-228	10.52	23.90	51.43	71.77	75.79	46.68
CIM--735	47.38	73.07	82.13	76.74	78.48	71.56
Average	24.0	50.3	60.9	66.2	68.0	

D.I = Disease Index, Disease incidence x Severity/ maximum severity value (4)

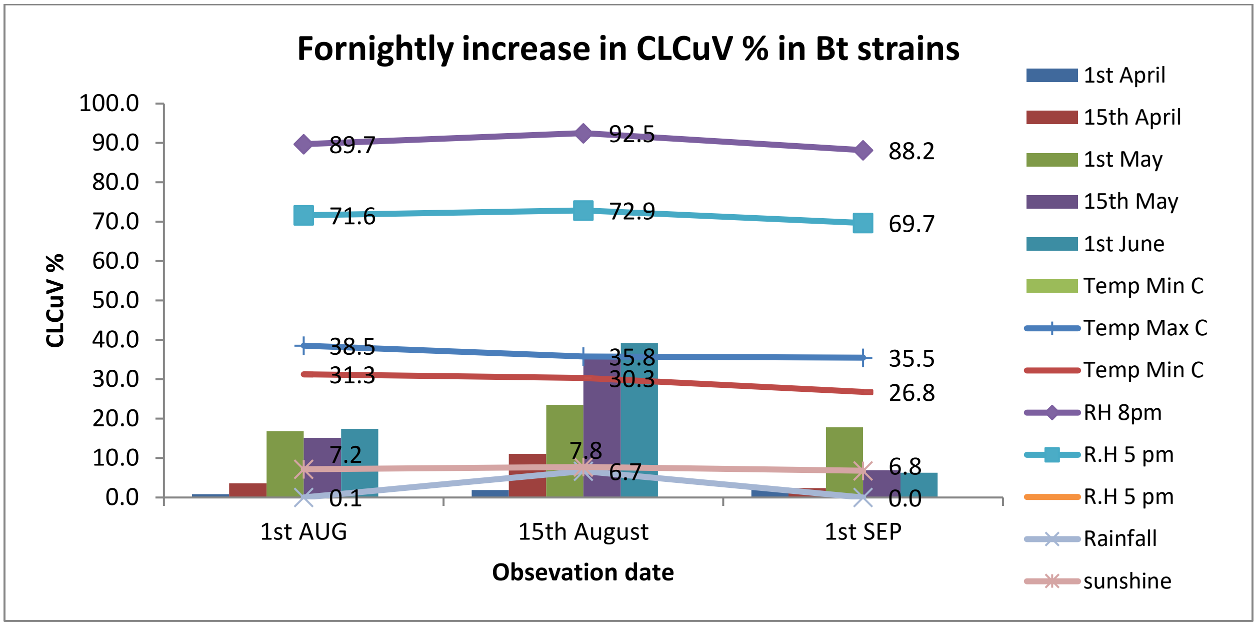

Fig 5.4 Relationship between fortnightly increases in CLCuD with weather parameters during 2021

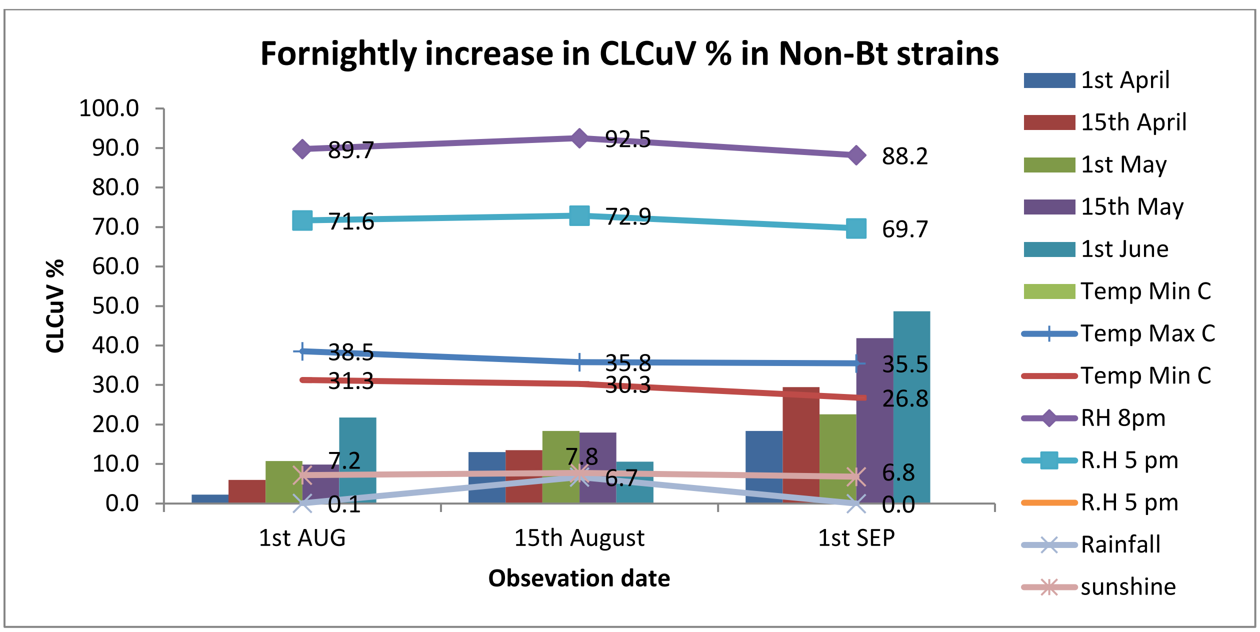

Fig 5.5 Relationship between fortnightly increases in CLCuD with weather parameters during 2021

5.4 Boll Rot of Cotton

5.4.1 Sowing Dates Trials

(a) Effect on *Bt*-Strains

An experiment was conducted to quantify the occurrence of boll rot disease in different Bt-strains planted at different dates from, 1st April to 1st June with fortnightly interval. The results are given in Table 5.10

Averaged across the strains, the crop planted on 15th April was more affected by boll rot as compared to other planting times. Similarly averaged across sowing dates, all strains showed boll rot less than 2 %. However, minimum boll rot was recorded in CIM-775 and CIM-633 as compare to other strains. The boll rot disease ranged from 0.41 to 0.89 % in all sowing dates on an average basis of varietes (Table 5.60).

(b) Effect on Non-Bt-Strains

Another experiment (non-Bt varieties) was conducted to quantify the boll rot disease in different strains planted from 1st April to 1st June with fortnightly interval. The boll rot disease was recorded and results are given in Table 5.7.

Averaged across sowing dates, maximum boll rot was recorded in CIM-610 as compared to other strains. Averaged across the strains, the crop planted on 15th April and 1stMay was more affected by boll rot as compared to other planting times. On an average basis, boll rot disease ranged from 0.56 to 1.11 % in different sowing dates (Table-5.11).

Table-5.6 Boll Rot Disease (%) on Bt cotton Cultivars planted at different times

Strains	1st April	15th April	1st May	15th May	1st June	Average
CIM-775	0.46	1.06	0.00	0.00	1.00	0.50
CIM-875	1.38	2.34	0.75	1.89	0.85	1.44
CIM--535	0.45	0.49	1.28	0.99	0.00	0.64
Cyto-536	0.90	1.15	0.00	0.48	0.45	0.60
Cyto-537	0.95	0.96	0.00	1.52	0.00	0.69
CIM-663	0.40	0.48	0.42	0.43	0.78	0.50
Average	**0.76**	**1.08**	**0.41**	**0.89**	**0.51**	

Table-5.7 Boll Rot Disease (%) on Non-Bt Cotton Cultivars planted at different times

Strains	1st April	15th April	1st May	15th May	1st June	Average
CIM-610	1.06	0.88	1.45	0.84	0.77	1.00
CIM-228	0.52	1.25	0.89	0.25	0.98	0.78
CIM-735	0.59	1.10	0.98	0.59	0.44	0.74
Average	0.72	1.08	1.11	0.56	0.73	

5.5 Evaluation of bio pesticides (Plants Extracts) to management of CLCuD vector

An experiment was conducted to evaluate different plants extracts against whitefly (CLCuV Vector). Planting of the crop was done on 19th May. The experimental design was RCBD. Six plant extracts @ 1ml/10ml of water were used. Data of Whitefly population were recorded 72 hours after spray. The spray of different treatments was done at 90 and repeated at 120 DAP. After 120 days the whitefly population crossed above ETL and minimum mortality has been observed with bio pesticides The crop was monitored regularly throughout the season. Data showed that not a single extract caused a significant decrease in the number of live adult of whitefly, respectively,. Although the whitefly population remained low in akk onion, extract treatment only at the early stage when whitefly did not flare-up to ETL. The results are given in (Table-5.12)

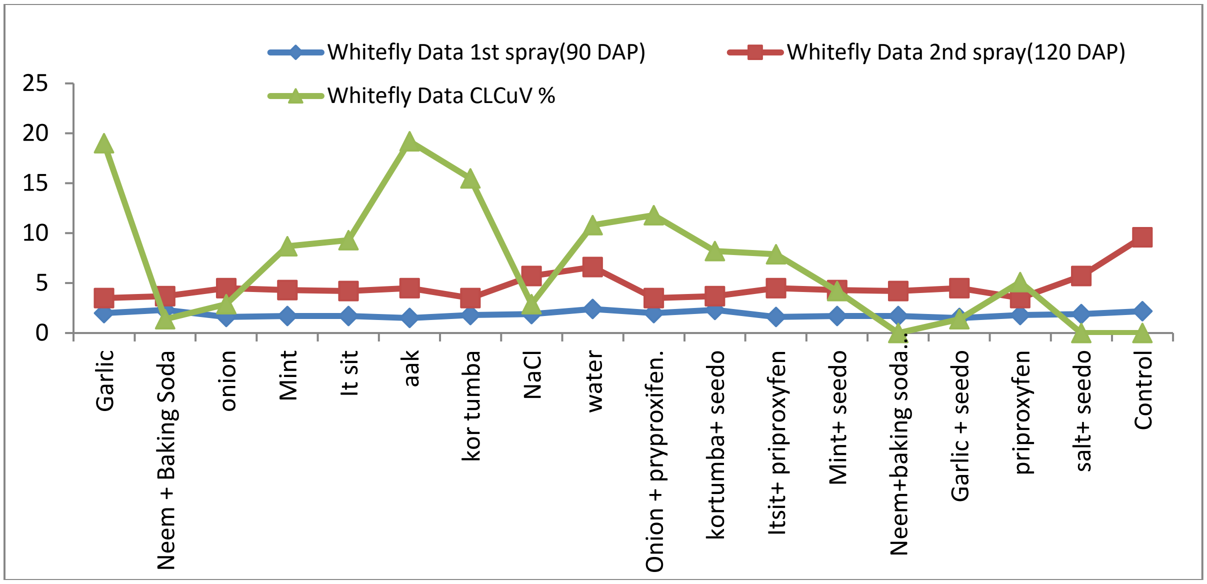

Fig 5.5.Effect of bio pesticides on whitefly population and CLCuV %

5.6 Blackening of cotton leaves

Symptoms of sooty mold were noted in approximately 30% of cotton leaves in different farmer fields. In the early stage of the disease, small patches of black fungal growth were observed on some parts of cotton leaves. As the crop matured, the black stain gradually covered the whole plant leaves to form sooty mold. Small pieces of affected leaves was plated on potato dextrose agar (PDA) containing 0.2% streptomycin and incubated at 28°C for 5 days. Observations of the morphological characteristics of the isolated culture suggested it was *Alternaria alternata*. Isolations from affected cotton leaves conducted on three separate occasions also resulted in the same fungal isolates. The conidia of *A.alternata* are abundant in the outdoor environment in the months of May to late October Although conidia can be spread by rain, the most common means of spread is through the air. The fungus grows on epidermal leaf wax of plants, and prefers an environment with high humidity and temperature range of 20–30 °C (68–86 °F).For pathogenicity, ten cotton plants were divided into two groups. One group was sprayed with spore suspension (1 × 106/ml) of the isolate, whereas the other group was sprayed with sterile distilled water as a control. All plants were incubated at 28 ± 2°C and 100% relative humidity. Ten days after inoculation, the inoculated leaves showed sooty mold symptoms similar to those noted in the field. The pathogenicity test was conducted three times. Koch’s postulates were fulfilled by re-isolation of *Alternaria alternata* from these inoculated leaves.(fig.5.6)

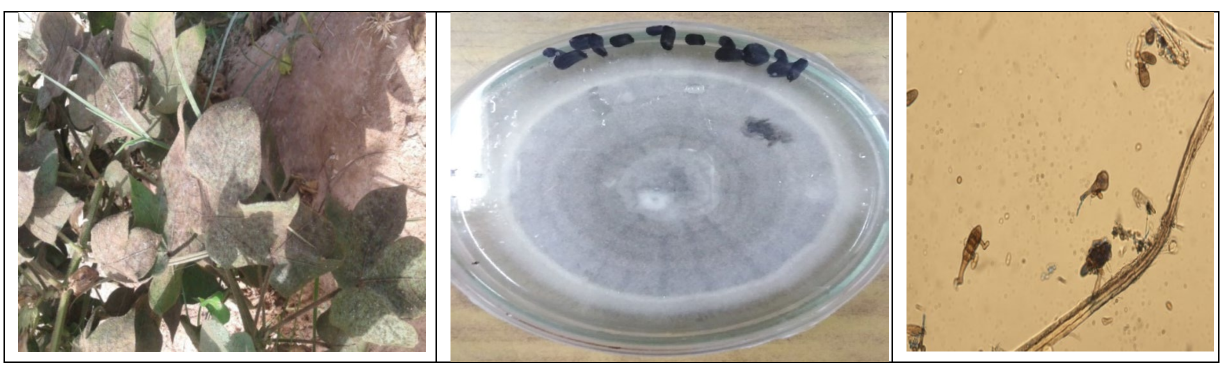

Figure 5.6. a: Field disease symptoms on cotton leaves; b Colonies on PDA (9 days) Conidia; c alternaria spores. Cotton crop was sprayed with sulfer @ 250 gm in 100 lit of water.

5.7 Cotton Wilt

Cotton wilting disease was observed in fields at Multan and different farmer fields during the month of June and July. The sudden death of affected plants occurred after appearance of syndrome. Upon examination, different types of wilt was observed. Para wilt that was due to abiotic stress. There was limited root growth, which leads to limited crop water and nutrient uptake. Hardpan was observed in those areas where soil was clayey or poorly drained. In some fields, plants showed wilted symptoms due to biotic stress, which infected plant's pith wood, bark of lower part of stem and upper taproot was slightly discolored. However, in some samples, brown streaks were found in and around the xylem vessels in the wood portion.Isolation was done on Potato Dextrose Agar (PDA) medium. The microscopic studies revealed that pathogenic fungi *Fussarium sp.* infested the root. Matalaxyl+Mencozen@ 300gm in 1000 lit water per acre applied with irrigation This fungicide gave an effectively control against Fusarium wilt

Figure 5.7. a: Field disease symptoms on cotton leaves' b cross section of infected plants c Colonies on PDA

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6. PLANT PHYSIOLOGY /CHEMISTRY SECTION

Agriculture in Pakistan is the second largest sector, after service sector, contributing 19.5 percent to GDP and employs around 42 percent of the total labor force. Agriculture is important for ensuring food security and reducing poverty. Low performance of this sector in Pakistan may be attributed to various factors such as high population growth, food insecurity, conventional agricultural management practices, slow rate of technological innovation, limited adoption of progressive farming techniques, water scarcity, rapid urbanization, dominance of small land holdings and climate change induced impacts, i.e., rising temperatures, droughts, floods and uneven pattern of rainfall. Agriculture sector in Pakistan is climate-sensitive and highly vulnerable to increasing weather variability and climate change and thereby, have become major barriers to achieving food security and alleviating poverty.

Multiple factors are involved in limiting the productivity of cotton, including biotic and abiotic stresses. Rising temperature due to climate change, squeezing profitability and shift of farmers to other crops for higher income have caused significant reduction in cotton crop area and its production. Apart from urbanization, intensification in cropping pattern and increasing demand for food and fibre have overloaded the already squeezing land and water resources for agriculture. One of the key factors to attain sustainability in crop production is to identify and best utilize the available resources (land, water, fertilizer, germplasm) with a precise and cost effective approach. Soil health being the backbone of crop production cannot be ignored as a deteriorated soil may limit agricultural productivity at a level much higher than the other factors. Introducing stress tolerance by the use of conventional plant based products and specific biochemicals are gaining attention to overcome yield losses due to variable stresses faced by the cotton plant during its growth period.

Physiology/Chemistry Section continued its endeavors to characterize cotton germplasm for its adaptability to high temperature stress and under conditions of water scarcity for its better utilization and making cotton production more profitable in stress prone areas. The stagnancy in yield could only be achieved by using balanced and integrated nutrition management approach so as to compensate the nutrient depletion and maintain soil fertility for sustained productivity. Different products were tested to mitigate the adverse effects of water and high temperature stresses, and to produce healthy cotton seed. Increasing input prices and current management practices have not only deteriorated soil health but also raised the cost of production to the unbearable extent, thus narrowing profit margin of the cotton farmers. Restoration and maintenance of soil health could be made possible by minimizing the cultivation practices with least disturbance to the dwelling soil micro- flora and fauna. A long-term study has been undertaken by adopting minimum tillage under cotton-wheat production system. Apart from the research studies conducted, scientists of the section participated in a number of diverse activities, some of which are described hereunder. The scientists of the section actively participated in different trainings/seminars organized by the Institute or other organizations. Trainings were imparted to technical staff of Agricultural Extension Dept. (KP & Balochistan), private seed companies and technical staff from agrochemical industry. Research internship facilities were provided to students from Ghazi University, DG Khan, Bahauddin Zakariya University, Multan and MNSUA, Multan. Supervision of PhD and MPhil students from different academic institutions remained continue. Organizing training programs for project staff, lead farmers and learning groups on Better Cotton production. Moreover, head of the section participated in lead farmer's training program organized at CCRI, Sakrand, Sindh. Imparted training to the farmers on soil health and nutrient management. Participated in TV and radio programs; contributed in Tele Cotton messages and technical advisory committee meetings. Video clips on topics of nutrient and crop management at critical growth stages were released and widely telecasted on social media for farmer's guidance. Moreover, the scientists participated in different national and international seminars/meetings (virtual or otherwise) conducted by CCRI, International Cotton Advisory Committee, Better Cotton Initiative and International Cotton Researchers Association. Scientists and other staff of the section participated in organizing Word Cotton day celebrations on October 7, 2020. Head of the section participated in World Soil Day celebrations at MNSUA, Multan. The scientists contributed in book chapters and research papers for national and international journals. The results of the studies conducted by the section are reported below in detail.

6.1 Genotype-Environment Relationship

6.1.1 Adaptability of genotypes to high temperature stress

Cotton is the most important cash crop with the largest value chain from raw cotton production to final clothing. This value chain employs more than 50% of the total industrial labor and accounts for more than 60% of total exports. Cotton crop is more sensitive to temperature change and availability of water during flowering and boll formation stages and thus its production is negatively affected with higher temperatures at the above critical growth stages. The cotton plant has a very good resilience to high temperature and drought-type situations due to its vertical taproot. Cotton plant is a perennial shrub that requires warmer days and nights for optimum growth and development. Recent research has indicated that a higher temperature is an important abiotic factor adversely affecting cotton yields. High temperatures (> 35°C) are common throughout the cotton growing season in many regions of the world which adversely affect growth and development of the crop and ultimately limiting the plant performance. The future cotton production is likely to face an increasing intensity of multiple abiotic stresses, including extreme and prolonged high temperatures. In Pakistan, cotton is generally cultivated in warm areas and the average temperature during the cotton season ranges between 40 and 45°C, which sometimes exceeds 50°C. The genotypes recommended for general cultivation in cotton growing areas face very high temperature of more than 45°C during the months of May, June and July, which is almost 15 to 20°C higher than the optimum temperature required for its normal growth. The existing and future increases in temperature during cotton crop urge to take initiatives for the evolution of germplasm with better tolerance to heat stress. The optimum temperature for the photosynthetic carbon fixation in cotton is about 32°C and photosynthesis decreases significantly at temperatures of 36°C and above. The high temperature environments (35-40°C) are frequently associated with infertility and cotton-boll retention problem and number of productive bolls.

Due to prevailing temperature stress during cropping season, the present studies were conducted to screen the advanced cotton germplasm and to identify the potential genotypes, which possess better tolerance to temperature and could produce appropriate yields in heat prone areas of the region. In the study reported, screening of sixteen cotton genotypes was carried out by planting the crop on mid-April so that the fruiting phase faces the hottest period of crop season. The experiment was conducted under field conditions in the research area of CCRI, Multan. Results revealed that the genotypes showed wide variation in various physiological parameters conferring heat tolerance in cotton. Genotypes CIM-541, CIM-775, CYTO-535 and CYTO-537 excelled in heat tolerance considering different traits compared with the other genotypes (Table 6.1).

Table 6.1 Physiological traits for determining heat tolerance in different genotypes

Genotypes	**AD** (%)	**PV** (%)	**SNNFB**	**SNHFB (cm)**	**% BSFP**	**% BSSP**	**RCIL** (%)	**EC** (μS cm^{-1})	**Proline** (μg/g)
CYTO-541	86	90	6	20	25	18	40	301	8.7
CIM-775	76	81	6	13	23	16	45	331	8.0
CYTO-535	74	77	8	23	21	14	49	363	7.8
CYTO-537	74	76	7	23	20	14	50	389	7.5
SLH-66	78	83	9	28	20	13	52	308	7.2
SLH-51	78	81	6	18	18	13	60	327	7.1
GH-Hamaliya	67	70	7	18	18	12	48	386	6.1
CYTO-536	64	71	6	18	16	11	49	334	5.9
GH-Sanabal	63	70	7	17	15	10	62	342	5.8
CRIS-682	60	69	7	23	13	10	69	397	5.1
GH-Sultan	61	68	7	23	12	9	70	327	4.8
GH-Baghdadi	54	65	9	23	12	8	78	334	4.5
GH-Mubarak	57	63	8	22	10	7	77	367	4.2
CIM-875	54	61	12	16	10	7	79	359	3.8
CRIS-674	53	60	7	16	9	6	82	380	3.7
SLH-50	48	53	8	21	8	6	88	415	3.3
Mean	**66**	**71**	**8**	**20**	**16**	**11**	**63**	**354**	**6.0**
LSD	9.18**	10.8**	2.77^{ns}	9.06*	5.58**	4.59**	7.77**	38.4**	0.84^{ns}

***significant at p<0.01; ns: non-significant*

AD: Anther dehiscence; PV: Pollen viability; FSSN: First sympodial node no.; FSNH: First symp. node height; SNNFB: Symp. node no bearing 1st boll; SNHFB: Symp. node height bearing 1st boll; BSFP: Boll set on 1st position; BSSP: Boll set on 2nd position; RCIL: Relative cell injury level; EC: Electrical conductivity

Physiological traits having relevance to heat tolerance were recorded in the genotypes. Results showed that there were positive correlations of pollen viability (r=0.91**), percent boll set on first (r=0.97**) and second (r=0.97) positions along sympodia with seed cotton yield. There were negative correlations of cell injury (r= –0.90**) and electrical conductivity (r = –0.50**) with the seed cotton yield. These traits can be taken into account while selecting future genotypes to overcome heat stress problems (Table 6.2).

Table 6.2 **Relationship between seed cotton yield and physiological traits determining heat tolerance**

Parameters	AD	PV	EC	RCI	BSFP	BSSP	NBPP	BW
PV	0.98**							
EC	-0.58**	-0.68**						
RCI	-0.90**	-0.87**	0.46**					
BSFP	0.96**	0.94**	-0.52**	-0.95**				
BSSP	0.96**	0.94**	-0.49**	-0.94**	0.99**			
NBPP	0.27**	0.31**	-0.41**	-0.17**	0.23**	0.27**		
BW	0.40**	0.35**	-0.33**	-0.35**	0.38**	0.34**	0.09**	
SCY	0.91**	0.91**	-0.50**	-0.90**	0.97**	0.97**	0.25**	0.40**

AD : Anther dehiscence *BSSP : Boll set on 2nd position* *NBPP : Number of bolls per plant*
PV : Pollen viability *RCIL : Relative cell injury level* *BW : Boll weight*
BSFP : Boll set on st position *EC : Electrical conductivity* *SCY : Seed cotton yield*

***significant at p<0.01; ns: non-significant*

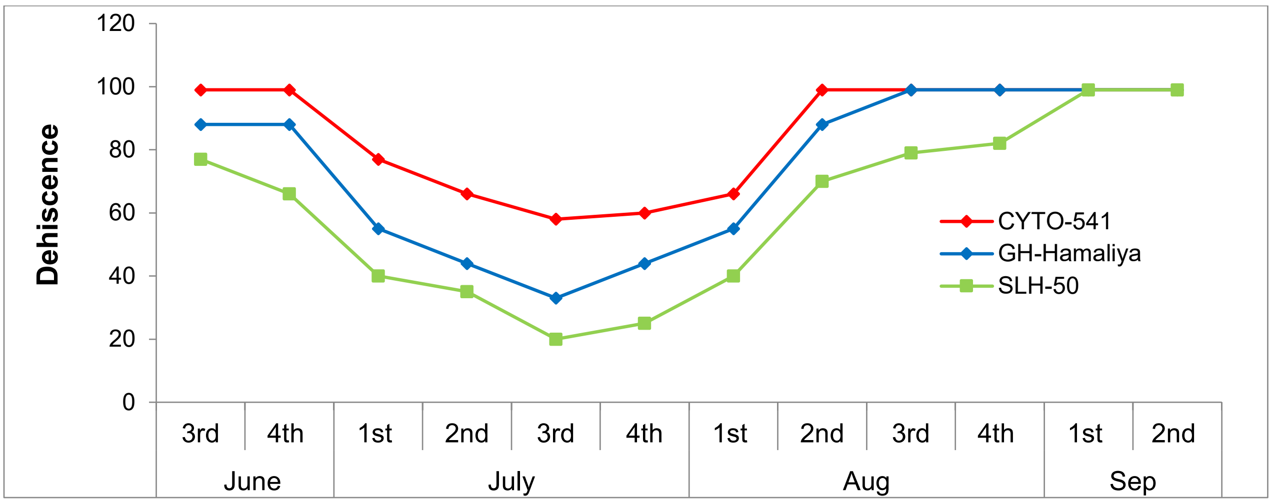

Fig. 6.1 **Dehiscence of anthers during the season for three genotypes**

Table 6.3 **Seed cotton yield in different genotypes planted in mid-April**

Genotypes	**Number of bolls per plant**	**Boll weight** (g)	**Seed cotton yield** (kg ha^{-1})
CYTO-541	43	3.13	3093
CIM-775	40	2.34	2995
CYTO-535	24	3.34	2744
CYTO-537	21	3.00	2601
SLH-66	28	2.75	2331
SLH-51	39	2.46	2241
GH-Hamaliya	25	2.27	2188
CYTO-536	33	2.51	2134
GH-Sanabal	34	2.91	2063
CRIS-682	34	2.01	2063
GH-Sultan	32	2.72	1972
GH-Baghdadi	24	2.22	1963
GH-Mubarak	33	2.75	1811
CIM-875	33	3.32	1668
CRIS-674	21	1.91	1524
SLH-50	35	2.21	1345
LSD	5.98**	2.62^{ns}	108.7**

**significant at p<0.01

The dehiscence of anthers decreased gradually dipping to the lowest level on 3rd week of July and then gradually increased up to the 2nd week of August reaching to 100% in 2nd (Cyto-541), 3rd (GH-Hamaliya) weeks of August and 2nd week of September (SLH-50). Among the genotypes studied, CYTO-541 showed the highest while SLH-50 the lowest dehiscence of anthers during the peak flowering period. The dehiscence of anthers for three genotypes, during the flowering phase is depicted in Fig. 6.1. Genotypes differed greatly in their overall yield performance. The genotype CYTO-541 produced the highest seed cotton yield than the other genotypes tested. Seed cotton yield of different genotypes ranged from 1345 to 3093 kg ha^{-1} (Table 6.3).

6.1.2 Physiological, biochemical and Molecular response of cotton to seed priming and high temperature stress

Priming of seeds is often known as pre-treatment. This process accelerates some of the metabolic processes that are required for proper germination and stimulation of other desirable functions for which the seed priming is done. Priming usually involves the use of solutions with high osmotic potential. Thus, in spite of promoting metabolic stimulation, the seeds cannot absorb enough water for the protrusion of radicles. The seeds are pushed to the lag phase of growth. The harmful effects of heat stress on crop physiology are major constraints on agricultural expansion in areas experiencing higher temperatures. Several agronomic and genetic strategies have been undertaken for improving crop resilience to heat. Cotton plant comes across a complex set of abiotic and biotic stresses very frequently during the growing season. Extreme heat stress induces damage to the cells and even necrosis in advance stage, resulting in collapse of the cellular organization. Physiological processes like germination, growth, development, reproduction, and productivity are compromised. Cotton plant raised from primed seeds exhibits instant cellular response against abiotic stresses. Primed seed acquires resistance through various cellular and metabolic pathways which involve cascades of signaling networks. Seed priming methods are widely used as an emerging technology to evaluate the tolerant crop varieties against abiotic stresses. Under stress conditions the priming of proline may also contribute to the detoxification of the active oxygen species. The proposed role of proline is as osmoregulator and it contributes in the maintenance of membrane integrity as an adaptation to conditions of any stress. Proline helps in fertility of pollen, in enhancing the biomass production, net photosynthetic rate, stomatal conductance, internal CO_2 concentration, nutrient uptake in roots and shoots under water deficit conditions, enhanced plant transpiration rate and reduce the inhibitory effects of NaCl on seed germination. Therefore, overall outcome is the plant growth, yield and superior seed germination. Seed priming with lower concentrations of salicylic acid (SA) increases the H_2O_2 level and also reduces the Catalase (CAT) activity which increases the potential of plants to withstand the heat stress. SA priming reduces electrolyte leakage with a concomitant enhancement in the activities of glutathione reductase and guaiacol peroxidase. Application of chemicals through priming offers an effective strategy to mitigate various abiotic stresses.

A field experiment was conducted to evaluate the efficacy of seed priming on heat tolerance mechanism of cotton genotypes viz. GH-Hamaliya, CIM-775 (heat tolerant) and CIM-789, Cyto-537 (heat susceptible). The crop was sown on 15th of April 2021 and 18th May 2021 in a randomized complete block design (RCBD) with split plot arrangement (genotypes; main plot and seed treatment; sub plots). The experiment was divided into two sets prior to sowing i.e. 15th April sowing (Set-A) and 18th May sowing (Set-B). Seed priming was done before sowing for improving heat tolerance in both sets. The crop was fertilized with recommended NPK fertilizers. Standard production and management practices were adopted. The detail of seed priming treatments applied is given below:

Treatments	Bio-chemicals	Dose
T1	No seed priming	---
T2	Proline	0.1%
T3	Salicylic Acid (SA)	0.01%

Plant reproductive development parameters like seed cotton yield, number of bolls per plant and boll weight differed significantly ($p<0.01$) among various treatments and among genotypes. Picking of seed cotton was done at maturity and yield calculated on hectare basis. Data showed that seed primed with proline and salicycylic acid prior to sowing, performed differently in seed cotton production. In heat tolerant genotypes (GH-Hamaliya & CIM-775), the seed cotton yield, number of bolls per plant and boll weight varied from 2409 to 2960 kg ha^{-1}, 30 to 38 and 2.33g to 2.88g respectively. While in heat susceptible genotypes (CIM-789 & Cyto-537) the seed cotton yield, number of bolls per plant and boll weight varied from 1996 to 3373 kg ha^{-1}, 25 to 37 and 2.36g to 3.39g, respectively, in different treatments (**Set-A**). In **Set-B**, the seed cotton yield, number of bolls per plant and boll weight varied from 497 to 1927 kg ha^{-1}, from 20 to 35 and 1.97g to 2.76g respectively in heat tolerant genotypes (GH-Hamaliya & CIM-775). While in heat susceptible genotypes (CIM-789 & Cyto-537) the seed cotton yield, number of bolls per plant and boll weight varied from 482 to 1124 kg ha^{-1}, 15 to 22 and 2.10g to 2.59g, respectively, in different treatments. In both sowing dates, SA seed treatment showed the substantial effect on seed cotton production and other parameters in all genotypes over other treatments. The crop sown on 15th April produced the higher seed cotton yield, number of bolls per plant and boll weight as compared to 18th May sown crop because in late sowing crop, plants faced the high insect pest infestation (Table 6.4 to 6.6).

Table 6.4 Effect of seed priming on seed cotton yield

Seed Treatments	Heat tolerant		Heat susceptible		Mean
	GH-Hamaliya	CIM-775	CIM-789	CYTO-537	
15th April					
Control (Untreated)	2588	2409	1996	2822	2454
Proline	2712	2781	2285	3276	2764
Salicylic Acid	2767	2960	2409	3373	2877
Mean	**2689**	**2717**	**2230**	**3157**	
Genotypes = **	Seed priming= **		Genotypes × Seed priming = ns		
18th May					
Control Untreated)	497	1583	482	688	809
Proline	587	1721	551	964	956
Salicylic Acid	551	1927	620	1124	1055
Mean	**540**	**1744**	**551**	**925**	
Genotypes = **	Seed priming= ns		Genotypes × Seed priming = ns		

Table 6.5 Effect of Seed priming on number of bolls per plant

Seed Treatments	Heat tolerant		Heat susceptible		Mean
	GH-Hamaliya	CIM-775	CIM-789	CYTO-537	
15th April					
Control (Untreated)	30	32	25	29	29
Proline	32	38	30	34	34
Salicylic Acid	38	38	35	37	37
Mean	**33**	**36**	**30**	**33**	
Genotypes = ns	Seed priming= **		Genotypes × Seed priming = ns		
18th May					
Control Untreated)	20	22	15	15	18
Proline	22	33	17	18	23
Salicylic Acid	24	35	18	22	25
Mean	**22**	**30**	**17**	**18**	
Genotypes = **	Seed priming= **		Genotypes × Seed priming = ns		

Table 6.6 Effect of seed priming on boll weight

Seed Treatments	Heat tolerant		Heat susceptible		Mean
	GH-Hamaliya	CIM-775	CIM-789	CYTO-537	
15th April					
Control (Untreated)	2.33	2.53	2.36	2.68	2.48
Proline	2.37	2.64	2.66	3.03	2.67
Salicylic Acid	2.44	2.88	2.76	3.39	2.87
Mean	**2.38**	**2.68**	**2.59**	**3.03**	
Genotypes = **	Seed priming= **		Genotypes × Seed priming = **		
18th May					

Control Untreated) Proline Salicylic Acid	2.00 2.39 2.47	1.97 2.33 2.76	2.24 2.10 2.54	2.30 2.39 2.59	2.13 2.30 2.59
Mean	**2.29**	**2.35**	**2.29**	**2.43**	
Genotypes = ns	Seed priming= **		Genotypes × Seed priming = **		

The assessment of biochemical parameters such as, total chlorophyll (a & b) and proline contents were determined from the leaves sampled from 90 days old crop (Tables 6.7 & 6.8). Results indicated that in **Set A,** the genotypes performed contrarily in seed primed with proline and salicylic acid prior to sowing in comparison to control. In heat tolerant genotypes (GH-Hamaliya & CIM-775), the total chlorophyll and proline contents varied from 5.56 to 8.16 (mg/g FW) and 3.37 to 5.86 (µg/g FW), respectively. While in heat susceptible genotypes (CIM-789 & Cyto-537) the total chlorophyll and proline contents varied from 4.80 to 8.51 (mg/g FW) and 6.59 to 8.37 (µg/g FW), respectively in different treatments. In **Set-B**, heat tolerant genotypes (GH-Hamaliya & CIM-775), the total chlorophyll and proline contents varied from 5.56 to 5.93 (mg/g FW) and 3.97 to 5.96 (µg/g FW), respectively. While in heat susceptible genotypes (CIM-789 & Cyto-537), the total chlorophyll and proline contents varied from 5.80 to 6.97 (mg/g FW) and 6.79 to 9.70 (µg/g FW), respectively in different treatments. Based on results, it was observed that in both sowing dates, the seed priming has substantially positive effects, on heat tolerant and susceptible genotypes, in improving their biochemical parameters. Seed priming with salicylic acid increased, remarkably, total chlorophyll and proline contents to cope up the plant with high temperature stress.

Table 6.7 Total chlorophyll (a+b) content (mg/g FW) in different genotypes

Seed Treatments	Heat tolerant		Heat susceptible		Mean
	GH-Hamaliya	CIM-775	CIM-789	CYTO-537	
15th April					
Control (Untreated) Proline Salicylic Acid	6.68 7.00 8.16	5.56 6.82 7.83	5.92 6.79 8.51	4.80 6.92 7.50	6.68 7.00 8.16
Mean	**7.28**	**6.41**	**7.07**	**6.41**	
Genotypes = **	Seed priming= **		Genotypes × Seed priming = **		
18th May					
Control Untreated) Proline Salicylic Acid	5.58 5.59 5.71	5.56 5.83 5.93	6.27 6.82 6.90	5.80 6.40 6.97	5.80 6.16 6.38
Mean	**5.62**	**5.77**	**6.66**	**6.39**	
Genotypes = **	Seed priming= **		Genotypes × Seed priming = **		

Table 6.8 Proline contents (µg/g FW) in different genotypes

Seed Treatments	Heat tolerant		Heat susceptible		Mean
	GH-Hamaliya	CIM-775	CIM-789	CYTO-537	
15th April					
Control (Untreated) Proline Salicylic Acid	4.12 3.99 3.37	5.86 5.26 4.99	8.37 7.66 6.59	7.82 7.78 7.50	6.54 6.17 5.61
Mean	3.83	5.37	7.54	7.7	
Genotypes = **	Seed priming= **		Genotypes × Seed priming = **		
18th May					
Control Untreated) Proline Salicylic Acid **Mean**	4.12 4.99 3.97 4.36	5.96 5.56 4.79 5.44	8.77 8.60 6.79 8.05	9.70 7.92 7.50 8.37	7.14 6.77 5.76
Genotypes = **	Seed priming= **		Genotypes × Seed priming = **		

6.1.3 Characterization of cotton germplasm for heat tolerance

Cotton is an international agricultural product of which quality and quantity are subject to various whims of nature. It occupies an important position in global status of commercial crops with annual impact of >US$50 billion in the economy of the world. The lint quality in general, while the quantities of produce, i.e., the seed cotton yield (SCY) particularly is highly sensitive to climatic conditions. In Pakistan cotton was grown across 2.3 million hectares during 2021-22 with an average per hectare yield of approximately 707 kg/ha compared with 2,320 and 1,765 kg/ha for Australia and China, respectively. The quality of lint produced is also inferior, having a short fiber length, coarse fiber fineness, and lower uniformity, resulting in a higher import of longer fiber and lower price of locally produced cotton lint. The cotton belt of Pakistan is mainly located in the high-temperature zone where mean maximum temperature often exceed 48°C during the cotton-growing season. The optimum temperature for a successful cotton production is about 35°C. However, temperatures above this threshold level badly affect the peak time of cotton flowers and boll setting, resulting in excessive evapo-transpiration and abscission/no boll set at lower half of the plant. There is also observed a strong negative correlation between high temperature and the lint yield, resulting in a yield decrease of about 110 kg/ha for each unit increase in maximum temperature. Identification of genotypes that have a greater ability to withstand the peaks of heat stress coupled with their limited water use is important to enhance the cotton productivity. However, suitable selection standards are required for measuring resilience of cotton germplasm against heat stress. Plant phenological traits especially flowering and boll retention capacity in high temperature environments are effective in repeatable heat stress screening environments. But genotypes that have better genotype × environment interaction in the field often best perform under hat stress. Therefore, screening of cotton genotypes can be exploited by targeting those traits that are closely associated with plant adaptation to high-temperature environment. Cell membrane thermostability (CMT) has been reported as the most relevant and suitable selection criteria for measuring heat tolerance. Therefore, the present study was carried out with the objectives to screen cotton germplasm for its heat tolerance characteristics, under field conditions, in collaboration with Plant Breeding and Genetics Section of the Institute.

Leaf samples of 97 accessions of the cotton genepool entries were collected from the field to determine relative cell injury (RCI%), an indicator of heat tolerance. RCI ranged from 14 to 97% in different accessions of genepool (Table 6.9).

Table 6.9 Relative cell injury in different accession of gene pool material

Acc. No	RCI%	Acc. No	RCI%	Acc. No	RCI%	Acc. No	RCI%	Acc. No	RCI%
1	65	35	84	846	77	895	43	2012	31
2	55	43	35	849	32	903	39	2013	58
3	47	47	55	855	27	904	15	2014	30
6	51	58	41	860	34	907	14	2015	60
7	50	67	56	861	25	917	26	2016	42
10	34	798	95	862	84	920	47	2017	45
11	45	799	70	866	43	922	57	2018	62
13	46	801	50	867	71	926	56	2019	33
14	46	809	30	868	35	929	58	2020	53
15	41	810	97	873	60	930	30	2021	27
16	54	812	50	878	78	931	67	2022	18
17	70	820	30	879	76	935	29	2023	40
20	40	822	63	880	37	936	41	2024	24
21	58	827	36	885	61	955	63	2025	24
28	55	828	25	886	77	956	36	2026	25
29	48	829	22	889	80	958	46	2027	67
30	55	833	19	891	78	982	51	2032	24
32	35	840	41	892	48	2009	52		
33	25	841	69	893	88	2010	17		
34	56	845	63	894	56	2011	37		

Based on RCI the accessions were grouped into 3 categories. Out of total, 23 accessions had RCI in the range of 14-30% and categorized as heat tolerant, 53 with RCI in the range of 31-60% and categorized as medium tolerant, and 21 accessions with RCI > 60% were categorized as heat susceptible (Figure 6.2).

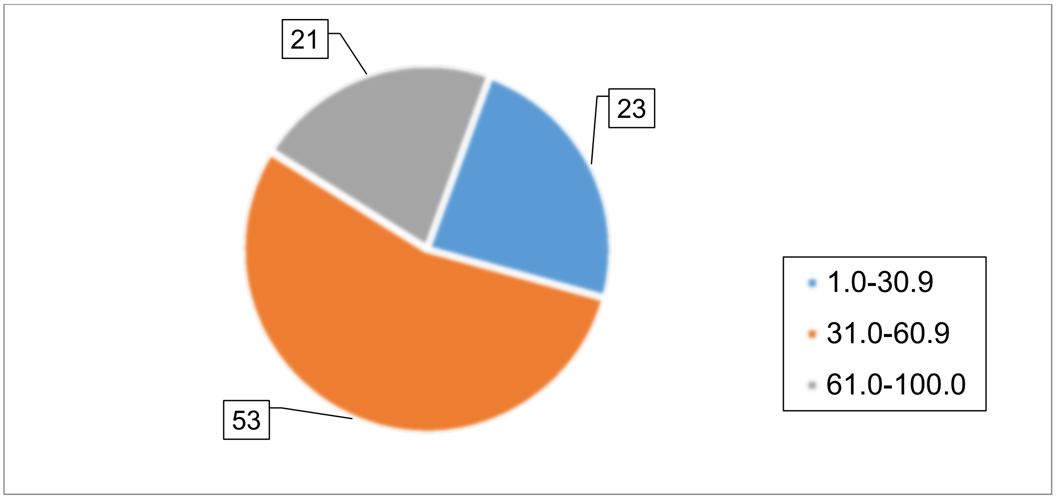

Figure 6.2 Categorization of genepool accessions based on relative cell injury levels

6.2 Soil Health and Plant Nutrition

6.2.1 Long term effects of reduced tillage on soil health and cotton-wheat productivity

The greatest challenge to the world in the years to come is to provide food to burgeoning population, which is likely to rise to 8,909 million in 2050. The scenario would be more terrible, when we visualize per capita availability of arable land. The fluctuating growth rate in agriculture has been the major detriment in world food production. The cultivation of agricultural soils, until recently, predominantly has been practiced by inverting the soil using tools such as the plough, thus burying the fertile portion of soil to lower depth. Soil tillage is one of the basic and important components of agricultural production technology. Various forms of tillage tools are practiced throughout the world, such as the use of simple stick or jab to the sophisticated para-plough. The practices developed, with whatever equipment used, can be broadly classified into no tillage, minimum tillage, conservation tillage and conventional tillage.

Soil tillage refers to physical, chemical or biological soil manipulation to optimize conditions for germination, seedling establishment and crop growth. Tillage is a labor-intensive activity in low-resource agriculture practiced by small landholders, and a capital and energy-intensive activity in large-scale mechanized farming. Continual soil inversion can in some situations result in degradation of soil structure, ultimately, leading to a compacted soil composed of fine dispersed particles with low levels of soil organic matter (SOM). Such soils are more prone to soil loss through water and wind erosion eventually resulting in desertification. This process can directly and indirectly cause a wide range of environmental problems. The conventional soil management practices result in losses of soil, water and nutrients in the field, and degrade the soil by lowering organic matter content and a fragile physical structure, which in turn lead to low crop yields and lower water and fertilizer use efficiencies apart from the increased fuel and labor costs. Therefore, scientists and policy makers are emphasizing to revisit the prevailing cultivation practices and turning to reduced tillage. Compared to conventional tillage, there are several benefits of reduced tillage such as economic benefits of labor costs and time saving, erosion protection, soil and water conservation, and ultimate increases of soil fertility.

Therefore, an experiment was conducted to evaluate the effect of reduced tillage on soil health and crop productivity as well as to lower the cost of production. Cotton genotype CIM 785 was selected to evaluate the impact of reduced tillage on productivity. Sowing was done on May 28, 2021.

Pre-plant soil samples were collected to determine the soil variability across the experimental field. Physio-chemical analyses of the samples revealed that the soil is silt loam in texture and alkaline in reaction. Soil pH was 8.15, electrical conductivity was 2.85 mS cm^{-1}, organic matter content was 0.71%, extractable phosphorus level at 21.4 mg kg^{-1} soil and extractable potassium at 153.8 mg kg^{-1}. Post-harvest soil sample analyses revealed that there was no change in soil texture while pH in normal tillage plot was 8.34 while in reduced tillage plot it was 8.23. Electrical conductivity remained at 2.23 mS cm^{-1} in normal tillage and 2.35 mS cm^{-1} in reduced tillage plots, organic matter content remained at 0.78% in normal tillage plot and 0.91% in reduced tillage plot, extractable phosphorus at 23.9 mg kg^{-1} soil in normal tillage while 29.5 mg kg^{-1} soil in reduced tillage plots, extractable potassium at 144 mg kg^{-1} and 161 mg kg^{-1} in normal and reduced tillage plots, respectively. Plant growth and development parameters were recorded from normal tillage and reduced tillage plots at maturity. The plant height was 141 cm and 138 cm, number of nodes 46 and 44, inter nodal length 3.06 and 3.13 cm, number of bolls per plant 15 and 14, boll weight 2.81 and 2.67 g, seed cotton yield 1138 kg ha^{-1} and 1124 kg ha^{-1}, seed index 8.1 and 8.9 g in normal tillage and reduced tillage plots, respectively. Data on fiber traits revealed that, staple length was 27.1 and 27.8 mm, uniformity index 81.6 and 83.9%, micronaire 5.0 and 5.1, fiber strength 26.8 and 26.2 g/tex in normal tillage and reduced tillage plots, respectively (Table 6.10).

Table 6.10 Summary of parameters taken from normal tillage and reduced tillage plots

Plant parameters	**Height (cm)**		**Node**		**Inter node (cm)**		**Bolls per plant**		**Boll weight (g)**		**Yield (kg ha^{-1})**		**Seed index (g)**	
	NT	RT	NT	RT	NT	RT	NT	RT	NT	RT	NT	RT	NT	RT
	141	138	46	43	3.06	3.13	15	14	2.81	2.67	1138	1124	8.1	8.9

Soil parameters	**pH**		**EC (mS cm^{-1})**		**OM (%)**		**Extractable- P (mg kg^{-1})**		**Extractable-K (mg kg^{-1})**	
Pre-plant	8.15		2.85		0.71		21.4		153.8	
	NT	RT	NT	RT	NT	RT	NT	RT	NT	RT
Post-harvest	8.34	8.23	2.23	2.35	0.78	0.91	23.9	29.5	144	161

NT=Normal Tillage RT= Reduced Tillage

6.2.2 Does phosphorus application time affect root development and cotton productivity?

Crop growth requires nutrients' availability and constant supply throughout the growing season. Cotton yield responds positively to application time of each nutrient, especially P. The time of fertilizer application in the soil affects the nutrients uptake by plant and dry matter accumulation in the cotton plant parts. The P application time is crucial as it influences earliness, root development, accumulation of other nutrient and plant biomass with greater tendency towards the vegetative and reproductive organs. Improving the cotton yield with better P management to obtain higher economic yield is of great importance to improve inorganic fertilizers use efficiency. The cotton cultivars respond differently to the P application time. The stunted growth and low yield resulted by P deficits in cotton have been reported. Due to present hike in phosphatic fertilizers, the P fertilizer use strategy needs a careful revision, considering its low recovery in the cotton belt. Conclusive experimental data regarding critical P application time are still lacking. Keeping in view, the significance of optimum time of P application for improved phosphorus use efficiency and productivity of cotton, the present experiment was conducted to find out the appropriate phosphorous application time in cotton crop.

Two cotton genotypes viz. CYTO-537 and Cyto-535 were selected for the study. The treatments were laid out in RCBD with split-plot arrangement (P application time: main plots; genotypes: sub-plots). Crop was sown on April 21, 2021. The detail of treatments applied is given below:

Treatments	**P application time**		
	Pre-sowing	25 DAP	50 DAP
T1	0	0	0
T2	50	0	0
T3	0	50	0
T4	0	25	25

P was applied @ 50 kg/ha in all treatments except control

Field was divided into four blocks to check indigenous soil nutrient status and variability. For this purpose pre-plant composite soil samples were collected from the plough layer of experimental field before imposition of treatments. Physical and chemical characteristics of the soil samples were determined. Results indicated that the soil is clay loam in texture and alkaline in reaction. Soil pH varied from 8.15 to 8.29, electrical conductivity from 2.04 to 2.38 mS cm^{-1}, organic matter content from 0.67% to 0.84%, extractable phosphorus from 14.8 to 26.2 mg kg^{-1} soil and extractable potassium from 162 to 191 mg kg^{-1} soil across the field (Table 6.11).

After cotton picking, composite soil samples were collected from each plot subjected to different P treatments and analyses performed in the laboratory for different soil parameters. Results revealed that pH varied from 8.28 to 8.41, EC from 1.36 to 1.64 mS cm^{-1}, OM varied from 0.64 to 0.88%, extractable P from 21.3 to 30.6 mg kg^{-1} soil and extractable K 153 to 198 mg kg^{-1}soils in different P treatments. Generally, the values of all parameters increased in post-harvest samples as compared to pre-planting samples, except EC that showed a decrease over initial level (Table 6.12).

Table 6.11 Physical and chemical characteristics of soil at pre-planting

Block No.	**pH**	**EC** (mS cm^{-1})	**O.M** (%)	**Extractable-P** (mg kg^{-1} soil)	**Extractable-K** (mg kg^{-1} soil)
1	8.29	2.38	0.78	26.2	181
2	8.21	2.27	0.77	23.3	178
3	8.15	2.04	0.84	16.6	162
4	8.23	2.07	0.67	14.8	191
Mean	**8.22**	**2.19**	**0.77**	**20.2**	**178**

Table 6.12 Physical and chemical characteristics of soil at post-harvest

P application time	**pH**	**EC (mS cm^{-1})**	**OM (%)**	**Extractable-P (mg kg^{-1} soil)**	**Extractable-K (mg kg^{-1} soil)**
Control	8.28	1.45	0.64	21.3	167
Full at Sowing	8.33	1.56	0.71	20.5	153
Full at 25 DAP	8.41	1.36	0.76	25.4	172
½ at 25+½ at 50 (DAP)	8.34	1.64	0.88	30.6	198

Data on plant structure development were recorded at maturity. In plots where P was applied at 25 DAP planting, the main stem height, number of nodes on main stem and inter-nodal length remained higher over control as well as over other P application treatments. Averaged across genotypes, the main stem height varied from 95.2 to 118.5 cm, number of nodes on main stem from 43 to 46 and intermodal distance from 2.23 to 2.56 cm among different treatments (Table 6.13).

Table 6.13 Plant structure at maturity in two genotypes under different P treatments

P application time	**Height (cm)**			**Node**			**Inter-nodal length (cm)**		
	Cyto-537	Cyto-535	Av.	Cyto-537	Cyto-535	Av.	Cyto-537	Cyto-535	Av.
Control	92.7	97.7	95.2	41	44	43	2.26	2.21	2.23
Full at Sowing	107.7	104.7	106.2	45	42	43	2.41	2.52	2.46
Full at 25 DAP	117.3	119.7	118.5	46	45	46	2.54	2.57	2.56
½ at 25 +½ at 50 DAP	113.3	108.5	110.9	45	44	45	2.40	2.56	2.48
Genotype		ns			*			ns	
P application time		*			*			*	
Interaction		ns			ns			ns	

The fresh biomass of different plant organs was determined from harvested plant samples. Data revealed that fresh weight of leaf, stalk and root was higher in plots where P was applied at 25 DAP and in split application of P viz. ½ at 25 DAP+½ at 50 DAP as compared to pre planting P application and control. In treatment where P was applied at 25 DAP, the fresh weight of leaf, stalk and root increased by 45%, 37%, 38% in Cyto-537 while 22%, 8% and 27% in Cyto-535 as compared to pre-planting P application (Table 6.14).

Table 6.14 Fresh weight of different plant parts at maturity in two genotypes under different P treatments

P application time	**Leaves weight (g)**		**Stalk weight (g)**		**Root weight (g)**	
	Cyto-537	Cyto-535	Cyto-537	Cyto-535	Cyto-537	Cyto-535
Control	118	155	169	258	26	30
Full at Sowing	121	169	217	373	29	33
Full at 25 DAP	176	207	298	403	40	42
½ at 25 +½ at 50 DAP	171	189	289	405	35	37
Genotype	*		*		*	
P application time	*		*		*	
Interaction	ns		*		ns	

Chlorophyll content and seed index varied among different P treatments and between cotton genotypes. Delayed application of P caused increase in chlorophyll content and seed index. The maximum chlorophyll content was observed in the treatment where P was applied as ½ 25 DAP+½ 50 DAP and at 25 DAP as compared to pre-planting P application and control, in both cotton genotypes, while maximum seed index was observed in the treatment where full dose of P was applied at sowing as compared to other treatments (Table 6.15).

Table 6.15 Chlorophyll content and seed index in two genotypes under different P treatments

P application time	Chlorophyll SPAD values		Seed Index (g)	
	Cyto-537	Cyto-535	Cyto-537	Cyto-535
Control	49.7	57.0	8.30	8.40
Full at Sowing	51.3	57.3	9.40	10.10
Full at 25 DAP	54.0	59.3	8.70	9.00
½ at 25 +½ at 50 DAP	55.0	60.7	8.90	9.00
Genotype	*		*	
P application time	*		*	
Interaction	ns		*	

Seed cotton yield, bolls per plant, and boll weights varied among different P treatments and between cotton genotypes. Delayed application of P caused increase in seed cotton yield and its components. The maximum seed cotton yield and yield contributing attributes were observed in the treatment where P was applied at 25 DAP as compared to pre-planting P application and split application of P at ½ 25 DAP+½ 50 DAP in both cotton genotypes (Table 6.16).

Table 6.16 Seed cotton yield and it components in two genotypes under different P treatments

P application time	Boll per plant		Boll weight (g)		Yield (kg ha^{-1})	
	Cyto-537	Cyto-535	Cyto-537	Cyto-535	Cyto-537	Cyto-535
Control	16	14	2.36	2.22	905	923
Full at Sowing	21	19	2.22	2.38	1909	1655
Full at 25 DAP	24	25	2.34	2.46	2168	2316
½ at 25 +½ at 50 DAP	16	21	2.31	2.41	1926	1930
Genotype	*		ns		*	
P application time	*		*		*	
Interaction	ns		ns		*	

Fiber traits such as staple length, uniformity index, micronaire and fiber strength varied considerably among treatments and between genotypes. In plots where P was applied at 25 DAP, staple length, uniformity index, micronaire and fibre strength were improved as compared to P applied at sowing or in two splits as ½ at 25 DAP+½ at 50 DAP, and control (Table 6.17).

Table 6.17 Fiber traits in two genotypes under different P treatments

P application time	Staple length (mm)		Uni. index (%)		Micronaire		Strength (G/Tex)	
	Cyto-537	Cyto-535	Cyto-537	Cyto-535	Cyto-537	Cyto-535	Cyto-537	Cyto-535
Control	26.3	27.2	80.4	82.1	4.4	4.9	27.2	26.3
Full at Sowing	26.5	27.4	83.4	82.9	4.5	4.9	27.7	27.5
Full at 25 DAP	27.3	27.8	81.7	83.8	4.3	4.5	28.5	28.0
½ at 25 +½ at 50 DAP	26.5	27.2	82.0	83.7	4.3	4.3	27.4	26.6
Genotype	*		ns		*		*	
P application time	*		*		*		*	
Interaction	ns		ns		*		ns	

6.2.3 Improving resource use efficiency and soil health by integrating rice crop in cotton

Cotton is an industrial as well as cash crop for the farmers in Pakistan. The area and production of cotton in the country are lower to fulfill annual industrial demand of 15 million bales. Cotton cultivated area has shifted to other season crops like rice, maize and sugarcane due to economic factors. One of the options to meet the country's lint demand is the vertical expansion of cotton plant to gain better yields per unit area. The other viable options adopted by different neighboring countries are to intercrop other crops along with cotton. Intercropping is the proven option of vertical expansion of cotton that can help to ensure both subsistence and disposable income to the farmers. Long duration with initially slow growing cotton and short duration fast maturing crop appeared to be the most compatible companion crops in the intercropping system that may prove to enhance productivity and economics of the farmers. The overall productivity in terms of land equivalent ratio (LER) and cotton yield equivalent ratio are generally higher in intercropping system than that in sole stand. The productivity and efficiency of intercropping system depends, to the large extent, on the nature and extent of plant competition and the spatial arrangement and densities of the component crops. Scientists are developing different crop production systems to increase productivity and sustainability since ancient times. This includes crop rotation, relay cropping and intercropping of major crops with other crops. However, several factors like cultivar selection, seeding ratios, planting pattern and competition between mixture components affect the growth of species in intercropping system. The proposed experiment was initiated to grow cotton on ridges and rice crop in furrows with the objectives to increase the farm income per unit land area and for making efficient utilization of available resources with concurrent improvement in soil health. One cotton genotype and one rice variety were selected for execution of the experiment. Detail of experiment is given below:

Treatments

T1	Cotton-sole
T2	Cotton on beds (1’) + Rice in furrows
T3	Cotton row skip+Rice in furrows
T4	Cotton (plant space 1.25’) +Rice in furrows
T5	Cotton (plant space 1.5’) + Rice in furrows

Pre-plant composite soil samples were collected from the plough layer of the experimental field before imposition of treatments. Physical and chemical characteristics of the soil samples were determined. Results indicated that the soil is silt loam in texture and alkaline in reaction. Soil pH varied from 8.17 to 8.38, electrical conductivity from 2.19 to 2.55 mS cm^{-1}, organic matter content from 0.51 to 0.67%, extractable potassium (K) from 121 to 143 mg kg^{-1} soil and extractable sodium from 373 to 479 mg kg^{-1} soil across the field (Table 6.18).

Table 6.18 Physical and chemical characteristics of experimental field at pre-planting

Sample No.	pH	EC (mS cm^{-1})	OM (%)	Ext. K (mg kg^{-1} soil)	Ext. Na (mg kg^{-1} soil)
1	8.23	2.26	0.63	143	435
2	8.17	2.19	0.67	134	387
3	8.31	2.32	0.51	121	373
4	8.26	2.55	0.58	134	479
5	8.38	2.34	0.63	128	457
Mean	**8.27**	**2.33**	**0.60**	**132**	**426**

Data on plant structure development in different treatments were recorded at maturity. Main stem height, nodes on main stem and inter-nodal length varied among different treatments. Plant height varied from 114 to 145 cm, number of nodes on main stem from 46 to 50, and inter-nodal distance from 2.44 to 3.04 cm in different treatments. Maximum plant height was observed in the treatment with row skip in cotton + rice (165 cm), while minimum height of 114 cm was observed in cotton-sole treatment (Table 6.19).

Table 6.19 Effect of different treatments on plant structure development

Treatment	Height	Node	Inter node
Cotton-sole	114	47	2.44
Cotton (1’ PxP)+Rice	133	47	2.82
Cotton row skip (1’ PxP)+Rice	145	50	2.89
Cotton (1.25’ PxP)+Rice	130	47	2.80
Cotton (1.5’ PxP)+Rice	139	46	3.04

Seed cotton yield, number of bolls per plant and boll weight varied significantly among various treatments. Number of bolls per plant varied from 24 to 34, boll weight from 2.44 to 2.54g and seed cotton yield from 1767 to 2531 kg ha^{-1}, in different treatments. In cotton-sole treatment maximum seed cotton yield was observed, while in cotton row skip + rice treatment maximum bolls per plant and boll weight was observed. Paddy rice yielded from 568 to 970 kg ha^{-1} paddy rice in different treatments. Maximum paddy yield was observed in row skip in cotton + rice in furrows treatment as compared to other treatments (Table 6.20).

Table 6.20 Effect of different treatments on yield and yield attributing factors

Treatment	Boll per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})	Paddy Rice yield (kg ha^{-1})
Cotton-sole	24	2.49	2531	0
Cotton (1' PxP)+Rice	25	2.44	2451	578
Cotton row skip (1'PxP)+Rice	34	2.54	1767	970
Cotton (1.25' PxP)+Rice	27	2.47	2186	627
Cotton (1.5' PxP)+Rice	31	2.44	2081	700
Statistical effect	*	*	*	*

Temperature of soil was recorded and soil samples were collected at reproductive stages of cotton and rice. Moreover, soil moisture content and bulk density were measured. Results revealed that soil temperature varied from 37.2 to 39.6^{0}C, and soil moisture content ranged from 12.3 to 17.5% and from 15.1 to 20.8 % in bed and furrows, respectively, while bulk density ranged from 1.43 to 1.57 (g/cc) and from 1.52 to 1.65 (g/cc) in bed and furrows, respectively, in different treatments (Table 6.21).

Table 6.21 Effect of different treatments on soil moisture content and bulk density

Treatment	Moisture %		Bulk Density (g/cc)		Soil Temp (^{0}C)
	Bed	Furrow	Bed	Furrow	
Cotton-sole	12.3	15.1	1.57	1.65	39.6
Cotton (1' PxP)+Rice	17.5	20.8	1.43	1.52	37.2
Cotton row skip (1' PxP)+Rice	14.5	17.1	1.51	1.59	38.6
Cotton (1.25' PxP)+Rice	15.9	18.7	1.46	1.56	38.0
Cotton (1.5' PxP)+Rice	15.1	17.6	1.48	1.57	38.4
Statistical Effect	*	*	ns	*	*

Fiber traits such as staple length, uniformity index, micronaire and fiber strength varied among different treatments. Staple length ranged from 26.7 to 27.8 mm, uniformity index from 81.6 to 83.6%, micronaire from 4.4 to 4.9 and fibre strength from 25.0 to 27.5 g/tex in different treatments (Table 6.22).

Table 6.22 Effect of different treatments on fiber traits

Treatment	Staple length (mm)	Uni. index (%)	Micronaire	Strength (G/Tex)
Cotton-sole	26.7	81.6	4.9	25.0
Cotton (1' PxP)+Rice	27.3	83.6	4.9	26.2
Cotton row skip (1' PxP)+Rice	27.8	82.9	4.8	26.0
Cotton (1.25' PxP)+Rice	27.4	83.5	4.8	27.5
Cotton (1.5' PxP)+Rice	27.2	83.4	4.4	26.5

Land equivalent ratio (LER), area time equivalent ratio (ATER) and cotton yield equivalent ratio (CYER) were calculated for different treatments. LER indicate the efficient utilization of land and higher value of LER indicate better utilization of land, ATER indicate efficient utilization of land within given time, less value of ATER than LER show the best utilization within given time and CYER indicate the additional benefits from intercrop in cotton. In the treatment Cotton (1' PxP)+ rice in furrows LER, ATER and CYER remained higher as compared to other treatments which indicated that Cotton (1' PxP)+ rice in furrows is more suitable and economical system for farmer (Tale 6.23).

Table 6.23 Effect of different treatments on economic analysis

Treatment	LER	ATER= (LERxDc/Dt)	CYER=SCY+(IYxIYP/PSC)
Cotton-sole	--	N/A	2531+000=2531
Cotton (1’ PxP)+Rice	1.35	0.89	2451+207=2658
Cotton row skip (1’ PxP)+Rice	0.83	0.55	1767+336=2103
Cotton (1.25’ PxP)+Rice	0.95	0.63	2186+217=2403
Cotton(1.5’ PxP)+Rice	0.92	0.61	2081+242=2323

LER: Land Equivalent Ratio, ATER: Area Time Equivalent Ratio, CYER=Cotton Yield Equivalent Ratio
Dc=Time taken by intercrop, Dt= Total time taken by system, IY= Intercrop yield, IYP= Intercrop yield Price, PSC=Price of one kg seed cotton

6.2.4 Enhancing nutrient use efficiency (NUE) by synchronizing application rate and methods

Nutrients supply is essential for growth and development in crop plants. Long term nutrients management is very important for ending hunger of the world. Low fertilizer use efficiency is a worldwide concern that is not limited to developing countries. Until now, many countries of the world have been highly dependent on importing mineral fertilizers for agriculture. Nutrients are important for optimum growth, metabolism and development of crops. Worldwide, nutrients are considered a key factor for increasing yield and productivity. Higher rate of minerals are required for cotton growth and development than other crops like rice and wheat. More than 30–40% of the agricultural lands across the world are deficient in macro-nutrients and micro-nutrients. In such soils, nutrients are regulated through exogenous addition of fertilizers to meet the requirement of cotton crop. Out of the total, only 20% of the applied fertilizers are used by the crops while the remaining 80% are lost via fixation, leaching, or in gaseous forms to the environment, resulting in less fertilizer use efficiency. To overcome this problem, foliar fertilization is a widely used practice that can increase nutrients uptake in plants. Among the different techniques, foliar fertilization has better potential to correct nutritional deficiencies in plants caused by the improper supply of nutrients to roots. This practice is usually more economical and effective under certain conditions and is generally considered efficient to supply nutrients quickly to a target organ. This technique is particularly adapted and important for crops to achieve maximum and best yield when crop nutrient demand is not completely fulfilled during the crop growth period. The foliar nutrients application could augment the soil-applied nutrients that may increase the nutrients use efficiency and reduce the crop dependence on soil nutrients. Resultantly, it will help in reducing the recommended dose of nutrients when applied in conjunction with foliar nutrients application. A new experiment was designed to synchronize the fertilizers application method and rate on cotton crop under field conditions with the objectives to find out the best fertilizers application method that would enhance fertilizer use efficiency and increase the farm income. Two cotton genotypes viz. Cyto-535 and Cyto-537 were used for execution of the experiment. Detail of experiment is given below:

Tr.	Nutrients
T1	Recommended dose of NPK nutrients (RD)
T2	50% of RD by fertigation
T3	40% of RD by fertigation + 10% foliar
T4	35% fertigation+15% Foliar

Field was divided into four blocks to check indigenous soil nutrient status and variability. For this purpose pre-plant composite soil samples were collected from the plough layer of the experimental field before sowing. Physical and chemical characteristics of the soil samples were determined. Results indicated that the soil is silt loam in texture and alkaline in reaction. Soil pH varied from 8.14 to 8.31, electrical conductivity from 2.16 to 2.53 mS cm^{-1}, organic matter content from 0.55 to 0.73%, extractable potassium (K) from 124 to 144 mg kg^{-1} soil and extractable sodium from 368 to mg 439 kg^{-1} soil across the field (Table 6.24).

Table 6.24 Physical and chemical characteristics of soil at pre-planting

Sample No.	pH	EC (mS cm^{-1})	OM (%)	Ext. K (mg kg^{-1} soil)	Ext. Na (mg kg^{-1} soil)
1	8.31	2.27	0.73	133	427
2	8.14	2.16	0.61	144	392
3	8.26	2.32	0.55	131	368
4	8.25	2.53	0.68	124	439
Mean	**8.24**	**2.32**	**0.64**	**133**	**407**

Data on plant structure development were recorded at maturity. In treatment T4 that received 35% of recommended dose by fertigation+15% by foliar spray of fertilizers, the main stem height, number of nodes on main stem and inter-nodal length remained higher over control as well as over other treatments in both genotypes. Averaged across genotypes, main stem height varied from 106 to 128 cm, number of nodes on main stem varied from 45 to 48 and intermodal distance from 2.36 to 2.61 cm among different treatments (Table 6.25).

Table 6.25 Plant structure at maturity in two genotypes under different fertilizer application methods

Tr.	Height (cm)			Nodes on main stem			Inter-nodal length (cm)		
	Cyto-537	Cyto-535	Av.	Cyto-537	Cyto-535	Av.	Cyto-537	Cyto-535	Av.
T1	113	118	115	47	48	48	2.40	2.46	2.43
T2	101	110	106	44	45	45	2.30	2.43	2.36
T3	120	126	123	48	49	48	2.50	2.51	2.51
T4	122	133	128	49	48	48	2.52	2.71	2.61
Genotype	*			*			ns		
Application method	*			ns			ns		
Interaction	ns			ns			ns		

The fresh weight of leaves and stalk was determined from harvested plant samples. Data revealed that fresh weight of leaf and stalk was higher in treatment where recommended dose of fertilizer was applied as compared to other treatments. In treatment, where 35% of recommend fertilizers was applied (RD) by fertigation+15% of RD by foliar, the fresh weight of leaf and stalk increased by 26% and 21% in Cyto-537, and 17% and 13% in Cyto-535, respectively, as compared to those where 50% of recommended fertilizer was applied by fertigation (Table 6.26).

Table 6.26 Fresh weights of leaves and stalk at maturity in two genotypes under different fertilizers application methods

Treatments	Leaves weight (g)		Stalk weight (g)	
	Cyto-537	Cyto-535	Cyto-537	Cyto-535
T1	88.8	99.0	148.8	212.0
T2	68.3	79.7	117.1	168.2
T3	83.2	90.7	138.3	185.8
T4	85.8	93.3	142.2	189.5
Genotype	*		*	
Application method	*		*	
Interaction	ns		*	

Seed cotton yield, bolls per plant, and boll weight varied among different treatments and between cotton genotypes. The maximum seed cotton yield was observed in the treatment where recommended dose of fertilizers was applied as compared to other treatments in both cotton genotypes. However, the treatment T4 where 35% of recommended dose was applied by fertigation+15% of RD by foliar spray performed better with regards to yield and yield attributing factors as compared to other treatments except T1 (Table 6.27).

Table 6.27 Seed cotton yield and it components in two genotypes under different fertilizer application method

Tr.	Boll per plant		Boll weight (g)		Yield (kg ha^{-1})	
	Cyto-537	Cyto-535	Cyto-537	Cyto-535	Cyto-537	Cyto-535
T1	29	28	2.78	2.91	2951	2802
T2	25	24	2.67	2.85	2390	2466
T3	27	26	3.08	2.98	2618	2615
T4	28	26	3.33	3.30	2691	2764
Genotype	*		*		*	
Application method	ns		ns		*	
Interaction	ns		ns		*	

Seed index, agronomic efficiency, and benefit/cost ratio varied among different treatments and between cotton genotypes. The maximum seed index, agronomic efficiency, and benefit/cost ratio was observed in T4 treatment where 35% of recommended fertilizer dose was applied by fertigation+15% by foliar as compared to other treatments in both cotton genotypes. Furthermore, T4 treatment showed the best method of fertilizer application as compared to other methods as indicated by higher values of seed index, agronomic efficiency and benefit/cost ratio in both genotypes (Table 6.28).

Table 6.28 Economic analyses in two genotypes under different fertilizer application method

Tr.	Seed index (g)		Agronomic efficiency of fertilizers		Benefit/cost ratio	
	Cyto-537	Cyto-535	Cyto-537	Cyto-535	Cyto-537	Cyto-535
T1	8.60	8.70	8.34	7.91	3.07	2.91
T2	8.50	8.20	9.67	8.85	3.11	3.21
T3	8.60	8.40	11.08	10.98	3.40	3.40
T4	9.00	9.10	13.33	11.30	4.50	4.13
Genotype	*		*		*	
Application method	ns		*		*	
Interaction	ns		ns		*	

Fiber traits such as staple length, uniformity index, micronaire and fiber strength varied considerably among treatments and between genotypes. In T4 treatment where 35% recommended dose was applied by fertigation+15% by foliar staple length, uniformity index, micronaire and strength were improved as compared to other treatments (Table 6.29).

Table 6.29 Fiber traits in two genotypes under different P treatments

Tr.	Staple length (mm)		Uni. index (%)		Micronaire		Strength (G/Tex)	
	Cyto-537	Cyto-535	Cyto-537	Cyto-535	Cyto-511	Cyto-535	Cyto-511	Cyto-535
T1	27.3	26.8	80.4	82.1	4.4	4.9	27.4	26.1
T2	26.3	26.2	81.7	80.8	4.6	5.0	27.5	25.0
T3	27.5	26.5	82.0	80.7	4.3	4.3	27.8	26.7
T4	28.5	27.7	83.4	82.9	4.5	4.9	28.7	28.5
Genotype	*		ns		*		*	
Application method	*		*		*		*	
Interaction	ns		ns		*		ns	

6.3 Plant-Water Relationships

6.3.1 Adaptability of genotypes to water stress conditions

By the twenty-first century, a considerable progress has been made in industry, economy and finance as well as great innovations in medicine; human health sector and in extending the lifespan. In spite of all this progress, today, more than 1 billion people, nearly a sixth of the world's population, suffer from chronic hunger and malnutrition due to lack of food. In addition, nearly 800 million people are under-nourished. A serious concern is that the world's hunger has been increasing at a rapid pace in recent years. The vast majority of the world's hungry people live in developing countries. Southern Asia also faces the greatest hunger burden with about 280 million undernourished people.

One of the important reasons for under nourishment, malnutrition and hunger is global and regional drought events, which reduce agricultural production. In addition to annual drought-related agricultural losses, long-term technology-increased global grain production, the principal indicator of food security, is currently growing slower than the population increase rate. Future prospects are not encouraging since it will require an increase in food production of nearly 70% to feed 2 billion more people by the mid of the century. This situation is further complicated by climate warming, which is assumed to intensify droughts, increasing their area, strength, duration and leading to a further reduction of agricultural production. In years, when moderate-to-intensive drought covers more than 20% of the world's main agricultural areas, there is less food production than what the world needs for consumption. The situation already deteriorated in the twenty-first century, when in the first 17 years, world grain production was below the consumption and in almost half of the years grain production was 3–6% below consumption. Moreover, in all of these years, drought was the major cause affecting food security and world's sustainability. Although, drought cannot be prevented, instead, it can be detected early and damages to agriculture could be predicted well in advance of harvest in order to provide on time food assistance to avoid hunger. Therefore, one of the most important tasks for prediction of food insecurity is to detect drought early and estimate agricultural production losses several months ahead of harvest. Drought effect not only decreases plant height, shoot growth rate, and yield but also diminishes root growth. It has been found from the earlier studies that varieties/cultivars in each species vary from one another in their reaction to drought conditions, signifying that drought tolerance in these groups can be improved through breeding. Physiological traits linked with drought tolerance in cotton have strong relationship with yield parameters. For example, shoot growth rate, root growth rate and photosynthetic rate, which significantly decrease with the imposition of water stress, can be used, effectively, for germplasm screening under drought conditions. Since, the germplasm with genetic variability may exhibit differential response under normal and water deficit conditions, regular screening of emerging germplasm need to be carried out for better adaptability and sustainable production. The following studies were, therefore, conducted to evaluate advanced cotton genotypes for drought tolerance characteristics under field conditions. Outcome of such studies can help to understand the relationship of different physiological and growth traits of cotton and their direct and indirect effects related to cotton productivity.

A field experiment was conducted at the experimental area of Central Cotton Research Institute, Multan during the cotton crop season 2021-22. A total of twelve cotton genotypes viz. CIM-775, CIM-875, CIM-789, Cyto-536, Cyto-537, Cyto-541, GH-Hamalyia, CRIS-674, CRIS-682,SLH-50, SLH-51 and SLH-66 were evaluated for their performance under two water regimes applied on the basis of leaf water potential (LWP) i.e. -1.6 $\pm$ 0.2 MPa Ψ_w (normal irrigation; NS) and -2.4 $\pm$ 0.2 MPa Ψ_w (water stressed; WS). The treatments were laid out in RCBD with split-plot arrangement (water stress main plots; genotypes: sub-plots). Crop was sown on April 19, 2021. Water stress was imposed at squaring phase i.e. at 40 days after planting that continued till cut off irrigation. Leaf water potential was continuously monitored by employing Pressure Chamber Technique. The quantity of irrigation water applied was measured through “Cut Throat Flume” during the season. Total quantity of water applied was 2987 m^3 in NS plots and 2115 m^3 in water stressed plots. The precipitation received was 70 mm during the crop growth period.

Data on plant structure and development were recorded at maturity. Main stem height, nodes on main stem and inter-nodal length varied significantly with water regime and among the genotypes. Main stem height ranged from 98 to 157 cm, nodes on main stem from 39 to 46 and inter-nodal length from 2.53 to 3.56 cm in different genotypes under normal irrigation. In water stress conditions, the main stem height ranged from 81 to 143 cm, nodes on main stem from 36 to 44 and inter-nodal length from 2.05 to 3.32 cm in different genotypes. Averaged across water regimes, main stem height varied from 95 to 150 cm, nodes on main stem from 37 to 45and inter-nodal length from 2.30 to 3.49 cm. Imposition of water stress caused a decrease of 9.40% in main stem height and 7.10% in inter-nodal length, irrespective of genotypes (Table 6.30).

Table 6.30 Plant structure at maturity in cotton genotypes under two water regimes

Genotype	Height (cm)			Node			Inter-Node (cm)		
	NS	WS	Avg	NS	WS	Avg	NS	WS	Avg
CIM-875	157	143	150	44	43	43	3.56	3.32	3.49
CIM-775	144	125	134	43	43	43	3.35	2.90	3.13
CRIS-674	132	114	123	46	44	45	2.88	2.57	2.73
Cyto-541	106	111	109	44	42	43	2.39	2.66	2.52
CIM-789	107	109	108	39	43	41	2.73	2.49	2.61
SLH-66	108	101	105	40	41	40	2.71	2.47	2.59
SLH-50	121	100	111	45	42	44	2.70	2.38	2.54
SLH-51	108	99	104	40	39	40	2.69	2.53	2.61
GH-Hamaliya	121	94	107	42	38	40	2.90	2.44	2.67
Cyto-536	98	91	95	39	36	37	2.53	2.56	2.55
CRIS-682	109	88	98	43	43	43	2.54	2.05	2.30
Cyto-537	112	81	96	44	38	41	2.54	2.16	2.35
Mean	117	106		42	41		2.77	2.58	
WR		*			ns			*	
G		*			*			*	
WRxG		*			*			*	

WR= Water Regime G= Genotype

Leaf area (LA) and leaf fresh weight per leaf varied significantly among genotypes and between water regimes. Leaf area ranged from 24.7 to 115.0 cm^2 and leaf fresh weight from 1.39 to 4.77 g in different genotypes, irrespective of water regimes. The imposition of water stress decreased LA and leaf fresh weight by 28.7% and 28.3 %, respectively (Table 6.31).

Table 6.31 Leaf area and fresh weight in different genotypes under two water regimes

Genotype	Leaf area (cm^2)			Leaf fresh weight (g)		
	NS	WS	Avg	NS	WS	Avg
CIM-875	115.0	89.0	102.0	4.77	3.67	4.22
CIM-775	77.3	53.7	65.5	3.14	1.91	2.53
CRIS-674	77.0	66.7	71.9	3.16	1.96	2.56
Cyto-541	71.3	45.0	58.2	2.96	1.76	2.36
CIM-789	71.0	40.3	55.7	2.79	1.90	2.35
SLH-66	71.0	29.7	50.4	2.95	1.62	2.29
SLH-50	70.3	56.7	63.5	2.84	2.29	2.57
SLH-51	67.7	32.7	50.2	2.44	1.81	2.13
GH-Hamaliya	66.7	42.3	54.5	2.49	2.10	2.30
Cyto-537	50.3	42.3	46.3	2.86	1.76	1.81
CRIS-682	46.3	57.7	52.0	2.85	2.43	2.64
Cyto-536	30.3	24.7	27.5	2.01	1.39	1.70
Mean	67.9	48.4		2.86	2.05	
WR	*			*		
G	**			**		
WR x G	*			ns		

Proline content, relative water content (RWC) and chlorophyll SPAD values varied significantly among genotypes and between water regimes. The proline ranged from 7.6 - 14.5 (μg g^{-1} FW), RWC from 80.1 - 95.6%, and chlorophyll content (SPAD) from 46.1 to 58.0 in different genotypes, irrespective of water regimes. The imposition of water stress increased proline content from 9.1 to 13.0 (μg g^{-1} FW), decreased RWC from 92.3 to 84.2%, and also lowered chlorophyll content from 53.7 to 52.0, on overall basis (Table 6.32).

Table 6.32 Proline content, relative water content and chlorophyll content in different genotypes under two water regimes

Genotypes	RWC (%)		Proline content (μg g^{-1} FW)		Chlorophyll content (SPAD values)	
	NS	WS	NS	WS	NS	WS
CIM-875	93.3	82.7	10.2	12.2	56.7	51.1
CIM-775	94.2	86.0	9.5	12.3	55.0	55.0
CRIS-674	95.1	85.1	8.5	11.0	56.7	47.6
Cyto-541	90.1	84.2	8.1	13.4	56.2	52.1
CIM-789	95.6	89.3	9.6	14.5	52.0	49.6
SLH-66	89.7	80.1	7.6	11.2	49.7	54.4
SLH-50	92.9	81.3	9.6	12.5	48.8	46.1
SLH-51	92.9	87.9	8.3	13.7	50.5	54.1
GH-Hamaliya	91.1	82.1	9.5	14.4	58.0	53.1
Cyto-536	90.6	81.4	8.6	11.7	54.4	53.8
CRIS-682	89.7	85.9	8.9	14.5	48.7	54.8
Cyto-537	91.9	84.3	10.5	14.5	57.5	52.1
Mean	**92.3**	**84.2**	**9.1**	**13.0**	**53.7**	**52.0**
G	**		**		*	
WR	*		*		ns	
GxWR	*		*		*	

WR= Water Regime G= Genotype

Data revealed that seed cotton yield, number of bolls per plant and boll weight varied significantly among the genotypes and under water regimes. Number of bolls per plant varied from 16 to 48, boll weight from 1.65 to 3.14 g, and seed cotton yield from 1147 to 2297 kg ha^{-1}, in different genotypes, irrespective of water regimes. With the imposition of water stress, seed cotton yield decreased from 2098 to 1769 kg ha^{-}

^{1}, bolls per plant from 29 to 23 and boll weight from 2.44 to 2.19 g irrespective of the genotypes. Water stress decreased the seed cotton yield, number of boll per plant and boll weight by 15.7%, 20.7% and 10.2%, respectively. The genotype GH-Hamaliya produced the maximum seed cotton yield of 2297 kg ha^{-1} with 22 bolls per plant and boll weight of 2.56 g in normally irrigated plots, similarly under water stress condition GH-Hamaliya maintained highest yield. The positive interactions among water regimes and genotypes for yield parameters reveal that the genetic variability and their differential response to varied conditions can help in varietal selection for better yield performance and use of identified desirable traits in breeding programs (Table 6.33).

Table 6.33 Seed cotton yield and yield components in different genotypes under two water regimes

Genotype	Boll per plant			Boll weight (g)			Yield (kg ha^{-1})		
	NS	WS	Avg	NS	WS	Avg	NS	WS	Avg
GH-Hamalyia	22	20	21	3.14	2.49	2.52	2297	2152	2225
Cyto-541	33	25	29	2.71	2.64	2.68	2296	1937	2117
Cyto-537	26	19	23	2.96	2.61	2.79	2226	2080	2153
CIM-775	27	26	27	2.47	2.33	2.40	2224	2080	2152
SLH-66	23	21	22	2.62	2.26	2.44	2223	1721	1972
Cyto-536	25	16	21	2.37	1.90	2.14	2151	1650	1901
CIM-789	23	20	22	2.17	2.08	2.13	2151	1865	2008
CRIS-682	35	29	32	2.03	1.89	1.96	2080	1793	1937
CIM-875	35	28	32	2.56	2.41	2.78	1937	1793	1865
CRIS-674	48	43	46	1.72	1.65	1.69	1937	1434	1686
SLH-50	22	19	21	2.29	1.96	2.13	1865	1147	1506
SLH-51	23	19	21	2.18	2.06	2.12	1793	1578	1686
Mean	29	23		2.44	2.19		2098	1769	
Treatment (Tr)	*			*			*		
Genotype (G)	*			*			**		
TrxG	*			*			**		

Staple length, uniformity index, micronaire and fiber strength varied among genotypes and between water regimes. The staple length ranged from 24.1 to 29.0 mm, uniformity index from 80.6% to 86.0%, micronaire from 4.1 to 5.5 and fiber strength from 23.0 to 30.7 G/Tex in different genotypes, irrespective of water regimes. The imposition of water stress caused a decrease in staple length, uniformity index and fibre strength (Table 6.34)

Table 6.34 Fiber traits in different cotton genotypes under two water regimes

Genotype	Staple length (mm)			Uni-Index			Micronaire			Strength		
	NS	WS	Mean	NS	WS	Mean	NS	WS	Mean	NS	WS	Mean
CIM-775	26.6	25.5	26.1	84.1	83.4	83.8	5.0	5.1	5.1	26.8	25.0	25.9
CIM-789	27.1	26.6	26.9	82.7	82.0	82.4	4.9	4.5	4.7	27.5	26.7	27.1
CIM-875	27.9	27.2	27.6	86.0	83.9	85.0	4.9	5.3	5.1	27.2	26.2	26.7
Cyto-541	27.1	26.4	26.8	84.4	84.4	84.4	5.0	5.3	5.2	26.0	25.8	25.9
SLH-66	27.4	27.2	27.3	82.2	82.1	82.2	4.3	4.7	4.5	28.6	28.5	28.6
Cyto-536	29.0	27.3	28.2	85.1	81.9	83.5	4.4	4.1	4.3	30.7	27.3	29.0
Cyto-537	26.0	25.9	26.0	83.7	83.1	83.4	5.5	5.2	5.4	24.3	24.9	24.6
GH-Hamaliya	25.5	25.1	25.3	81.1	81.7	81.4	4.8	5.3	5.1	25.2	25.0	25.1
SLH-51	27.4	26.3	26.9	83.8	82.4	83.1	4.4	4.9	4.7	28.9	27.0	28.0
Cris-674	24.6	24.1	24.4	80.6	81.4	81.0	4.7	5.1	4.9	23.6	23.0	23.3
SLH-50	24.3	25.5	24.9	83.2	82.8	83.0	5.1	5.3	5.2	27.6	23.3	25.5
Cris-682	28.3	27.7	28.0	83.1	83.4	83.3	5.2	4.7	5.0	27.4	28.7	28.1
Mean	26.7	26.3		83.3	82.7		5.0	5.0		27.0	26.0	
WR	ns			ns			ns			*		
G	**			*			*			*		
WRxG	ns			ns			ns			ns		

6.3.2 Exogenous application of bio-chemicals to improve drought tolerance in cotton

Increasing scarcity of irrigation water is a principal threat to sustainable production of cotton. Water-deficit stress is a major environmental factor restricting more than one third of the arable land for cultivation across the world. Drought is a common abiotic stress during the cotton-growing season, which causes a series of negative effects on cotton plant growth, yield and fiber quality. Cotton is dreadfully drought sensitive crop and is prone to yield reduction by drought, because drought stress is a complex phenomenon that affects the physiology of cotton plant. In addition, cotton is a very susceptible plant to the quantity of irrigation water and therefore, irrigation management is very complicated. The flowering and boll-forming stage is the key yield determinant period of cotton plants. Water stress occurring during this stage seriously affects cotton development and final productivity. During the last decade, the foliar application of plant growth regulators and biomolecules, such as brassinosteroids and polyamine has become an established procedure in crop production to increase yield and quality of the crop under abiotic stresses including drought.

Foliar application of plant growth regulator, at low concentrations, plays an important role in plant's defense systems against biotic and abiotic stresses. These bio-chemicals are involved in the regulation of plant physiological processes including stomatal closure, chlorophyll and protein synthesis, nutrient uptake, transpiration, and photosynthesis. Studies have indicated that exogenous application of bio-chemicals may lead to improvements in morpho-physiological traits that are involved in determination of plant yield. Furthermore, application of bio-chemicals induces the degradation of reactive oxygen species and increases the activity of antioxidant enzymes especially under water stress. The objective of the present work was to investigate the possible role of bio-chemicals in mitigating water deficit stress and quantification of parameters that improve cotton productivity. The detail of biochemicals applied along with their concentrations is given in Table 6.35.

Table 6.35 Bio-chemicals and their concentration applied through foliar spray in two cotton genotypes

Bio-chemicals	Water Regimes
IAA @150 µM	No Stress
	Water stress
Calotrope Leaf Ext. @ 50 ml/L	No Stress
	Water stress
Salicylic acid @ 20 mM	No Stress
	Water stress
$AgNO_3$ @40 µM	No Stress
	Water stress
Acetic acid @ 50 mM	No Stress
	Water stress
Control (Water alone)	No Stress
	Water stress

The crop was sown on April 19, 2021 in a randomized complete block design with split-split plot arrangement. Bio-chemicals were applied through foliar sprays; first application starting from squaring stage and subsequent applications after 20 days intervals. Two cotton genotypes CIM-785 and CIM-775 were used as test crop. The NPK fertilizers were applied to soil according to recommended fertilizer doses. Standard production and management practices were adopted.

Plant structure development in different treatments was recorded at maturity. Main stem height, nodes on main stem and inter-nodal length varied among different treatments. In NS plots, main stem height varied from 121 to 150 cm, number of nodes on main stem from 43 to 55 and inter-nodal length from 2.82to 3.11 cm in CIM-785, while in CIM-775, the main stem height varied from 141 to 209 cm, number of nodes on main stem from 40 to 55 and inter-nodal length from 3.14 to 3.79 cm in different treatments. However, in WS plots, the main stem height varied from 100 to 140 cm, number of nodes on main stem from 39 to 52 and inter-nodal length from 2.44 to 2.98 cm in CIM-785. While in CIM-775 the main stem height varied from 124 to 178 cm, number of nodes on main stem from 39 to 48 and inter-nodal length from 3.02 to 3.71 cm in different treatments (Table 6.36).

Table 6.36 Plant structure at maturity in different treatments under no stress and water stress condition in two genotypes

Treatments	Water level	Height (cm)		Node		Inter-nodal	
		CIM-785	CIM-775	CIM-785	CIM-775	CIM-785	CIM-775
Control	NS	121	141	43	40	2.82	3.53
	WS	109	133	39	39	2.80	3.41
$AgNO_3$	NS	123	154	43	49	2.86	3.14
	WS	112	124	40	41	2.80	3.02
Salicylic Acid	NS	150	182	50	48	3.00	3.76
	WS	140	166	47	45	2.98	3.71
Acetic acid	NS	131	160	46	44	2.85	3.66
	WS	100	151	41	42	2.44	3.59
Calotrope Leaf Ext.	NS	149	209	55	55	2.73	3.79
	WS	140	178	52	48	2.71	3.70
IAA	NS	134	166	43	45	3.11	3.68
	WS	100	150	39	41	2.56	3.67
Treatment (Tr)		*		*		*	
Genotype (G)		*		*		ns	
Biochemical (Bio)		**		ns		*	
TrXG		*		ns		*	
TrxBio		*		*		ns	
BioxG		*		ns		ns	
TrXGXBio		*		ns		ns	

Proline content, relative water content (RWC) and chlorophyll (SPAD) varied significantly among different treatments and between genotypes under normal irrigation and water stress condition. The proline content varied from 8.86 to 11.57 µg g^{-1} FW, RWC from 73 to 89 % and chlorophyll (SPAD) values from 48 to 58in CIM-785, while in CIM-775 the proline content varied from 8.22 to 11.22 µg g^{-1} FW, RWC from 73 to 91% and chlorophyll (SPAD) values from 46 to 58 in different treatments, irrespective of water regimes. Maximum proline contents were observed where calotrope leaf extract was applied and maximum chlorophyll contents were observed where both acetic acid and IAA were applied (Table 3.37).

Table 3.37 Proline content, RWC and chlorophyll content (SPAD) in different treatments under NS and WS condition in two genotypes

Treatments	Water level	Proline (µg g^{-1} FW)		RWC (%)		Chlorophyll (SPAD)	
		CIM-785	CIM-775	CIM-785	CIM-775	CIM-785	CIM-775
Control	NS	8.92	8.60	85	84	51	50
	WS	9.65	9.09	73	73	48	52
AgNO3	NS	8.86	8.22	89	87	57	55
	WS	9.89	9.67	74	75	49	48
Salicylic Acid	NS	9.79	8.80	89	84	51	52
	WS	11.19	10.04	80	78	51	52
Acetic acid	NS	9.09	9.29	87	88	57	58
	WS	9.62	9.57	74	79	52	46
Calotrope Leaf Ext.	NS	9.39	9.15	86	91	49	56
	WS	11.57	11.22	77	76	55	50
IAA	NS	9.69	8.74	85	88	58	56
	WS	9.69	9.02	79	76	52	52
Treatment (Tr)		**		*		**	
Genotype		*		ns		**	
Biochemical		**		**		**	
TrXG		*		ns		**	
TrxBio		ns		ns		**	
BioxG		**		**		**	
TrXGXBio		**		ns		**	

Seed cotton yield and yield contributing factors differed variably among various treatments and between genotypes under normal irrigation and water stress condition. Data on seed cotton yield, bolls per plant and boll weight were recorded at maturity. In normal irrigated plots (NS), bolls per plant varied from

24 to 37, boll weight from 2.37 to 3.36 g and seed cotton yield from 3071 to 3748 kg ha^{-1} in CIM-785, while in CIM-775 bolls per plant varied from 34 to 44, boll weight from 2.28 to 2.76g and seed cotton yield from 3140 to 3640 kg ha^{-1} in different treatments. However, in water stressed plots (WS), bolls per plant varied from 22 to 30, boll weight from 2.21 to 2.95 g and seed cotton yield from 2852 to 3467 kg ha^{-1} in CIM-785, while in CIM-775 bolls per plant varied from 31 to 35, boll weight from 2.16 to 2.39 g and seed cotton yield from 2662 to 3008 kg ha^{-1} in different treatments. Foliar application of bio-chemicals enhanced the yield and yield attributing factors both in normal irrigation and water stress condition as compared to control, however in normal irrigation and water stress condition maximum yield was obtained in the treatment where salicylic acid @ 20 mM was applied in CIM-785, while in CIM-775 in normal irrigation and water stress condition maximum yield was obtained in the treatment where acetic acid @ 50 mM was applied (Table 6.38).

Table 6.38 Seed cotton yield and yield attributing factors in different treatments under no stress and water stress condition in two genotypes

Treatments	Water level	Boll per plant		Boll weight (g)		Yield (kg ha^{-1})	
		CIM-785	CIM-775	CIM-785	CIM-775	CIM-785	CIM-775
Control	NS	24	34	2.79	2.28	3071	3140
	WS	22	31	2.54	2.16	2852	2662
$AgNO_3$	NS	33	39	3.36	2.69	3463	3389
	WS	29	34	2.88	2.29	3139	2704
Salicylic Acid	NS	37	39	2.72	2.45	3748	3157
	WS	30	32	2.52	2.31	3467	2711
Acetic acid	NS	27	40	3.10	2.76	3455	3640
	WS	25	35	2.95	2.39	3067	3008
Calotrope Leaf Ext.	NS	31	44	2.37	2.44	3370	3291
	WS	28	31	2.21	2.30	3084	2816
IAA	NS	26	37	3.16	2.38	3453	3408
	WS	23	33	2.37	2.29	3156	2882
Treatment (Tr)		*		*		*	
Genotype		**		*		**	
Biochemical		ns		ns		*	
TrXG		**		ns		ns	
TrxBio		ns		ns		ns	
BioxG		ns		**		ns	
TrXGXBio		ns		ns		ns	

Staple length, uniformity index, micronaire and fiber strength varied between genotypes. The staple length ranged from 24.5 to 26.2 mm, uniformity index from 79.0 to 81.4%, micronaire from 4.3 to 5.2 and fiber strength from 24.5 to 26.2 G/Tex in CIM-785, while in CIM-775 staple length ranged from 24.5 to 26.4 mm, uniformity index ranged from 79.8 to 82.8%, micronaire from 4.9 to 5.3 and fiber strength from 23.3 to 26.8 G/Tex in different treatments, irrespective of water regimes. The imposition of water stress caused a decrease in staple length, uniformity index and fibre strength (Table 6.39).

Table 6.39 Fiber traits in different treatments under no stress and water stress condition in two genotypes

Treatments	Water level	Staple length (mm)		Uni-Index (%)		Micronaire		Strength (G/tex)	
		CIM-785	CIM-775	CIM-785	CIM-775	CIM-785	CIM-775	CIM-785	CIM-775
Control	NS	26.0	26.2	80.6	82.4	4.4	5.2	25.4	24.8
	WS	24.7	25.3	80.3	81.1	4.5	5.0	26.1	24.2
$AgNO_3$	NS	26.2	25.8	80.9	82.2	4.6	5.3	24.9	24.0
	WS	24.7	25.6	79.0	82.2	5.0	5.3	25.3	24.8
Salicylic Acid	NS	25.3	26.4	79.4	81.9	4.6	4.9	25.0	24.9
	WS	24.5	24.9	79.4	82.8	4.6	5.0	25.3	26.3
Acetic acid	NS	25.6	26.4	79.9	81.2	4.3	5.1	25.7	26.5
	WS	24.8	24.5	80.0	81.0	4.4	4.9	25.7	24.1
Calotrope Leaf Ext.	NS	25.3	26.1	81.4	82.0	4.5	5.2	24.6	24.4
	WS	24.9	25.3	79.6	79.8	5.2	4.9	25.6	26.8

IAA	NS WS	25.6 25.2	25.8 25.0	81.1 81.0	82.1 81.6	4.5 4.7	5.3 5.1	25.8 25.7	23.3 24.4
Treatment (Tr)		ns		ns		ns		ns	
Genotype		*		*		*		*	
Biochemical		ns		ns		ns		ns	
TrXG		ns		ns		ns		ns	
TrxBio		ns		ns		ns		ns	
BioxG		ns		ns		ns		ns	
TrXGXBio		ns		ns		ns		ns	

6.3.3 Seed coating with PGPR's to ameliorate drought stress and enhancing nutrient use efficiency in cotton

Cotton is a major crop after wheat and it occupies the largest area in Pakistan compared to other crops. Cotton crop earns the country largest export revenues and in addition to the lint, the seed of cotton for oil and meal accounts for 80 percent of the national production of oilseed. Cotton and cotton related products contribute 10 percent to gross domestic product (GDP) and 55 percent to the foreign exchange earnings of the country. Despondently, declining water resources challenge the large area under cotton cultivation as affected by drought. Many areas of cotton production in developing countries located in arid and semi-arid regions, where drought spells account for large harvest losses and thus threaten sustainability of the agricultural and cotton industry. As compared to other crops, cotton is more sensitive to drought stress at flowering and boll production stages.

Crop yield is the end product of photosynthesis and other interlinked physiological processes. Lower plant growth and productivity due to drought are mainly caused by altered plant water relations, decreased photosynthetic process, cellular-oxidative load, membrane damage, and in some instances, inhibited enzyme activity. Water shortages are among the most serious limitations to global agricultural production due to the complexity of water-deficient environments and climatic variation. Drought is an important and complicated abiotic stress that affects the growth, development, and reproduction of plants. Drought limits cotton productivity and fiber quality, drought resistance is a complex, quantitative trait controlled by more than two factors. It is, therefore, of great significance to improve the drought tolerance of cotton and increase its yield under drought stress conditions. Drought occurrence, especially during bolls production affects yield by decreasing both number and weight of bolls. To ensure a sustainable cotton yield in an agro-system with ever increasing environmental stresses, the plant breeders are challenged to develop varieties having potential genetic makeup for high yield and resistance against environmental stresses. So far, by conventional breeding and advanced biotechnological and transgenic approaches an auspicious contribution has been made to drought tolerance development in crop plants. Due to restricted biodiversity and ecological limitations, the further development in such advanced expertise may be limited to get increased production of crops. However, crop management approaches aimed at improving tolerance to adversative conditions can offer a great potential to alleviate effects and yield losses under stress conditions.

Plant growth-promoting rhizobacteria (PGPR) are naturally occurring soil bacteria and are known to induce plant growth promotion. The beneficial effects of PGPR have been studied in many crop species. The benefits of plant–PGPR interactions have been reported in improved seed germination, root development, shoot and root weights, leaf area, chlorophyll content, hydraulic activity, protein content, nutrient uptake, and yields in several crops. There is also evidence that beneficial microbes can enhance plants' tolerance against adverse environmental conditions. For example, Arbuscular mycorrhizal fungi enhanced salinity-tolerance of *Panicum turgidum* by favorably altering photosynthetic and antioxidant pathways. Due to application of potassium-releasing PGPR an enhanced plant growth and potassium uptake have been reported under nutrient deficiency and heavy metal contamination in cotton and rapeseeds. Similarly, the plants of tomato, okra, and African spinach treated with PGPR displayed their improved osmoregulation, oligotrophic, endogenous metabolism, resistance to starvation, and thus showed their efficient metabolic processes to adapt dry and saline environments. However, a new experiment was initiated to evaluate the role of PGPR's in drought tolerance and in improving nutrients use efficiency in cotton crop.

Before sowing, the PGPRs were coated on cottonseed. The crop was sown on May 28, 2021 in a randomized complete block design with split-split plot arrangement. Two cotton genotypes Cyto-535 and Cyto-537 were used as test crop. The NPK fertilizers were applied to soil according to recommended fertilizer doses. Standard production and management practices were adopted.

Following treatments were imposed during the season:

Water level	PGPR treatment	
Normal Irrigation	Seed-coated	Seed-uncoated
Water stress		

Data regarding plant structure development were taken at maturity. Results revealed that in PGPR-coated treatment the plant height remained at 90 cm and 87 cm, number of nodes on main stem 29 and 30, intermodal length 3.10 and 2.90 cm in Cyto-537 and Cyto-535, respectively, under NS, while plant height remained at 79 cm and 66 cm, number of nodes on main stem 26 and 23, inten nodal length 3.04 and 2.87 cm in Cyto-537 and Cyto-535, respectively, under WS condition. Similarly, in PGPR-uncoated treatment, plant height remained at 86 cm and 78 cm, number of nodes on main stem 28 and 27, inter-nodal length 3.07 and 2.89 cm in Cyto-537 & Cyto-535, respectively, under NS condition, while plant height remained at 74 cm and 65 cm, nodes on main stem 25 and 23, inter-nodal length 2.96 and 2.83 cm in Cyto-537 and Cyto-535, respectively, under WS condition **(Table 6.40).**

Table 6.40 Plant structure development in PGPR coated-uncoated seed under different water level

PGPR-treatment	Water levels	Height (cm)		Nodes on main stem		Inter-nodal length	
		Cyto-537	Cyto-535	Cyto-537	Cyto-535	Cyto-537	Cyto-535
Seed-coated	NS	90	87	29	30	3.10	2.90
	WS	79	66	26	23	3.04	2.87
Seed-uncoated	NS	86	78	28	27	3.07	2.89
	WS	74	65	25	23	2.96	2.83
PGPR		*		*		*	
Water level (WT)		*		*		*	
Genotype (G)		ns		ns		ns	
PGPRxWT		*		*		*	
PGPRxG		ns		ns		ns	
WTXG		*		*		*	
PGPRxWTxG		*		*		*	

Seed index and benefit/cost ratio differed variably among various treatments and between genotypes under normal irrigation and water stress condition. Results revealed that in PGPR-coated treatment, the seed index at 8.54 and 8.65g, benefit/cost ratio at 1.70 and 1.65 in Cyto-537 and Cyto-535, respectively, under no stress, while seed index remained at 7.62 and 8.23 g, benefit/cost ratio at 1.43 and 1.29 in Cyto-537 and Cyto-535, respectively, under water stress condition. Similarly, in PGPR-uncoated treatment seed cotton index remained at 8.41 and 8.47, benefit/cost ration at 1.43 and 1.46 in Cyto-537 and Cyto-535, respectively, under no stress, while seed cotton index remained at 7.03 and 7.91, benefit/cost ration at 1.29 and 1.26 in Cyto-537 and Cyto-535, respectively, under water stress condition (Table 3.42).

Table 6.41 Seed index and benefit/cost ratio in PGPR coated-uncoated seed under different water level

PGPR-treatment	Water level	Seed index		Benefit/Cost ratio	
		Cyto-537	Cyto-535	Cyto-537	Cyto-535
Seed-coated	NS	8.54	8.65	1.70	1.65
	WS	7.62	8.23	1.34	1.29
Seed-uncoated	NS	8.41	8.47	1.43	1.46
	WS	7.03	7.91	1.29	1.26
PGPR		*		*	
Water level (WT)		*		*	
Genotype (G)		ns		ns	
PGPRxWT		*		*	
PGPRxG		ns		ns	
WTXG		*		ns	
PGPRxWTxG		*		*	

Seed cotton yield and yield contributing factors differed variably among various treatments and between genotypes under normal irrigation and water stress condition. Data regarding seed cotton yield, bolls per plant and boll weight were taken at maturity. Results revealed that in PGPR-coated treatment the bolls per plant remained at 15 and 13, boll weight at 2.86 and 2.88, seed cotton yield at 567 and 551 kg ha^{-1}, in Cyto-537 and Cyto-535, respectively, under no stress, while the bolls per plant remained at 12 and 11, boll weight at 2.32 and 2.61, seed cotton yield at 448 and 430 kg ha^{-1} in Cyto-537 and Cyto-535, respectively, under water stress condition. Similarly, in PGPR-uncoated treatment the bolls per plant remained at 13 and 12, boll weight at 2.53 and 2.74 g, seed cotton yield seed at 478 and 487 kg ha^{-1}, in Cyto-537 and Cyto-535, respectively, under no stress, while the bolls per plant remained at 11 and 10, boll weight at 1.86 and 2.55, seed cotton yield at 429 and 420 kg ha^{-1} in Cyto-537 and Cyto-535, respectively, under water stress condition (Table 6.42).

Table 6.42 Seed cotton yield and yield attributing factors in PGPR coated-uncoated seed under different water level

PGPR-treatment	Water level	Boll No.		Boll weight (g)		Yield	
		Cyto-537	Cyto-535	Cyto-537	Cyto-535	Cyto-537	Cyto-535
Seed-coated	NS	15	13	2.86	2.88	567	551
	WS	12	11	2.32	2.61	448	430
Seed-uncoated	NS	13	12	2.53	2.74	478	487
	WS	11	10	1.86	2.55	429	420
PGPR		*		*		*	
Water level (WT)		*		*		*	
Genotype (G)		ns		ns		ns	
PGPRxWT		*		*		*	
PGPRxG		ns		ns		ns	
WTXG		*		*		*	
PGPRxWTxG		*		*		*	

6.4 Seed Physiology

6.4.1 Effect of Seed priming on heat tolerant and susceptible genotypes at different sowing time in improving the cottonseed health and quality

Cottonseed is one of the most sensitive agronomic seeds and more prone to deterioration due to high oil contents. Seed germination and post-germination seedling development are well-regulated processes involving high metabolic activity and generation of reactive oxygen species (ROS) in the cell. ROS can lead to changes in the selective permeability of bio-membranes, causing membrane leakage and changes in the activity of membrane-bound enzymes. Membrane disruption is one of the main reasons of seed deterioration. As a result, seed cells are not able to retain their normal physical condition and functioning. The major causes of membrane disruption are increase in free fatty acid level and free radicals productivity by lipid peroxidation. Cotton plant has a natural mechanism to prevent itself from different stresses such as inadequate and inconsistent rainfall, salinity, water shortage, extreme temperature, and some other factors are not only limiting crop yields by square drying, premature floral abscission and failure to set the bolls also associated with poor productivity and effect the cottonseed health. Seed priming with biochemicals like proline and salicyclic acid not only enhance the germination, vigour but also prevent the production of ROS under any oxidative stress conditions by completing the defense network. They play a key role in internal control mechanism of plant growth by interacting with key metabolic processes such as nucleic acid and protein synthesis. Seed priming provides a means of quickly correcting plant defense mechanism, when plant identifies the stress.

The aim of this investigation was to evaluate the response of cotton plant in terms of growth, cottonseed health and productivity subjected to seed priming under heat stress conditions. A field experiment was conducted to evaluate the efficacy of seed priming on four cotton genotypes viz. GH-Hamaliya, CIM-775 (heat tolerant) and CIM-789, Cyto-537 (heat susceptible). The crop was sown on 15th of April 2021 and 18th May 2021 in a randomized complete block design (RCBD) with split plot arrangement (genotypes; main plot and seed treatment; sub plots). The experiment was divided into two sets i.e. 15th April sowing (Set-A) and 18th May sowing (Set-B). Seed priming was done before sowing for improving heat tolerance in both sets. The crop was fertilized with recommended NPK fertilizers. Standard production and management practices were adopted.

Seed Treatments	Bio-chemicals	Dose
T1	Control	No priming
T2	Proline	0.1%
T3	Salicylic Acid (SA)	0.01%

The assessment of seed quality parameters was done from the mature cottonseeds. Results indicated that the seed priming of four-cotton genotypes viz. GH-Hamaliya, CIM-775 (heat tolerant) and CIM-789, Cyto-537 (heat susceptible) improved seed health parameters such as seed germination, seed index, oil and crude protein content. Average across the genotypes, pH and electrical conductivity of the seed exudates increased with late sowing and seed priming of biochemicals. T3 showed the maximum change in the above parameters where SA was applied @0.01%. Biochemical analysis of the oil revealed that the free fatty acids of all genotypes (both sets) were within safe limits i.e. < 1.0%. **In Set -A**, in heat tolerant genotypes, seed germination varied from 35-80%, seed index from 5.9-8.1g, oil content from 15 to 20% and crude protein from 15 to 22 % while in heat susceptible genotypes, seed germination varied from 40-70%, seed index from 7.0-9.9g, oil content from 13 to 21% and crude protein from 17 to 26% in different treatments. In **Set-B**, in heat tolerant genotypes, seed germination varied from 31-77%, seed index from 6.0-8.3g, oil content from 14 to 20% and crude protein from 17 to 27% while in heat susceptible genotypes, seed germination varied from 26-64%, seed index from 6.1-8,3g, oil content from 13 to 22% and crude protein from 20 to 28%, in different treatments (Table 6.43).

Table 6.43 Effect of seed priming on seed quality parameters

Seed Treatments	**Heat tolerant**		**Heat susceptible**		**Mean**
	GH-Hamaliya	CIM-775	CIM-789	CYTO-537	
pH					
15th April					
T1 (C)	6.19	6.31	6.17	6.11	6.20
T2 (P)	6.21	6.35	6.19	6.16	6.23
T3 (S.A)	6.37	6.41	6.26	6.29	6.33
Mean	**6.26**	**6.36**	**6.21**	**6.19**	
18th May					
T1(C)	6.22	6.40	6.66	6.77	6.51
T2 (P)	6.30	6.70	6.74	6.87	6.65
T3 (S.A)	6.70	6.78	6.89	6.98	6.84
Mean	**6.41**	**6.63**	**6.76**	**6.87**	
EC (µS cm^{-1})					
15th April					
T1(C)	238	244	255	269	252
T2 (P)	309	322	344	377	338
T3 (S.A)	377	387	376	388	382
Mean	**308**	**318**	**325**	**345**	
18th May					
T1(C)	461	426	450	455	448
T2 (P)	493	437	478	489	474
T3 (S.A)	510	486	482	515	498
Mean	**488**	**450**	**470**	**486**	
Germination (%)					
15th April					
T1(C)	35	44	40	43	41
T2 (P)	66	70	56	65	64
T3 (S.A)	80	77	69	70	74
Mean	**60**	**64**	**55**	**59**	
18th May					
T1(C)	31	36	29	26	31

T2 (P)	63	67	50	58	60
T3 (S.A)	70	77	59	64	68
Mean	**55**	**60**	**46**	**49**	
Seed index (g)					
15th April					
T1(C)	6.8	5.9	7.0	8.7	7.1
T2 (P)	7.3	6.3	7.5	8.8	7.5
T3 (S.A)	8.1	6.6	7.5	9.9	8.0
Mean	**7.4**	**6.3**	**7.3**	**9.1**	
18th May					
T1(C)	6.0	6.2	6.1	7.9	6.6
T2 (P)	7.5	6.9	7.2	8.1	7.4
T3 (S.A)	8.3	7.4	7.7	8.3	7.9
Mean	**7.3**	**6.8**	**7.0**	**8.1**	
Oil Contents (%)					
15th April					
T1(C)	15	16	13	15	15
T2 (P)	18	17	17	19	18
T3 (S.A)	20	19	18	21	20
Mean	**18**	**17**	**16**	**18**	
18th May					
T1(C)	14	16	13	16	15
T2 (P)	16	18	17	19	18
T3 (S.A)	17	20	21	22	20
Mean	**16**	**18**	**17**	**19**	
Free fatty acid (%)					
15th April					
T1(C)	0.98	0.88	0.96	0.78	0.90
T2 (P)	0.78	0.77	0.85	0.69	0.77
T3 (S.A)	0.77	0.72	0.71	0.61	0.70
Mean	**0.84**	**0.79**	**0.84**	**0.69**	
18th May					
T1(C)	0.99	0.90	0.95	0.87	0.92
T2 (P)	0.88	0.89	0.91	0.84	0.88
T3 (S.A)	0.77	0.81	0.82	0.73	0.78
Mean	**0.92**	**0.91**	**1.02**	**0.93**	
Crude protein (%)					
15th April					
T1(C)	15	18	17	19	17
T2 (P)	16	21	22	21	20
T3 (S.A)	18	22	24	26	23
Mean	**16**	**20**	**21**	**22**	
18th May					
T1(C)	17	19	20	21	19
T2 (P)	22	22	24	25	23
T3 (S.A)	26	27	27	28	27
Mean	**22**	**22**	**24**	**24**	

C= control, P=Proline@0.1%, S.A=Salicyclic Acid@0.01%

7. TRANSFER OF TECHNOLOGY SECTION

Transfer of Technology Section is playing a key role to disseminate the outcomes of research findings/ practices of cotton scientists/experts for the development of new cotton production & seed technologies to cotton growers & the stakeholders to enhance their skill & knowledge through information & communication technologies (ICT) / mass media.

7.1 Human Resource Development

7.1.1 Training Programs

The following training programs were conducted during the season:

i) Cotton Production Technology
ii) Agronomic practices of the cotton crop
iii) Cotton Production Technology & Plant Mapping
iv) Advance agronomic practices for better cotton production
v) Cotton seed technologies
vi) Nutritional requirements of the cotton plant
vii) Cotton insect pest management
viii) Weed Management
ix) Cotton varieties & their characteristics
x) Principles of better cotton production
xi) Management of PBW & sucking insect pests
xii) Cotton Plant Mapping
xiii) Cotton Fibre Traits
xiv) Off-season management of the cotton crop through PB-Ropes
xv) Use of PBW Manager Machine for control of PBW
xvi) Management of seasonal and non-seasonal Pink Bollworm (PBW)

Training programs for Field Staff Agri. (Extension) Department/ farmers & with other departments

Date	Organized/ Coordinated by	Venue	Resource Person	Participants
03.03.2021	CCRI,Multan	CCRI,Multan	Dr.Zahid Mahmood & all heads of sections	**Total=70** Master Trainees from private sector
08.03.2021	PCSI,Multan	CCRI,Multan	Dr.Zahid Mahmood	**Total=09** Cotton Selectors
03.06.2021	Agri.Ext.Deptt. Punjab & CCRI Multan	Tehsil Jatoi.Muzaffar Garh	i.Dr. Zahid Mahmood ii. Mr.Sajid Mahmood	**Total=95** Farmers = 83 DD(Ext) =01 AD(Ext) =02 F.A =06 FFC =03
-do-	-do-	Tehsil Ali Pur.Muzaffar Garh	-do-	**Total=122** Farmers = 107 DD(Ext) =01 AD(Ext) =03 FA =08 FFC =03
04.06.2021	-do-	District Muzafar Garh	Dr. Muhammad Naveed Afzal	**Total=109** Farmers = 91 DD(Ext) =01 AD(Ext) =03 F.A =11 FFC =03

07.06.2021	CCRI Multan	CCRI Multan	i.Dr. Zahid Mahmood ii. Dr. Muhammad Naveed Afzal iii. Dr.Fiaz Ahmed	**Total=53** Lead Farmers = 53 Distt.Multan
10.06.2021	CCRI Multan & Agri.Ext.Deptt. Punjab	CCRI Multan	Dr. Zahid Mahmood & other Scientific officers of Entomology Section	**Total=56** Master Trainees = 56 Agri.Extt.Punjab
11.06.2021	CCRI Multan	CCRI Multan	i.Dr. Zahid Mahmood ii.Dr Fiaz Ahmad	**Total=37** Master Trainees = 37 Crop Reporting Services ,Punjab
12.06.2021	South Asian Sourcing (SAS),NGO & CCRI Multan	Bahawalnagar	Dr. Zahid Mahmood	**Total=75** Lead Farmers = 75 Distt.Multan
19.06.2021	CCRI Multan & CCRI Sakrand	CCRI Sakrand	i.Dr. Zahid Mahmood ii.Dr. Muhammad Naveed Afzal iii. Dr.Fiaz Ahmad	**Total=84** Lead Farmers = 53 Sindh Master Trainees= 31
23.06.2021	CCRI Multan under BCI Project	D.G.Khan	i.Dr. Zahid Mahmood ii. Dr.Fiaz Ahmad iii. Mr.Sajid Mahmood iv.Mr.Kumail Fiaz	**Total=40** Lead Farmers = 40
24.06.2021	CCRI Multan.	CCRI Multan	i.Dr. Zahid Mahmood ii. Dr.Fiaz Ahmed iii. Dr.M.Naveed Afzal	**Total=33** Officers from Crop Reporting Service Department Punjab
01.11.2021	CCRI,Multan	CRI Khanpur(RYK)	i.Dr.Zahid Mahmood ii.Mr.Sajid Mahmood iii. Mr. Juanid Ahmad	**Total=55** Farmers = 43 AD Ext) =02 F.A =10
03.11.2021	CCRI,Multan	CRS,BWP	i.Dr.Zahid Mahmood ii.Mr.Sajid Mahmood iii. Mr. Juanid Ahmad	**Total=63** Farmers = 53 AD(Ext) =02 F.A =08
24.11.2021	CCRI,Multan	AARI,Faisalabad	i.Dr.Zahid Mahmood ii.Mr.Sajid Mahmood iii. Mr. Juanid Ahmad	**Total=25** Farmers = 07 Cotton In charge AARI,Faisalabad =01 RO =04 Others = 13
14.12.2021	CCRI,Multan	CCRI,Multan	i.Dr.Zahid Mahmood ii.Dr.Rabia Saeed	**Total=65** Master Trainees Agri. Ext.Dept. Punjab = 65 (AO & Field assistants) Vehari,Lodhran,Bahawalpur,Bahawalnagar & RYKhan
15.12.2021	CCRI,Multan	CCRI,Multan	i.Dr.Zahid Mahmood ii.Dr.Rabia Saeed	**Total=42** Master Trainees Agri. Ext.Dept. =42 Punjab (AO & Field assistants) Multan,Khanewal,Faisalabad,Sahiwal
16.12.2021	CCRI,Multan	CCRI,Multan	i.Dr.Zahid Mahmood ii.Dr.Rabia Saeed	**Total=32** Master Trainees Agri. Ext.Dept. =32

				Punjab (AO & Field assistants) Rajanpur,Muzafar Garh, DG Khan & Mianwali
21.12.2021	CCRI Multan	CCRI Multan	Dr.Zahid Mahmood ii.Dr.Rabia Saeed	**Total=15** Master Trainees PWQC,. Punjab = 15 (AO & Field assistants) Vehari,Lodhran,Bahawalpur,Bahawalnagar & RYKhan
22.12.2021	CCRI Multan	CCRI Multan	i.Dr.Zahid Mahmood ii.Dr.Rabia Saeed	**Total=18** Master Trainees PWQC,. Punjab = 18 (AO & Field assistants) Multan,Khanewal,Faisalabad,Sahiwal
23.12.2021	CCRI Multan	CCRI Multan	i.Dr.Rabia Saeed ii.Mr.Sajid Mahmood	**Total=16** Master Trainees PW&QC,. Punjab = 16 (AO & Field assistants) Rajanpur Muzafar Garh & DG Khan
28.12.2021	CCRI Multan	CCRI Multan	i.Dr.Zahid Mahmood ii.Dr.Rabia Saeed	**Total=17** Master Trainees AO of Adaptive Research Farms of Punjab = 17
29.12.2022	CCRI Multan	CCRI Multan	.Dr.Zahid Mahmood ii.Dr.Rabia Saeed iii.Mr.Sajid Mahmood	**Total=50** Farmers under Project "Sindh Irrigated Agriculture Productivity Enhancement (PSIAPE)

***DD=**Deputy Director
***AD=**Assistant Director
***FA**= Field Assistant
***RO**= Research Officer

7.1.2 Training by Virtual Lecture

Date	Name of Institution	No. of Students	Briefed by
09.06.2021	PMAS Arid Agriculture University Rawalpindi	**50** PhD, MSc (Hons) and BSc (Hons) Entomology	Dr. Rabia Saeed

7.1.3 TV Programs/ SOT’s

Thirty six (36) SOT’s /programs were conducted during the season.

7.1.4 Radio Programs

Nine (09) Radio Programs and one (01) documentary were conducted during the season.

7.1.5 Press Coverage/Media Talk

The section arranged fifteen (15) press coverage and four (04) media talks during the season.

7.1.6 Preparation of Video Clips

Two (02) video clips were prepared and uploaded on social media for farmer’s advice /information during the season.

7.1.7 Urdu Articles

Nine (09) Urdu articles on Cotton Production Technology/others were sent & published in newspapers during the season.

7.1.8 Press Releases

Eighty seven (87) press releases throughout the season 2020-21 were sent to the press time to time for the guidance of cotton farming community.

7.1.9 Press Report

A press report on “cotton revival meeting with Stakeholders” headed by Jamshed Iqbal Cheema, SPAM was sent to Daily Aftab, Multan, and published on August 18, 2021.

7.1.10 Distribution of Printed Material

a. The following leaflets were distributed among growers, extension workers, agri. students of different colleges/universities etc. & field officers of Agri. Extension (Punjab) for their information and guidance during the season:

- Recommendations of Cotton Variety CIM-496
- Recommendations of Cotton Variety CIM-534
- Recommendations of Cotton Variety CIM-573
- Recommendations of Cotton Variety CIM-608
- Recommendations of Cotton Variety CIM-620
- Recommendations of Cotton Variety Cyto-124
- Recommendations of Cotton Variety Cyto-179
- Recommendations of Cotton Variety Bt.CIM-598
- Recommendations of Cotton Variety Bt.CIM-599
- Recommendations of Cotton Variety CIM-496
- Recommendations of Cotton Variety Bt.CIM-602
- Management of Pink Bollworm
- Recommendations for better seed germination
- *Kapsa Ki Kasht Aur Nighehdasht*
- *Kapas K Beej Ka Ugaaou Aur Behtar Sifarshat*
- *Kapaas mein Potash ki Ahmiyat*
- *Kaps Ki Mealy Bug Aur Oos Ka Insdaad*
- *Kapaas Ki Patta Maror Bemari Sy Bachaou Ki Hikmat-E-Amli*
- *Kapaas ki Meleybug*
- *Kapaas Ki gulabi sundi aur os ka insdaad*
- *Kapaas ki gulabi sundi ka tadaruk bazarya pb-ropes*
- *PBW Manager for PBW management*
- *Sifarshaat braey Kapaas ki gulabi sundi ka insdaad*
- *CCRI Multan….. an introduction*

b. Preparation of Leaflets

The following leaflets in Urdu were prepared and got printed under Cotton Productivity Enhancement PBW Project-CCRI-Multan for distribution among cotton growers and other stakeholders as well.

Sr#	Leaflet	No. of Copies
1.	پنک بولورم مینیجر اور معاشی فوائد	3000
2.	گلابی سنڈی اور اس کا انسداد	3000
3.	گلابی سنڈی کا انسداد بذیعہ پی بی روپس	3000
4.	سفارشات برائے گلابی سنڈی کا انسداد	3000

7.1.11 Agriculture Exhibitions

The institute planted a stall in agricultural exhibition during the season:

Date	Organized by	Venue	Event	Resource Persons
June 22,2022	CCRI Multan	CCRI Multan	6th National Seminar on "Pink Bollworm Management"	i.M.Ilyas Sarwar ii.Dr.Khadim Hussain iii.Dr.Muhammad Tariq
7th October,2021	CCRI Multan	CCRI Multan	World Cotton Day	-do-

7.2 Meetings

7.2.1 Future of Cotton Research& Development

Meeting regarding "Future of Cotton Research & Development" was held at the institute on 23rd August 2021. This meeting was chaired by Syed Fakhar Imam, Federal Minister for National Food Security & Research. The meeting deliberated improvement in cotton research programs for revival of cotton crop in the country. The meeting was attended by The meeting was attended by Special Assistant to the Ministry of National Food Security Dr Muhammad Akmal Siddique, Cotton Commissioner Dr Khalid Abdullah, Director CCRI Dr Zahid Mahmood, Dr Iqbal Bandesha, Dr Saghir Ahmed, Dr Rabia Saeed, Dr Manzoor Ahmed Manj and Sajid Mahmood. Dr. Mehboob-ur-Rehman, Dr. Muhammad Ehsan, Director CCRI Sakrand, Hidayatullah Bhutto, Muhammad Farhan, and Musarat Hussain participated in the online meeting .

7.2.2 Agriculture Policies

A meeting regarding agriculture policies was held at the institute on May 29, 2021 under the chairmanship of honorable Jamshed Iqbal Cheema, Special Assistant to Prime Minister for food security. Dr. Muhammad Ali Talpur, Vice President; Dr. Tassawar Hussain Malik, Director Research; Dr. Zahid Mahmood, Director CCRI Multan; Mr. Gul Hasan, Director Marketing and other officials both CCRI & PCCC attended the meeting. Mr. Jamshed Iqbal Cheema stated that the government is taking all possible measures for enhancing cotton productivity including substantial amounts on subsidies for inputs (seed, fertilizer, pesticide, credit). He asked all the stakeholders to join hands for revival of cotton crop. He also stated that the restructuring of Pakistan Central Cotton Committee is also in the process to make it more vibrant and at par excellence with international institutions through provision of research funds, induction of local and foreign scientists for varietal development and skill development of scientists. He also visited cotton fields and laboratories at CCRI Multan.

7.2.3 Revival of cotton with stakeholders

Revival of cotton crop meeting was held at CCRI Multan on 9th August 2021 under the chairmanship of Mr. Jamshed Iqbal Cheema, Special Advisor to the Prime Minister on Food Security. The meeting was also attended by Dr. Khalid Abdullah, Cotton Commissioner MNFS&R; Mr. Saqib Ali Ateel, Secretary Agriculture South Punjab Secretariat; Dr. Muhammad Anjum Ali, DG Agri Ext Punjab; Mr. Khalid Khokhar, Chairman Pakistan Kissan Itehad and representatives of Irrigation, MEPCO; PCPA, APTMA, PCGA attended the meeting. The meeting deliberated the current cotton crop situation and measures to be taken in the coming weeks for fertilizer and pesticide application to manage the cotton crop effectively.

7.2.4 4th meeting of cotton planning committee

4th meeting of Cotton Planning Committee 2021 was held at Cotton Research Institute (CRI), Multan on March 29, 2021 chaired by Syed Hussain Jahania Gardezi, Agriculture Minister Punjab. Director CCRI, Multan, Dr. Zahid Mahmood attended this significant meeting with high officials of agriculture department, Punjab and other stake holders as well.

7.2.5 55th meeting of Punjab Seed Council

Punjab Agriculture Minister Syed Hussain Jahanian Gardezi chaired the 55th meeting of the Punjab Seed Council at Agriculture House Lahore on 21st September 2021. In this meeting 5 new Bt varieties CIM 663, CIM 678, CIM 785, Cyto 533, Cyto 535, and one non-Bt variety Cyto 226 of Central Cotton Research Institute, Multan were approved for general cultivation in Punjab.

Dr.Muhammad Ali Talpur ,VP ,PCCC, Dr.Zahid Mahmood, Director CCRI Multan, Dr. Muhammad Idrees Khan Head, PBG & Mr.Sajid Mahmood, Head, TTS attended the meeting along with other participants.

7.2.6 81st meeting of the Sub-Expert -Committee

81st meeting of the Sub-Expert -Committee of Punjab Seed Council was held at Ayub Agriculture Research Institute, Faisalabad on 12th July 2021 headed by Dr.Zafar Iqbal Qureshi, DG Agri. Research. In the meeting, seven new varieties of CCRI were recommended. Dr.Zahid Mahmood, Director CCRI Multan along with his team comprising of Dr Muhammad Akbar, Scientific Officer, Breeding Section and Sajid Mahmood, Head, Transfer of Technology attended the meeting.

7.2.7 Reviewing financial progress of the cotton project

The team from ICARDA Pakistan Office Islamabad including Mr. Muhammad Arshad, Cotton Consultant; Ms Sumera Younas, Farmer Program Specialist and Mr. Arshad Mahmood, Accountant visited CCRI Multan on April 6, 2021 in connection with reviewing financial progress of the cotton project. Dr. Muhammad Idrees Khan, Head, Plant Breeding & Genetics / Focal Person, ICARDA Project and Mr. Nazar Abbas, Superintendent (Accounts) briefed about project activities.

7.2.8 Spot Examination

A significant meeting of spot examination of cotton candidate strains 2021 was held at Punjab Seed Corporation Experimental Farm, Perowal, Khanewal. Dr. Zahid Mahmood, Director CCRI Multan participated in the meeting along with other experts.

7.2.9 Fibre Standards Committee

A meeting of Fibre Standards Committee was held at Lahore on June 8,2021 under Dr.Muhammad Zafar Iqbal Director General Agriculture Punjab. Dr. Zahid Mahmood, Director CCRI Multan also attended the meeting with other participants.

7.2.10 2nd meeting for reconsidering the Fibre Quality Standards

The 2nd meeting for reconsidering the Fibre Quality Standards of Cotton was held on 7th July 2021 at Rapid Soil Fertility Survey & Soil Testing Institute Punjab, Lahore under the Chairmanship of Chief Scientist Agri. (Research), AARI, Faisalabad.Dr.Zahid Mahmood ,Director ,CCRI,Multan attended the meeting with other participants

7.2.11 Meeting of Cotton Stakeholders

A meeting of cotton experts, ginners, agriculture extension officials and farmers was held in the cotton fields located in Basti Malok for revival of cotton crop in the country on May 24, 2021. Dr. Zahid Mahmood, Director CCRI Multan also attended the gathering and deliberated measures and strategies for enhancing the cotton productivity. The participants also visited adjoining cotton field areas.

7.2.12 Restructuring of PCCC

Meeting regarding Restructuring of Pakistan Central Cotton Committee in the office of Director Research PCCC held on 5th July 2021. Director Research PCCC, Dr. Taswar chaired the meeting.

7.2.13 Advisory Committee Meeting

Ten (10) meetings of farmers' advisory committee were held at the Institute under Dr. Zahid Mahmood, Director of the Institute during the season 2021-22. Fortnightly recommendations were presented in the meeting for the guidance of cotton growers.

7.3 a. World Cotton Day

CCRI Multan celebrated the World Cotton Day on the 7th October 2021. Mr. Saqib Ali Ateel, Secretary Agriculture, South Punjab Secretariat was the chief guest of the program. Meanwhile, Federal Minister for National Food Security Syed Fakhar Imam, Punjab Minister for Agriculture Syed Hussain Jahanian Gardezi, Vice President PCCC Dr Muhammad Ali Talpur and Cotton Commissioner Dr Khalid Abdullah addressed the participants online. Dr. Zahid Mahmood, Director CCRI Multan; Dr. Sohail Mahmood Haral, Chairman PCGA, Mr. Khalid Khokhar, President Kisan Itehad and Mr. Suhail Talat, Convener FPCCI, Dr. Shafqat Saeed ,Professor MNSUAM highlighted the importance of cotton crop in the economy of Pakistan. Cotton production problems were discussed and measures were suggested for its enhancement and revival in the country. More than 500 participants from various stakeholders, NGOs and farmers attended the program.

b. Cotton Walk

On the eve of World Cotton Day at the institute, a walk was arranged in commemorating the importance of cotton for the economy of Pakistan. Mr. Saqib Ali Ateel, Secretary Agriculture & Dr. Zahid Mahmood, Director CCRI Multan along with other officials participated in the walk.

7.4 14th August Ceremony 2021

Hoisting of National Flag ceremony & Tree Plantation was held on 14th August 2021. Dr. Zahood Mahmood, Director, CCRI Multan hoisted the national flag. All the staff members and their kids also participated in the ceremony and prayed for the country's prosperity. The national anthem was also sung in the ceremony. Dr. Zahid Mahmood, Director CCRI Multan stated that we must all work with complete dedication and devotion for the country.

7.5 Seminars

a. 6th National Seminar on “Pink Bollworm Management”

CCRI Multan organized the "6th National Seminar on Pink Bollworm Management" on 22nd June ,2021. Mr. Saqib Ali Ateel, Secretary Agriculture South Punjab Secretariat Multan; Mr. Bilal Israel, Chairman Punjab Cotton R&D Board; Dr. Zahid Mahmood, Director CCRI Multan addressed the farmers. Dr. Muhammad Ali Talpur, VP, PCCC; Dr. Khalid Abdullah, Cotton Commissioner, MNFS&R; Dr. Shah Nawaz Khuro attended the program via zoom link. More than 200 Cotton Researchers, representatives of pesticide companies, and almost 170 farmers attended the seminar.

b. Seminar on “Cotton Production Technology”

A seminar on "Cotton Production Technology” organized by Agren group (pvt) Ltd was held on 15th July 2021 at Industrial Estate, Multan. Dr. Fiaz Ahmad, Head, Plant Physiology & Chemistry dept. CCRI Multan was the expert speaker & Chief guest of the seminar. Dr. Muhammad Naveed Afzal & Mr. Sajid Mahmood also accompanied him. More than 300 farmers attended the seminar.

c. International Seminar on Cotton Pink Bollworm management

International Seminar on Cotton Pink Bollworm management was held at Dr.Mehboob Ali Auditorium, CCRI Multan on November 17, 2021 under "Cotton productivity Enhancement through PBW Management Project (2020-22) under PM Agriculture Emergency Program. Various national and international cotton experts delivered their talks regarding effective PBW management.Dr. Tassawar Hussain Malik, Director Research PCCC; Mr. Bilal Israel, Chairman Punjab Cotton R&D Board; Dr. Zahid Mahmood, Director CCRI Multan addressed the farmers. Dr. Muhammad Ali Talpur, VP, PCCC; Dr. Khalid Abdullah, Cotton Commissioner, MNFS&R; Dr. Keshav Kranthi, Chief Scientist, International Cotton Advisory Committee, USA, Dr. A. G. Sreenivas, Centre for Agro-climatic Studies, University of Agricultural Sciences, India, Dr. Jodi Scheffler, Research Geneticist, USDA-ARS, USA attended the program via zoom link. More than 200 cotton researchers, representatives of pesticide companies, and farmers attended the seminar.

7.6 Participation in Workshop/Conference

Date	Workshop/Conference	Venue	Organized by	Participants
December 08, 2021	Workshop on "Sustainable Solutions for Revival of Cotton in Pakistan"	Multan Ramada Hotel	WWF-Pakistan & PCGA	i.Dr.Khalid Abdullah ii.Dr.Zahid Mahmood iii.Mr.Sajid Mahmod

7.7 Visits

a. Dignitaries

Dignitaries/Delegation	Dated
Mr. Imtiaz Hussain, Regional Director, Plant Protection Department, Multan	17.03.2021
Honorable Jamshed Iqbal Cheema, Special Assistant to Prime Minister for food security	29.05.2021
Additional Secretary South Punjab,Barak Ullah Khan	09.06.2021
Mr. Bilal Israel, Chairman, Cotton Research & Development Board Punjab along with Mr. Shah Qasim Khan, CEO, Indus Oil Mills Multan	21.06.2021
Mr. Saqib Ali Ateel, Secretary Agriculture, South Punjab Secretariat	14.06.2021
Ex Lt General and Lahore Corps Commander Mr.,Zarar Azeem	28.06.2021
Mr. Sohail Talat, representative of Pakistan Cotton Ginners Association	28.06.2021
Brig. Muhammad Bakhsh Sobhi from Bahawalnagar	29.06.2021
Dr. Muhammad Yousaf Ali, Program Manager, Research and Education Development Program with his team members	01.07.2021
Col. Syed Javed Raza from Chak No. 79-10/R, Khanewal	05.07.2021
Mr. Muhammad Azam Khan, Regional Director FSC & RD(Punjab),	08.07.2021
Mr. Rashid Ahmad, Executive Director, CropLife Pakistan; Mr. Muhammad Aamir Majeed, Senior Manager Technical & Development, Mr. Nadir N. Jaffer, Chief Operating Officer, Jaffer Brothers Pvt Ltd	29.07.2021
Additional Secretary Agriculture South Punjab Barkullah Khan and his team	05.08.2021
Jamshed Iqbal Cheema,SAPM	09.08.2021
Saqib Ali Ateel, Secretary Agriculture South Punjab	09.08.2021
Dr.Khalid Abdullah Cotton Commissioner	09.08.2021
Khalid Khokhar, President Kissan Ittehad	09.08.2021
Dr Muhammad Akmal Siddique, Special Assistant to the Ministry of National Food Security	23-08-2021
Dr Khalid Abdullah ,Cotton Commissioner,MNFSR	-do-
Dr Iqbal Bandesha Head,PBG,IUB	-do-
Mr.Sohail Harral,Ex Chairman ,PCGA with his delegation members	-do-
Mr. Yasir Arfat, Focal Person (South Punjab) for Special Assistant to Prime Minister on Food Security, Ministry of National Food Security and Research	01.10.2021
Rana Suleman ,Chairman Seed Association of Pakistan	07.10.2021
Mr. Muhammad Zeeshan and Mrs Sadia Sarwar; Assistant Directors (Farms), Punjab Seed Corporation visited CCRI Multan	28.10.2021
A team from Cotton Research Station, Bahawalpur with Malik. Kamran, a progressive grower from Bahawalpur	05.11.2021
Dr. Ghulam Ali, Director, Air University, Multan Campus	10.11.2021
Lt Col(Retd) Syed Baqar Ahsan , a progressive cotton grower from Lodhran	29.11.2021
Ms Florence Rolle, FAO Head Pakistan along with her team comprising Mr. Jam Khalid, National FFS Specialist, Mr. Umar Saeed, Agronomist, Mr Faheem Ahmad, Mr. Ansar Ahmad, Mr. Qadeer ul Hussain	30.11.2021
Director PSDP, PARC Mr.Munir Shahid	02.12.2021
Muhammad Waseem Azhar, Budget & Accounts Officer, MNFS&R, Islamabad along with Mr. Aftab Qadir, Audit Officer	07.12.2021
Dr. Khalid Abdullah, Cotton Commissioner, Ministry of National Food Security & Research	08.12.2021
Mr. Asif Majeed, Chairman, Evoyl Group	08.12.2021
Muhammad Alamgir Chaudhry, Chief Executive Officer, National Productivity Organization (NPO Pakistan)	13.12.2021
FAO Consultant Ms Rizwana Warriach, Islamabad with her team	20.12.2021
Shahid Hussain Leghari, Environmental & Social Development Specialist, Sindh Irrigated Agriculture Productivity Enhancement Project (SIAPEP) along with Dr. Abdul Sattar Buriro, Training Coordinator (SIAPEP).	29.12.2021
Mr. Shan Ali Junejo, Grower Member PCCC Governing Committee	03.01.2022
Honorable Federal Minister for National Food Security Syed Fakhar Imam	02.01.2022

b. 32 Mid-Career Management Course, NIM, Lahore

A group of 10 member trainees from 32 Mid-Career Management Course (In-land Study Tour) from National Institute of Management, Lahore visited CCRI Multan on December 10, 2021. Dr. Zahid Mahmood, Director, CCRI Multan briefed them about the cotton research & development activities carried out at the Institute. Participants also visited Entomology Laboratories of the Institute and appreciated the research work conducted by the scientists.

c. Student Study Tour

Students visited CCRI Multan during the season:

Name of University/Institution	Participants
University of Agriculture, Faisalabad	70
University College of Agriculture, BZU, Multan	164
Government Post-Graduate College Layyah	105

d. Others

- **Visit of Four Brothers Research Farm Multan**
  Dr Fiaz Ahmad Head Plant Physiology & Chemistry Section CCRI Multan & Dr Javed Hassan Cotton Advisor APTMA Islamabad visited Four Brothers Research Farm Multan on 8th July, 2021. Both Scientists appreciated the efforts being made by Four Brothers Group Pakistan for revival of cotton in Pakistan. Dr. Fiaz Ahmed provided proper advice on nutrition management in some fields.

- **Visit of Tara Group Research Farm Multan**
  Dr. Zahid Mahmood Director CCRI Multan with his team including Dr. Fiaz Ahmad, Dr. Muhammad Naveed Afzal and Mr. Sajid Mahmood visited Cotton Research and Production Farm of Tara Group at Lodhran on 3rd August 2021. CEO Dr. Khalid Hameed and his team briefed about research trials, activities and production blocks of cotton varieties at the farm. Dr. Zahid Mahmood and his team had technical discussion and provided guidance to the field team and also appreciated the research work conducted by Tara Group

7.8 Face book Page CCRI, Multan

A page on Face book www.facebook.com/CCRIM.PK is being regularly updated by the Section to disseminate the research activities of the Institute on social media.

7.9 Multimedia Presentations

During the month, the scientists of the Institute prepared almost 3414 multimedia slides for training programs/seminars etc.

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8 FIBRE TECHNOLOGY SECTION

Fibre Technology section was established in 1976. The prime objective of Fibre Technology section is to provide technical support to Plant Breeding & Cytogenetics sections in testing of fibre characteristics, spinning potential of newly developed cotton cultivars & strains, facilitate the other sections of the institute and to investigate the effect of different agricultural practices on fibre characteristics. The section also extended the facilities to the cotton breeders working in Central Cotton Research Institute Sakrand, Cotton Research Stations at Ghotki, D.I. Khan, Mirpur Khas, Lasbella, Sibbi, and to other relevant public and private parties. Research activities were focused to study the effect of bio-chemicals' application on cotton fibre properties through improve drought tolerance, and the effect of planting and picking time on cotton fibre quality.

The section was unable to conduct "Quality Survey" for the crop year 2021 in the core cotton producing districts due to financial constraints. Hence the lint samples collected from ginning factories could not be carried out for determining the quality of cotton fibre available in market.
Moreover, the collaborative study with spinning industry was not conducted due to financial constraints. In-addition the joint proposal by CCRI, Multan & University of Agriculture Faisalabad, entitled, "Development of Artificial Neural Network-based system for intelligent prediction of the potential of high yielding as well as high quality indigenous cotton varieties/genotypes" was submitted in Planning Commission of Pakistan for approval. The achievements are given as under:

8.1 Testing of Lint Samples

The lint samples received from various sections of the institute, research stations of PCCC and government research stations were tested for different fibre characteristics. The detail of the samples tested is given in Table 8.1.

Table 8.1 Number of Samples Tested for Various Fibre Characteristics

Source	Fibre Length (mm)	Fibre Strength (g tex^{-1})	Micro-naire	Color grade	Total
Breeding & Genetics Section, CCRI, Multan	5756	5756	5756	-	17268
Cyto-genetics Section, CCRI, Multan	1765	1765	1765	-	5295
Agronomy Section, CCRI, Multan	205	205	205	132	747
Fibre Technology Section, CCRI, Multan	115	115	115	75	420
Plant Physiology/Chemistry Section, CCRIM	63	63	63	-	189
Entomology Section, CCRI, Multan	68	68	68	-	204
Research Material Director CCRI, Multan	8400	8396	8400	-	25196
Central Cotton Research Institute, Sakrand	1045	1045	1045	-	3135
Cotton Research Station, Mirpur Khas	107	107	107	-	321
Cotton Research Station, Ghotki	523	523	523	-	1569
Cotton Research Station, Sibbi	80	80	80	-	240
Punjab Seed Corporation, Khanewal	79	79	79	-	237
AARI, Faisalabad (Chief Scientist)	35	35	35	-	105
FSC & RD, Khanewal	73	73	73	-	219
Total	**18314**	**18310**	**18314**	**207**	**55145**

8.2 Testing of Commercial Samples

The section has extended the testing services to facilitate private sector. The number of samples tested is given in Table 8.2

Table 8.2 Number of Samples Tested for Various Fibre Characteristics

Source	Fibre Length (mm)	Micronaire	Fibre Strength (g tex^{-1})	Color grade	Total
Private Sector	104	104	104	51	**363**

8.3 The effect of bio-chemicals application on cotton fibre properties to improve drought tolerance

The objective of this study was to evaluate the role of bio-chemicals application on cotton fibre properties and to improve drought tolerance. This experiment was conducted with the collaboration of Plant

Physiology/Chemistry section of the institute. Two cotton genotypes were selected for this experiment. The layout of experiment was randomized complete block design with three replications. The sowing and application of chemicals was done by Plant Physiology/Chemistry section. Five plants of both genotypes were tagged from each treatment for each replication. Picking was done at maturity and ginned on miniature ginning machine. The samples were tested for fibre characteristics on High Volume Instrument (HVI-900A). The results obtained are presented in Table 8.3.

Table 8.3 Fibre characteristics of genotypes CIM-785 and CIM-775 as affected by water stress and bio-chemicals

Genotype	Water Stress	Bio-Chemicals	Fibre length (mm)	Uni. Index	MIC	Strength (g/tex)	Lint (%)
CIM-785	No Stress	Calotrope Leaf Extract	27.8	82.1	4.2	29.4	40.3
		Salicylic Acid	26.9	80.9	4.0	28.0	38.5
		Acetic Acid	28.4	83.6	4.0	30.0	42.0
		$AgNo_3$	27.1	82.7	4.1	29.4	43.1
		Indole Acetic Acid	27.8	83.3	4.3	29.7	49.1
		Control	26.7	83.5	4.3	28.9	37.6
	Stress	Calotrope Leaf Extract	27.1	81.3	4.1	29.7	37.8
		Salicylic Acid	27.1	82.0	4.1	29.6	39.6
		Acetic Acid	27.4	83.6	4.1	29.4	38.9
		$AgNo_3$	28.4	84.3	4.2	30.3	40.3
		Indole Acetic Acid	28.4	81.9	3.9	30.1	41.6
		Control	25.7	84.2	5.1	24.7	37.6
CIM-775	No Stress	Calotrope Leaf Extract	26.1	81.1	3.8	28.7	38.5
		Salicylic Acid	26.7	80.1	3.8	28.4	37.6
		Acetic Acid	26.3	81.1	3.8	28.0	37.7
		$AgNo_3$	26.4	82.7	4.2	28.5	38.9
		Indole Acetic Acid	26.1	81.7	4.0	28.2	33.1
		Control	26.0	83.0	3.6	28.8	39.6
	Stress	Calotrope Leaf Extract	26.1	82.9	4.2	27.7	40.6
		Salicylic Acid	27.4	83.0	4.2	27.8	37.8
		Acetic Acid	26.6	83.6	4.0	28.7	42.6
		$AgNo_3$	26.0	83.1	3.8	28.6	38.2
		Indole Acetic Acid	26.3	82.7	3.6	28.5	37.6
		Control	26.0	80.8	3.7	25.9	39.6

8.3.1 Genotypic Variation in Fibre Characteristics

Genotype	Fibre length (mm)	Uni. Index	MIC	Strength (g/tex)	Lint (%)
CIM-785	27.4	82.8	4.2	29.1	40.5
CIM-775	26.3	82.2	3.9	28.2	38.5

8.3.2 Water Stress effect on Fiber Characteristics

Water Stress	Fibre length (mm)	Uni. Index	MIC	Strength (g/tex)	Lint (%)
Stress	26.9	82.8	4.1	28.4	39.4
No Stess	26.9	82.2	4.0	28.8	39.7

8.3.3 Bio-chemicals effect on Fiber Characteristics

Bio-Chemicals	Fibre length (mm)	Uni. Index	MIC	Strength (g/tex)	Lint (%)
Indole Acetic Acid	26.8	81.9	4.1	28.9	39.3
Calotrop Leaf Extract	27.0	81.5	4.0	28.5	38.4
Acetic Acid	27.2	83.0	4.0	29.0	40.3
Sylicylic Acid	27.0	83.2	4.1	29.2	40.1
$AgNO_3$	27.2	82.4	4.0	29.1	40.3
Control	26.1	82.9	4.2	27.1	38.6

The whole data of the experiment are presented in Table 8.3. Table 8.3.1 represent the genotypic variation in fibre characteristics which showed that genotype CIM-785 had better fibre characteristics. Table 8.3.2 represent the water stress effect on fibre characteristics. No stress treatment had better fiber strength and lint percentage. Table 8.3.3 represent the bio-chemicals effect on fibre characteristics which showed that Calotrop Leaf Extract, Acetic Acid, Sylicylic Acid and $AgNO_3$ improved fibre characteristics than other treatments' and control (Figures, 8.3.1, 8.3.2, 8.3.3 & 8.3.4)

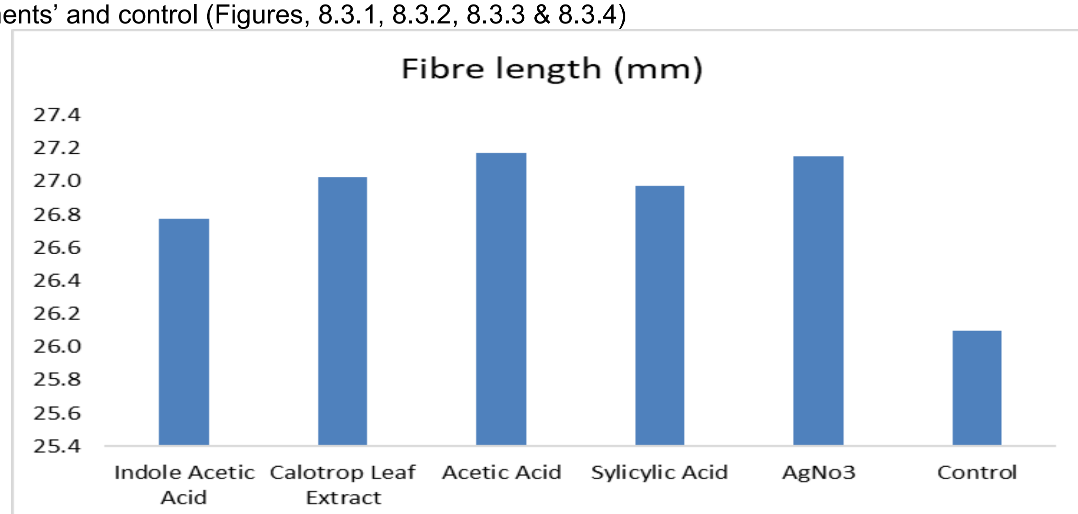

Fig. 8.3.1 Effect of bio-chemicals on fibre length

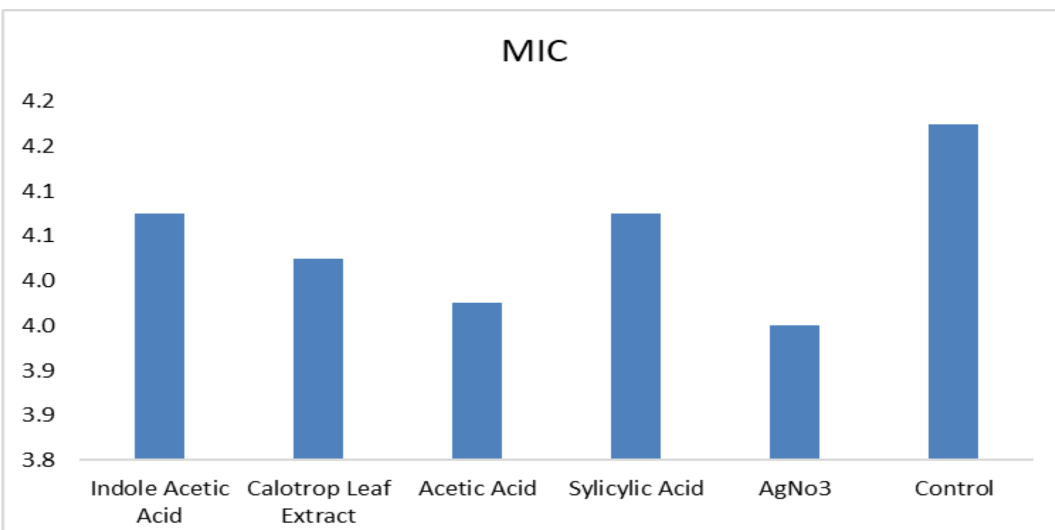

Fig. 8.3.2 Effect of bio-chemicals on MIC

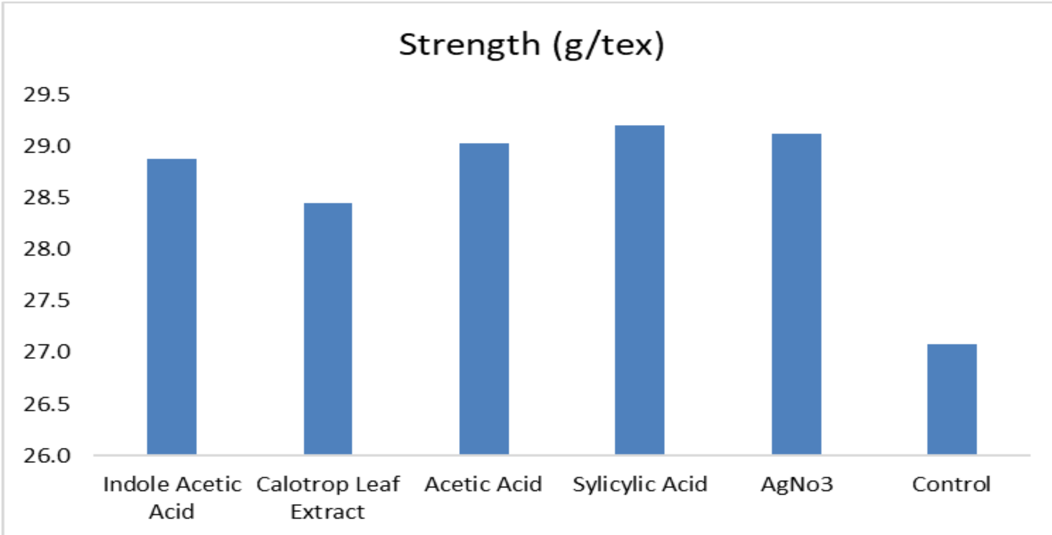

Fig. 8.3.3 Effect of bio-chemicals on fibre strength

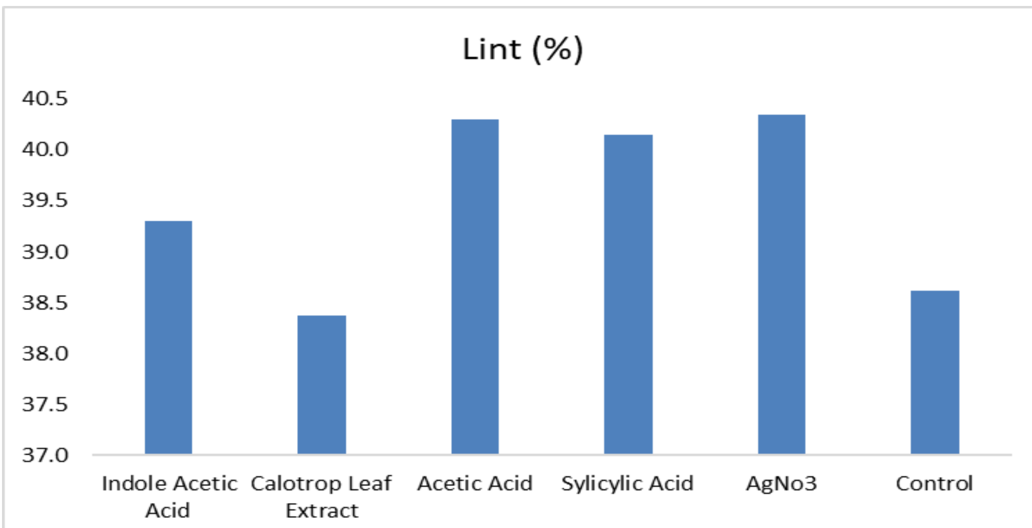

Fig. 8.3.4 Effect of bio-chemicals on lint percentage

8.4 Effects of planting & picking time on cotton fibre quality

The objective of the experiment was to evaluate the impact of planting and picking time on cotton fibre quality characteristics. This study was conducted with the collaboration of Agronomy section of the institute. *Bt.*CIM-663 was selected and sown at five sowing dates viz., 01st April 2021, 15th April 2021, 1st May 2021, 15th May 2021 and 30th May 2021. Cotton bolls were picked at three intervals viz., 5th September 2021, 26th October 2021 and 10th November 2021. The seed cotton was ginned. The lint samples were tested for various fibre characteristics. The results are presented in Tables 8.4.1 and 8.4.2.

8.4.1 Effect of Picking on Fibre Characteristics

Picking	Lint (%)	Fibre length (mm)	Uni. Index	MIC	Strength (g/tex)	Degree of Whiteness	Degree of yellowness
Picking 1	38.2b	25.4a	80.8a	4.0b	26.3a	69.8a	9.5a
Picking 2	41.2a	25.3a	79.9b	4.2ab	26.4a	66.9b	8.9b
Picking 3	40.6a	25.2a	80.0b	4.3a	25.7a	65.5c	8.6c

8.4.2 Effect of Sowing Time on Fibre Characteristics

Sowing Date	Lint (%)	Fibre length (mm)	Uni. Index	MIC	Strength (g/tex)	Degree of Whiteness	Degree of yellowness
1st April	37.6d	25.5ab	80.7a	3.7d	26.5ab	68.3a	9.5a
15th April	39.7c	25.3abc	79.7b	4.0c	25.9c	66.5c	8.5c
1st May	41.1ab	25.7a	80.3ab	4.1bc	26.7a	66.5c	8.7bc
15th May	41.5a	25.0c	80.3ab	4.6a	25.2d	67.4b	8.9b
30th May	40.0bc	25.1bc	80.1ab	4.3b	26.0bc	68.2a	9.3a

The results revealed that the fibre length, fibre strength, degree of whiteness and degree of yellowness decreased while micronaire and lint percentage increased with the delay in picking. In terms of sowing date micronaire and lint percentage increased with delayed sowing while other fibre parameters showed irregular pattern. But in 15th April sowing each fibre parameter had less value with respect to other sowing dates.

The lint percentage, uniformity index, micronaire, degree of whiteness and degree of yellowness showed considerable differences due to picking time. Similarly, fibre characteristics showed considerable differences in different sowing dates.

The fibre length, fibre strength, degree of whiteness and degree of yellowness decreased while micronaire and lint percentage increased with late picking. The difference may be attributed to temperatures of August and September that remained favorable. After the 1st picking to onward each picking date cotton variety *Bt.* CIM-663 showed a declining trend in fibre quality parameters because of the continuous decrease in day night temperature in the months of September and October along with the high relative humidity.

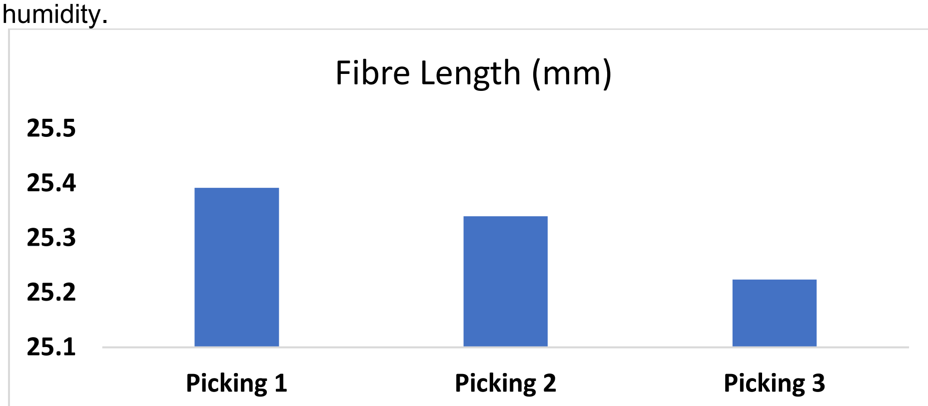

Fig. 8.4.1 Effect of pickings on fibre length

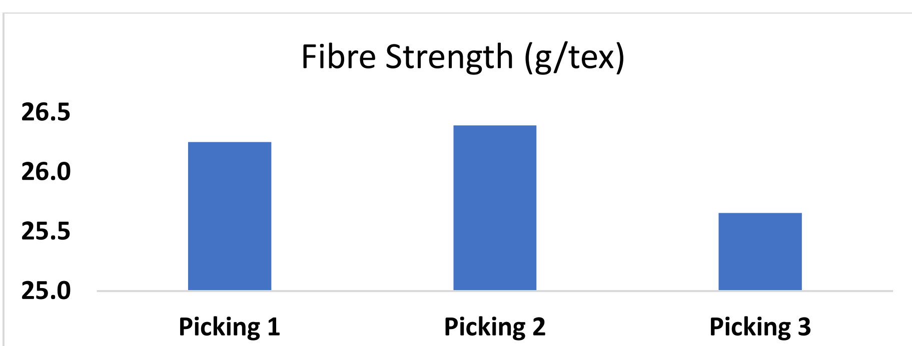

Fig. 8.4.2 Effect of pickings on fibre strength

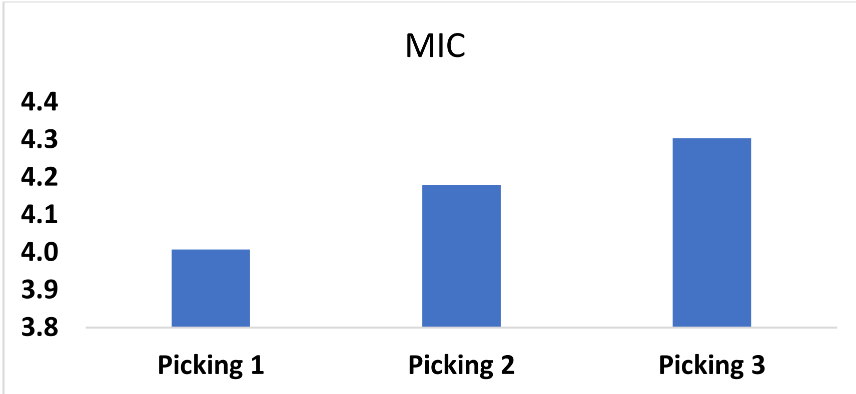

Fig. 8.4.3 Effect of pickings on MIC

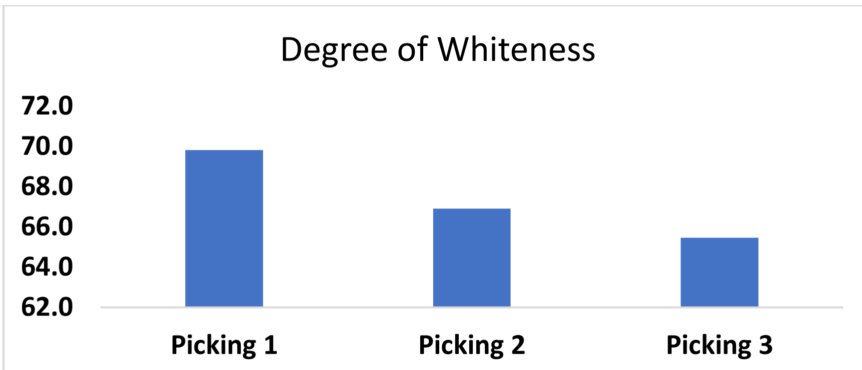

Fig. 8.4.4 Effect of pickings on degree of whiteness

8.5 Quality survey of lint collected from ginning factories

The Quality Survey of Ginning industry for the crop year 2021 could not be conducted due to financial constraints.

8.6 ICA-Bremen cotton round test program

The Fibre Technology Section participated in the ICA-Bremen Cotton Round Test Program with Faser Institute, Germany to keep the fibre testing equipment in calibrated form. Three lint samples were received during the year 2021. The lint samples were tested for different fibre characteristics. The results were submitted to the Faser Institute, Germany and fibre analysis compared with other testing laboratories in the world. The results of the Institute's Laboratory and the average results of the other participating laboratories are presented in Table 8.6.

Table 8.6 ICA-Bremen Cotton Round Test Program with Faser Institute, Germany

Date of Test	Sample No.	Name of Test	Results of CCRI, Multan (1)	Avg. results Of all Labs (2)	Difference (1-2)
11.03.21	**2021/1**	**<u>Conventional Instruments</u>**			
		Micronaire	4.39	4.37	0.02
		Pressley Index (0")	8.33	8.29	0.04
		G / tex (1/8")	32.1	--	--
		Elongation (%)	6.0	--	--
		<u>HVI-900A</u>			
		U.H.M.L. (mm)	30.8	30.15	0.65
		Uniformity Index (%)	83.9	82.78	1.12
		Micronaire	4.3	4.42	-0.12
		G/tex (1/8")	32.2	31.63	0.57
		Elongation (%)	--	--	--
		Rd (Reflectance)	80.2	81.16	-0.96
		+b (Yellowness)	10.1	9.62	0.48
16.07.21	**2020/2**	**<u>Conventional Instruments</u>**			
		Micronaire	3.80	3.81	-0.01
		Pressley Index (0")	7.58	6.85	0.73
		G / tex (1/8")	24.8	--	--
		Elongation (%)	6.2	--	--
		<u>HVI-900A</u>			
		U.H.M.L. (mm)	28.7	28.13	0.57
		Uniformity Index (%)	81.6	81.08	0.52
		Micronaire	3.75	3.80	-0.05
		G/tex (1/8")	29.5	28.95	0.55
		Elongation (%)	6.4	6.64	-0.14
		Rd (Reflectance)	76.1	76.76	-0.66
		+b (Yellowness)	12.3	12.24	0.06
02.09.21	**2020/3**	**<u>Conventional Instruments</u>**			
		Micronaire	3.78	3.84	-0.06
		Pressley Index (0")	7.24	7.16	0.08
		G / tex (1/8")	24.8	--	--
		Elongation (%)	5.2	--	--
		<u>HVI-900A</u>			
		U.H.M.L. (mm)	29.0	28.62	0.38
		Uniformity Index (%)	82.2	81.59	0.61
		Micronaire	3.72	3.82	-0.10
		G/tex (1/8")	29.7	29.96	-0.26
		Elongation (%)	5.7	6.45	-0.75
		Rd (Reflectance)	74.6	75.01	-0.41
		+b (Yellowness)	9.3	9.08	0.22

8.7 Survey of spinning industry of Pakistan

A. No spinning mill was surveyed due to financial constraints. The objectives of the proposed study were to compare the fibre quality of the available cotton, imported cotton and non-cotton fibres.

B. Development of Artificial neural network-based system for intelligent prediction of the potential of high yielding as well as high quality indigenous cotton varieties/genotypes. Project submitted to the Planning Commission of Pakistan for funding.

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9. STATISTICS SECTION

This Section assisted other sections of the Institute in the experimental design and statistical analysis of experimental data. The record of cotton statistics and daily market rates of cotton commodities were maintained.

9.1 Experimental Design Layout:

This section provided assistance in designing layout of field experiments conducted by different sections of Central Cotton Research Institute Multan. Randomized complete block design was used in eighty three experiments while split plot and split-split plot was used in nine and thirteen experiments respectively. Furthermore F-pool design was used in 9 experiments with having location at CCRI, Multan and PSC Farms, Khanewal.

9.2 Statistical Analysis

105 set of experimental data were analyzed by Statistics Section during 2021-22 in which thirty one data sets of Breeding & Genetics, five Cytogenetics, thirty eight Entomology, forty Fibre Technology sections of the institute and detail presented in Table 9.1

Table 9.1 **Detail of Statistical Analyses.**

Sections	RCBD	Split	Split-Split	F-Pool	Regression	Total
Agronomy	---	---	---	---	---	**---**
Physiology	---	---	---	---	---	**---**
Breeding	22	---	---	9	---	**31**
Cytogenetics	5	---	---	---	---	**5**
Pathology	---	---	---	---	---	**---**
Entomology	38	---	---	---	---	**38**
Fiber	18	9 ---	13	---	---	**40**
Total	**83**	**9**	**13**	**9**	**---**	**114**

9.3 Prices of Seed Cotton and its Components

Daily Spot Rates of Cotton (lint) were documented. The average weekly price for Base Grade cotton per 40 kg for the three cotton seasons i.e. 2019-20, 2020-21 and 2021-22 exclusive of upcountry charges are shown in Fig 9.1.

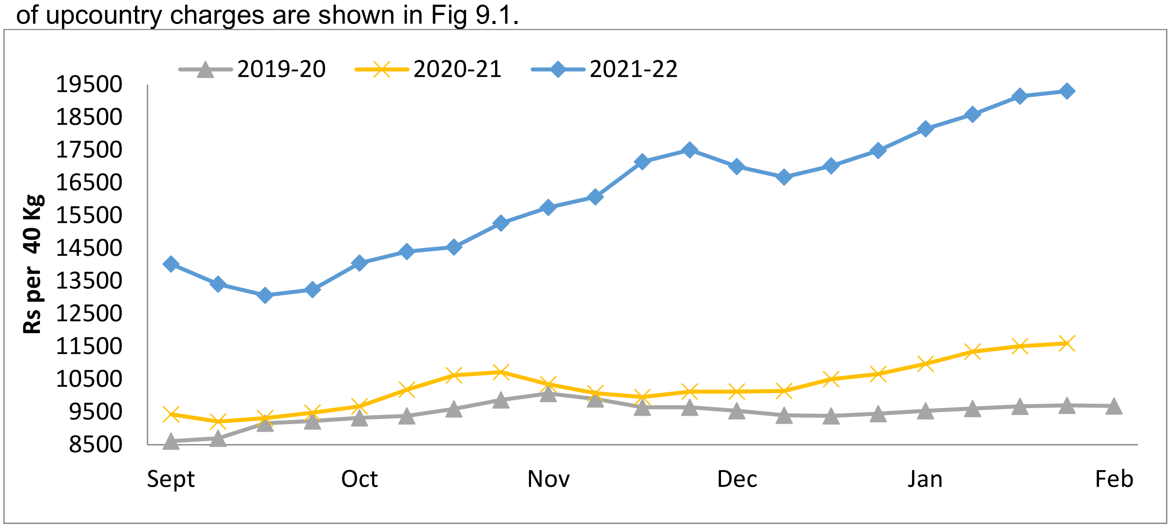


Figure 9.1: Weekly Average Spot Rates of Lint announced by Karachi Cotton Association during Cotton Seasons 2019-20, 2020-21 and 2021-22.

The data presented in Figure 9.1 showed the fluctuation of rate during the seasons of last three years. In year 2020-21 rates were comparatively higher than previous years. In year 2020-21 the average price was at Rs.10299 per 40 kg with the minimum value of Rs.9208 per 40 kg in the month of September 2020 and maximum of 11597 per 40 kg in January 2020 while in 2021-22 the average price was at Rs.16089 per 40 kg with the minimum value of Rs.13064 per 40 kg in September 2021 and maximum value of Rs.19300 per 40 kg in January 2022.

Rates of seed-cotton, Cottonseed cake and Cottonseed were collected from Market Committee Bahawalpur. The prices are provided for Rs. per 40kg, temporal trend of rates for three years on weekly basis is illustrated in Fig. 9.2. to 9.4.

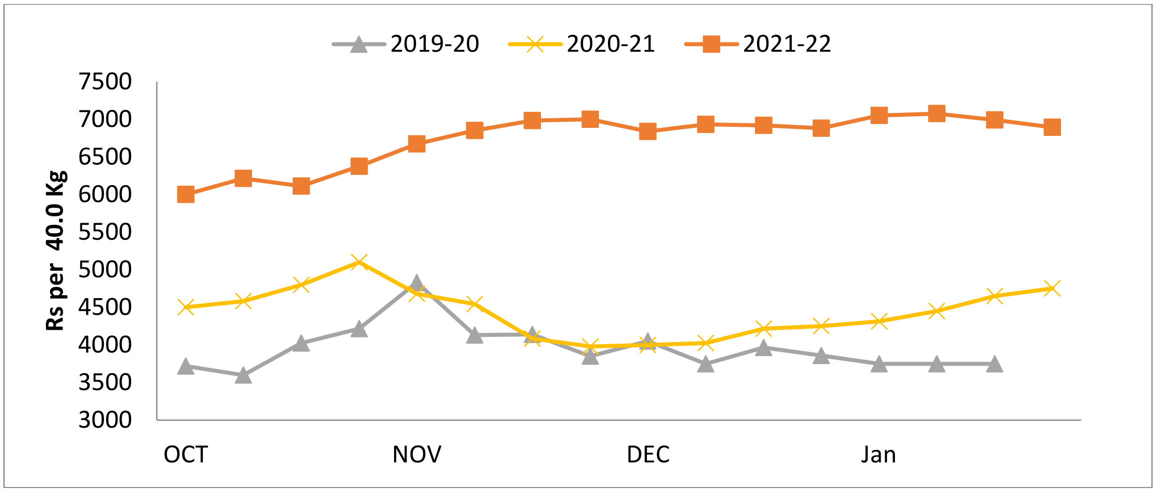


Figure 9.2: Weekly Average Rates (Rs /40Kg.) of Seed-cotton of Bahawalpur Market during 2019-20, 2020-2021 and 2021-22.

The seed-cotton rates are presented in figure 9.2 showed that the rates of 2021-22 are much higher than that of previous years. In 2020-21 the average seed-cotton rates of Bahawalpur market were at 4433 per 40 kg with minimum of 3980 per 40 kg and maximum Rs.5100 per 40 kg while in 2021-22 the average rate was Rs.6737 per 40 kg with maximum rate was 7075 per 40 kg and minimum rate was Rs.6000 per 40 kg. The percent increase of prices in 2021-22 average price over 2020-21 is 51.97%, and from 2019-20 is 70.16%.

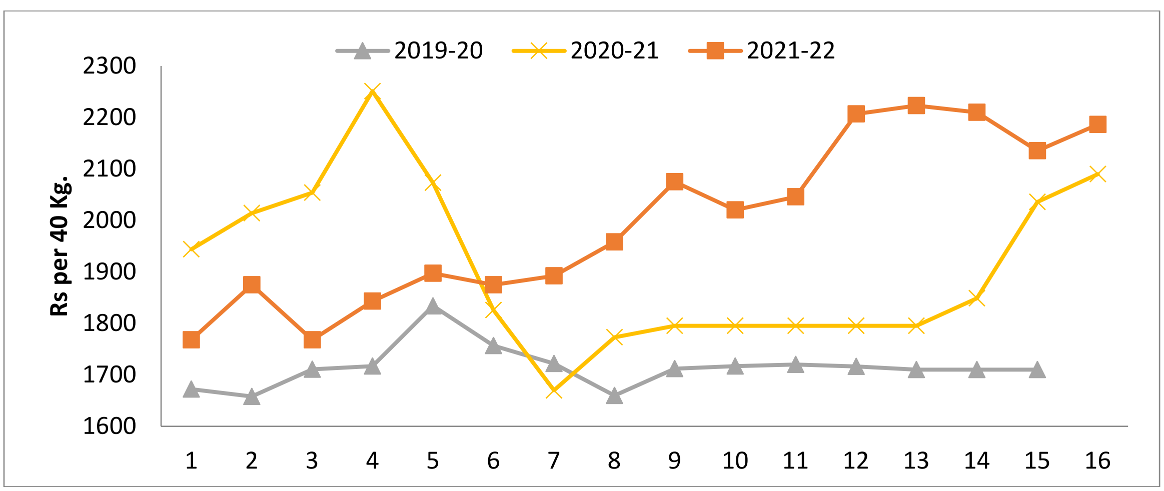


Figure 9.3: Weekly Average Rates (Rs /40Kg.) of Cottonseed cake of Bahawalpur Market during 2019-20, 2020-21 and 2021-22.

The cottonseed cake rates remained higher than the previous years. The maximum value of Rs.2223 was in January 2022 while minimum price of Rs.1768 was in October 2021. The average price for 2021-22 was 1999 per 40 kg. Price comparison from last year revealed that average price Rs.1910 per 40 kg was attained in 2020-21 with minimum price of Rs.1670 per 40 kg and maximum price of Rs.2251 per 40 kg in November & October 2020 respectively while the average price Rs.1715 per 40 kg was obtained in 2019-20 with maximum price was Rs.1834 per 40 kg and minimum price was 1658 per 40 kg.

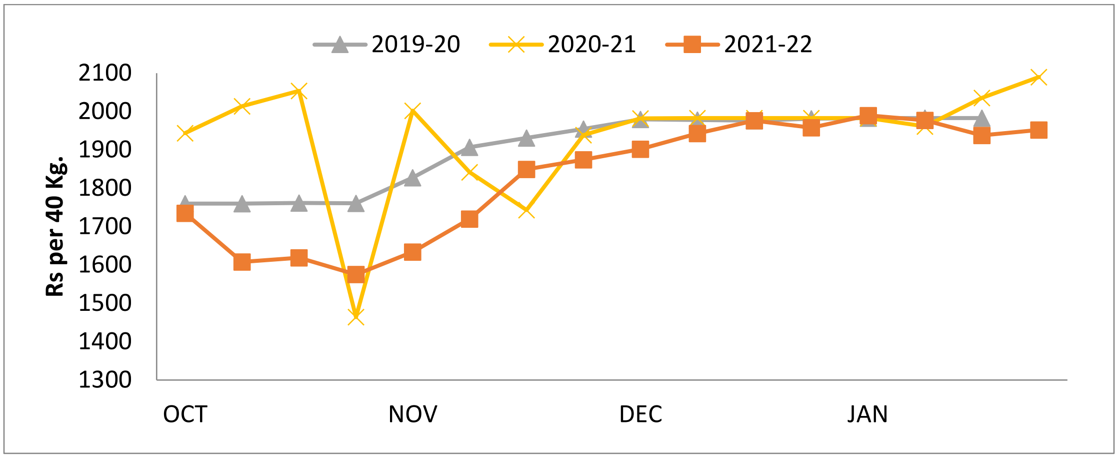


Figure 9.4: Weekly Average Rates (Rs/40Kg.) of Cottonseed of Bahawalpur Market during 2019-20, 2020-21 and 2021-22.

Cottonseed rates of year 2021-22 were lower than year 2020-221. Average rate of 2021-22 was Rs.1828 per 40 kg with maximum at Rs.1990 per 40 kg and minimum Rs.1575 per 40 kg while in 2020-21 the average rate was Rs.1938 per 40 kg with maximum Rs.2090 per 40 kg and minimum at Rs.1464 per 40 kg.

9.4 Rates of seed-cotton in four different cities of Punjab:

Figure 9.5 depicts the comparative rates of seed-cotton in Bahawalpur, Burewala, Rahim-Yar Khan and Vehari districts.

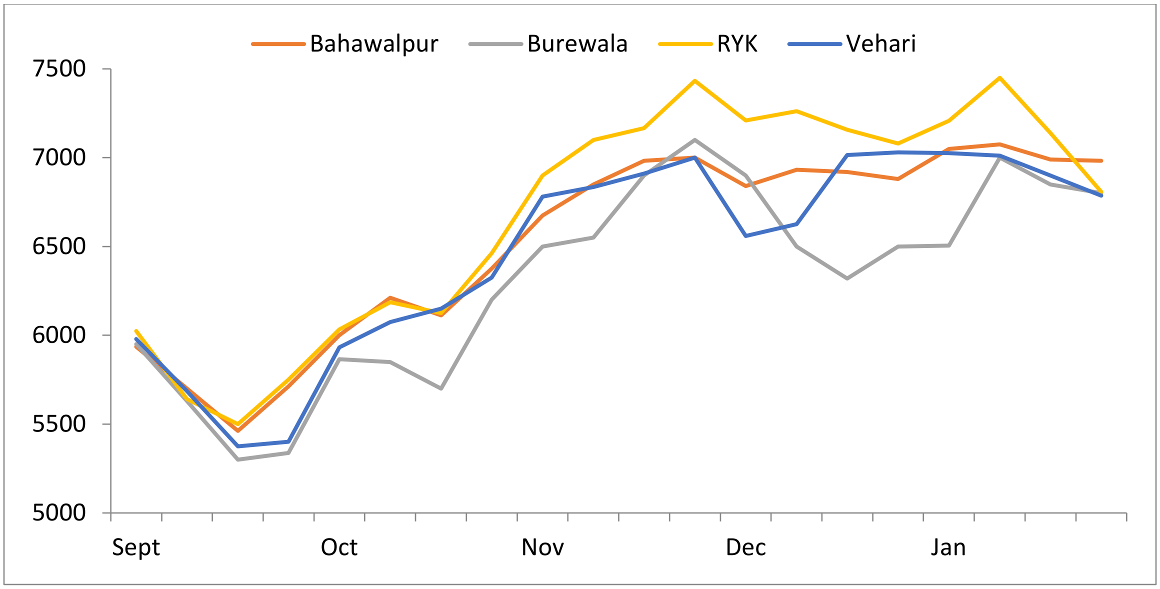


Fig 9.5: Rates of seed-cotton 2021-22 in Punjab

The highest average rate was Rs.6682 per 40 Kg in Rahim-yar Khan, and the lowest average rate was Rs.6313 in Burewala. The maximum rate of Rs.7450 per 40 Kg was in Rahim-yar Khan in the second week of January and the lowest rate was Rs.5300 in Burewala in third week of September.

9.5 Rates of seed-cotton in four different cities of Sind:

Figure 9.6 depicts the comparative rates of seed-cotton in Hyderabad, Mirpurkhas, sukkur and Khairpur districts..

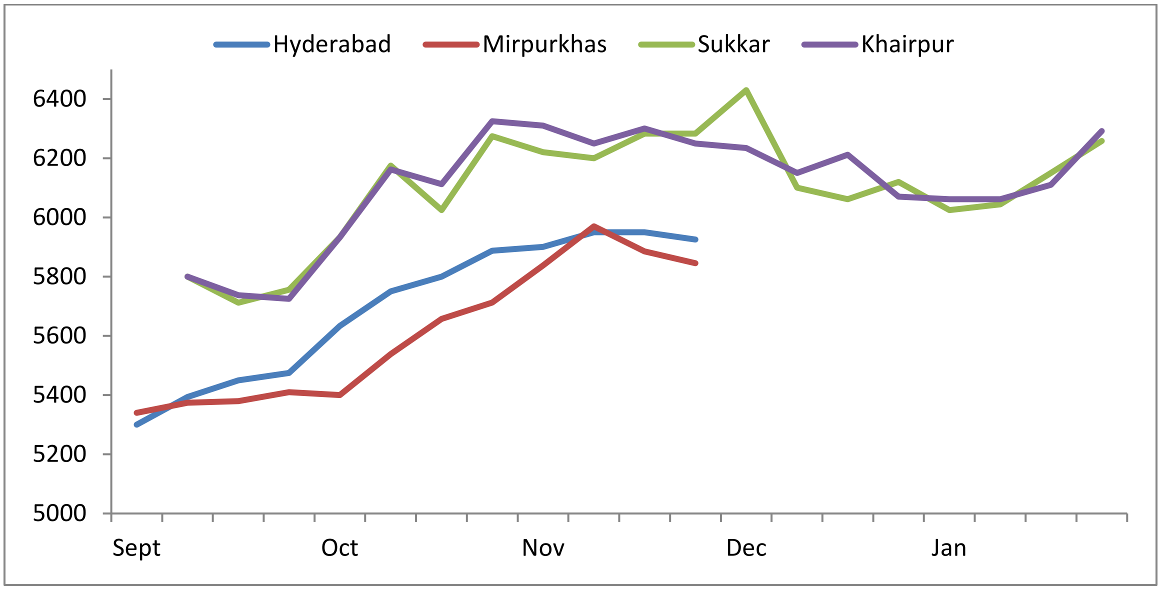
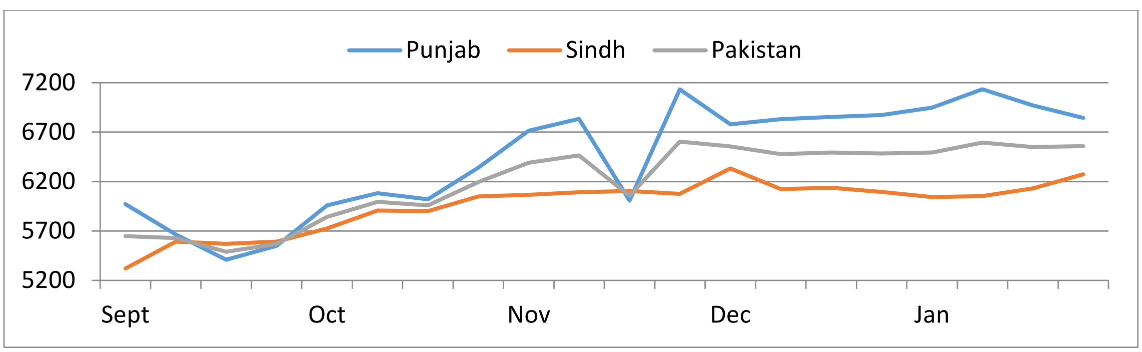


Fig 9.6: Rates of seed-cotton 2021-22 in Sind

The highest average rate was Rs.6110 per 40 Kg in Khairpur, and the lowest average rate was Rs.5612 in Mirpurkhas. The maximum rate of Rs.6430 per 40 Kg was in Sukkur in the first week of and December lowest rate was Rs.5300 in Hyderabad in first week of September.

9.6 Rates of Seed-cotton in Pakistan

The graph in fig 9.7 shows the average rate of seed-cotton in Punjab, Sind and Pakistan. The rates in Punjab remained significantly higher than Sind except for few weeks of September.



9.7 Study of factors affecting the Lint rates in Pakistan.

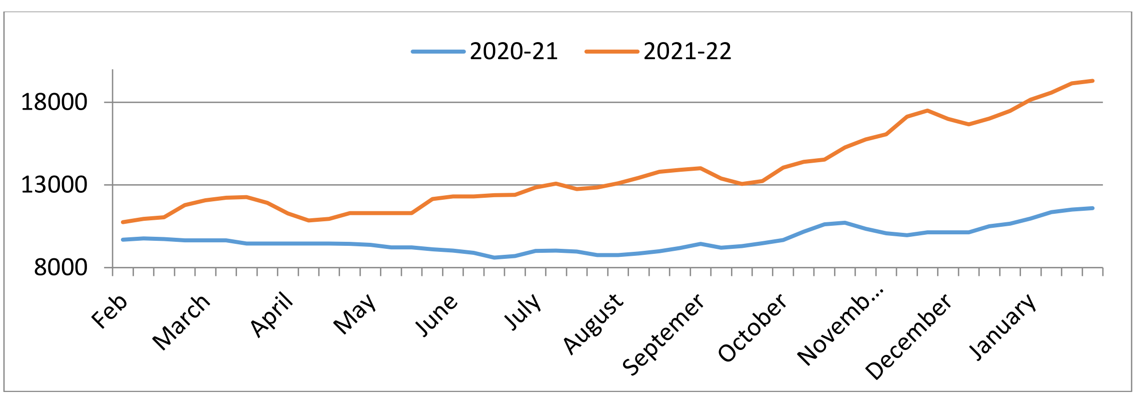
The year 2021 had been a roller coaster year for farmers and industry. In the beginning of 2021 about 20% industry was closed due to covid restrictions which resulted in unemployment and decrease in demand in demand of apparel. But as the year progressed it became evident that cotton production has significantly decreased in the world. The international market became bullish and rates touched an all-time high level of 1.2775 dollar per pound.

The second factor which made import of cotton expansive was the rise in dollar price. In the past huge quantity of cotton was imported by the industry to suppress the rate in local market. But this year the imported cotton was so expansive that it made the local market bullish and the lint rate became 19300 per maund for the first time in the history of Pakistan. Due to better rates the farmers are satisfied and excited to sow more cotton next year. Previously the profitability of cotton was lower than to its substitutive crops and due to which area under cotton was decreasing.

For the consistent growth of textile sector in the country it is necessary that Pakistan should produce 1.5 million bales of cotton annually. Otherwise, the foreign exchange earned by exporting textile products will be consumed for importing cotton in the country. It is the need of the time that government announce a support price for cotton, because by ensuring the profitability of farmer the revival of cotton will become possible in Pakistan. Secondly a crop zoning should also be implemented in the country. The weekly KCA rates (40 Kg) are given in the following table.

Date	**Base Grade** Fibre Length 25.9-26.4 mm Micronaire 3.8-4.9	Date	**Base Grade** Fibre Length 25.9-26.4 mm Micronaire 3.8-4.9
07.02.21	10750	07.08.21	13100
15.02.21	10950	15.08.21	13428
23.02.21	11042	23.08.21	13800
28.02.21	11779	31.08.21	13914
07.03.21	12066	07.09.21	14016
15.03.21	12233	15.09.21	13400
23.03.21	12271	23.09.21	13064
31.03.21	11914	31.09.21	13233
07.04.21	11283	07.10.21	14050
15.04.21	10857	15.10.21	14400
23.04.21	10942	23.10.21	14533
30.04.21	11300	30.10.21	15271
07.05.21	11300	07.11.21	15750
15.05.21	11300	15.11.21	16066
23.05.21	11300	23.11.21	17142
31.05.21	12150	31.11.21	17500
07.06.21	12300	07.12.21	17000
15.06.21	12300	15.12.21	16671
23.06.21	12385	23.12.21	17014
30.06.21	12396	30.12.21	17485
07.07.21	12850	07.01.22	18150
15.07.21	13085	15.01.22	18585
23.07.21	12750	23.01.22	19142
31.07.21	12842	31.01.22	19300

The average rate from February 2021 till January 2022 was Rs.13758 per 40 kg while the lowest rate was Rs.10750 in first week of February 2021 and the highest rate was Rs.19300 in last week of January 2022. The following graph shows the rates of lint in KCA for 2021 and 2022. It is evident that the rates in 2021-22 were significantly higher than previous year. The average rate of lint per maund increased by 42 percent.



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10. RECOMMENDATIONS

Unlike other countries, cotton crop in Pakistan faces a number of challenges such as weather adversaries including higher (day & night) temperatures, irregular rainfall pattern, shortage canal irrigation water supplies, availability of water at sowing time and peak demand period, non-judicial use of crop inputs (irrigation, fertilizer, pesticide etc.), deteriorating soil health (salts, fertility problems) rising cost of inputs resulting in un-economical crop yields, insect-pest complex (whitefly, jassid, thrips, Bollworms, dusky & red cotton bugs etc), diseases (CLCuV, stem & twig blight) and fluctuating produce prices. In addition, the *Bt* cotton has now become vulnerable to Pink Bollworm infestation which not only increases the cost of production through additional use of pesticides but also limits crop yield. To ensure sustainable crop productivity along with economic returns for the farmers, concerted efforts need to be carried out at all levels involving the cotton sector stakeholders through public and private partnership approach. Based on the research work conducted by the scientists of the Institute, all the way through, following recommendations are made to dilute cotton production problems and getting maximum yield from the available resources.

IMPROVEMENT OF SOIL HEALTH

- Improvement and maintenance of soil physical condition ensures better soil productivity. Therefore, green manuring/farm yard manure should be incorporated one month before sowing to improve the physical condition of the soil. Among green manure crops, berseem is the best choice. Green manuring crops should be buried into the soil at tender stage 3-4 weeks ahead of cotton planting for timely decomposition and soil conditioning. For rapid decomposition of buried green matter apply ½ bag urea followed by irrigation.
- After the use of combine harvester, tradition of burning wheat straw is not beneficial. It must be incorporated into the soil as it improves the physical properties and organic matter content of soil. Disc harrow instead of rotavator followed by irrigation along with ½ bag urea per acre must be used.
- Preserve the farmyard manure properly in pits. Do not keep in heaps in the open sky.
- Reclamation of saline-sodic soils is accomplished by incorporating recommended quantity of gypsum into the soil followed by 2-3 heavy irrigations. This should be followed by green manuring to restore soil fertility.
- Chiseling after 2-3 years should be practiced in order to break the hard and plough pan to improve root growth and soil health.

SOIL SELECTION AND ITS PREPARATION

- Select best piece of land available for cotton cultivation.
- Farm machinery should be optimized and bring in ready condition for efficient and timely operations.
- Where plant growth is restricted and downward penetration of water in the soil is slow, chiseling/ripping or deep ploughing should be done.

PLANTING

- In problem soils (saline, alkaline, clayey and lands with salt patches of varying sizes) planting on bed-furrow is better than drill planting.
- Bed-furrow planting ensures better germination. It saves 32% irrigation water over conventional planting (flat cultivation). It also saves the crop from the damages of untimely and heavy rains. Apply second irrigation after sowing on bed-furrow to ensure better seedling emergence and growth. Afterwards, apply irrigation as per need of the crop. Weeds are the major problems in cotton, therefore, use pre-emergence herbicides to control weeds.
- To sustain the good physical soil conditions, always cultivate the fields in '*wattar*' condition (workable condition) and never cultivate in dry condition.
- Level the fields properly with laser leveler for uniform and economized application of irrigation water.

- Apply ½ bag of urea at the time of land preparation for efficient and accelerated decomposition of previous crop residues to avoid white-ant problem and to ensure better seed emergence.
- Apply single '*rouni'* on well-leveled fields for flat (conventional) planting due to scarcity of canal water.
- After wheat harvesting, apply one heavy irrigation for seedbed preparation simultaneously for conventional as well as bed-furrow cotton planting to avoid possible delay in planting as early planting after wheat produces better yields.

RECOMMENDATION OF COTTON VARIETIES FOR GENERAL CULTIVATION

- Recommendation of *Bt*. & Non *Bt* cotton varieties for general cultivation in core and non-core cotton areas of the Punjab.

***Bt* Varieties**	**Non-*Bt* Varieties**
Bt.CIM-678, *Bt*.CIM-785, *Bt*.Cyto-535, *Bt*. CIM-663, *Bt*. CIM-632, *Bt*.CIM-602, *Bt*. Cyto-177, *Bt*. Cyto-178, *Bt*.CIM-600, *Bt*.cyto-179,	Cyto-226, CIM-610, CIM-620, Cyto-124, CIM-496, CIM-506, CIM-554, CIM-573,

- Always purchase 10% more cotton seed than required for re-planting in case of any damage or lower germination.
- Always sow 10% area with Non-*Bt* along with *Bt* varieties, as refuge crop, to avoid development of resistance in insects.
- Generally use delinted seed. One liter of commercial sulphuric acid is sufficient for delinting 10 kg fuzzy cotton seed. Wash thoroughly and dry the seed under shady and well ventilated area. Always store cotton seed in gunny bags or cotton cloth bags in such a way that air could pass across the bags from bottom to top. Avoid the storage cotton seed in plastic bags.
- In case of sandy soil fuzzy seed should be used for getting good crop stand.
- Check seed germination before planting. Use delinted seed @ 6-8 kg/acre with 75 percent germination for flat planting. Adjust seed rate according to germination percentage.
- Ensure that seed drill is in perfect condition and drop the seed uniformly at appropriate depth for perfect emergence of cotton seedlings.
- Optimum sowing time for core areas in Punjab is from 1st April to 31st May and non-core areas is 1st April to 15th May. The yield decreases drastically in June planting. Planting up to May 15th should be preferred. It gives better yield than late planting.
- Ensure 23,000-25,000 plants per acre for obtaining profitable yield.

<u>THINNING</u>

- Thinning should be completed after dry hoeing and before first irrigation in flat planting (conventional) by keeping 9-12" plant to plant distance to obtain 17000-23000 plants per acre. On bed-furrow planting, thinning should be completed within 20-25 days, when plants are 10cm (4") in height. Remove weak or virus affected plants, if any, while thinning.
- A uniform early good crop stand ensures profitable cotton production.

<u>WEED CONTROL</u>

- The first 40-70 days after sowing are crucial and growth of weeds is faster than cotton plant, therefore, all possible measures should be adopted to control weeds.
- Use of pre-emergence herbicides saves the crop from early weed infestation when the crop does not permit mechanical hoeing operations.
- S-Metolacholor 960 EC should not be incorporated in the soil at sowing time. It causes mortality of cotton seedlings during germination. It is used on bed-furrow planting as surface application within 24 hours of sowing/ irrigation on moist soil.
- Pendimathelin 330 EC can be used as pre-emergence herbicide in flat planting at seed bed preparation by incorporating into soil at 5 cm depth.

- Pendimathelin 330 EC can be used in bed-furrow planting in dry condition before sowing.
- Glyphosate 490 G/L @ 4.7 lit ha^{-1}can is used as post-emergence weedicide provided that the cotton plants are protected against the damage caused by spray drift by employing the shield.
- Grasses especially "*Swanki*" and "*Madhana*" at 3 to 4 leaf stage can be controlled by spraying Haloxifop @ 400ml/ac and *quizalofop* @ 20g per acre post-emergence without protecting the cotton plants. Haloxifop can be used more than one time at any growth stage of cotton plant. No phyto-toxicity was observed on crop by the spray of said herbicide.
- In flat planting, interculturing is very effective for weed eradication at early stage. After every shower of rain, and irrigation when the fields attain '*wattar*' conditions (workable condition) hoeing should be done and this practice should be continued as long as the crop permits. After every interculturing, weeds which are not killed/eradicated by interculturing must be removed manually and the crop should be earthed up during the last interculturing operation.

IRRIGATION

- To flat (conventional) planting, apply first irrigation 30-40 days after sowing keeping in view the variety, soil type, crop and weather conditions. Subsequent irrigation should be applied according to crop need. There should be no water stress to the crop from 1st August to end of September. In bed-furrow planting, after the application of irrigation for germination subsequent irrigation should be given at 8-10 days interval. Apply such quantity of irrigation water that can easily absorbed by the soil within 24 hours. Water standing in field even upto 24 hours causes shedding of the fruit. Be sure that white flower should not appear at the top of the plant which is an indication of water stress to the crop especially before the month of September.
- Last irrigation should be given by 1st week of October to avoid delay in crop maturity and late season pest attack.
- In case of excessive vegetative growth, mepiquat chloride @ 400 ml per acre in 3-4 split doses (if needed) during the months of July and August may be used to regulate the plant growth so that plant should start bearing the fruit.

FERTILIZER

- Fertilizers should be used on the basis of soil test reports. Soils which show available phosphorus less than 10 ppm, use upto 50 kg P_2O_5 per hectare after thinning. Mixing of phosphate fertilizer with farmyard manure in 1:2 ratio improves its efficiency. Use 50 kg K_2O per hectare to soils showing available potassium less than 125 mg kg^{-1} soil after thinning. Cotton-wheat is the major cropping pattern in the cotton area. Farmers should also use recommended levels of phosphorus and potassium fertilizers for wheat crop.
- In normal season planting, 150 kg N per hectare should be applied in split doses and fertilizer application should be completed by end of August. Excessive use of nitrogen does not improve the yield but attracts the pests, delays the crop maturity and adds up cost of production.
- To improve the efficiency of nitrogen, phosphorus and potassium fertilizers, these may be applied in split doses. Band placement or fertigation of phosphorus in splits is more efficient than the broadcast at time of sowing.
- The crop showing deficiency of nitrogen late in the season can be sprayed in morning/evening with 2% urea solution (2 kg urea per 100 litre water) but it should not be mixed with the insecticides.
- Fertigation (fertilizer solution dripping into irrigation water) of N fertilizer is also a useful method to apply nitrogen during the cropping season. For fertigation in flat sowing (drill sowing), field must be laser levelled.
- The adverse effects of water shortage in cotton crop may be minimized by the combined application of phosphorus and potassium fertilizers.
- Gypsum as a source of sulphur may be added @ 50-100 kg per hectare in light textured and saline-sodic soils to correct sulphur deficiency syndrome. Alternatively use elemental sulfur @ 10 kg ha^{-1}.

- To improve fruiting, three-four foliar sprays of boron and zinc @ 250g zinc sulphate with 21% Zn, and 300g boric acid per 100 litre water should be done to improve fruiting.
- Mixing of 2% urea in the spray tank along with B and Zn nutrients enhances the efficacy of foliar spray.
- Potassium application through foliar sprays of 2% K_2SO_4 (soluble potash) solution improves yield over non-sprayed crop and minimizes the adverse effects of biotic and abiotic stresses.
- Two third of the recommended dose of NPK fertilizers i.e. $75N+25P_2O_5+25K_2O$ kg ha^{-1} is as effective as recommended dose ($150N+50P_2O_5+50K_2O$ kg ha^{-1}) when applied in (treated) conjunction with 300 kg poultry broiler litter.
- For early germination and seedling vigor, cotton seed may be primed with gibberellic acid (GA @ 10 mg per litre) prior to sowing.
- Application of magnesium sulphate both by fertigation and foliar sprays proved benefial in improving seedcotton production. However, foliar application of magnesium @ 6 kg per hectare in three splits was more productive and cost-effective.
- Seed priming and subsequent foliar sprays of amino acid proline @ 0.1% increases cotton seed health and production. The efficiency of proline is further increased by addition of B & Zn in foliar sprays.

FRUIT SHEDDING

- Fruit shedding results either due to natural adversaries like high temperature coupled with high relative humidity, cloudiness, and intermittent rains or due to insufficient nutrition, excessive or shortage of water and pest attack.
- Take care of nutritional deficiency, irrigation, pests and don’t worry about natural shedding.

PLANT PROTECTION

✪ Keeping in view the losing efficacy of *Bt* cotton against pink bollworm, farmers are advised to plant cotton not before the 1st April.
✪ Always use seed delinted with sulphuric acid to avoid carryover of pink bollworm residing in double seed.
✪ Seed treatment with insecticide ensures better crop growth and saves it from sucking pests at early stage.
✪ The first spray should be delayed as long as crop tolerates pests so that predators and parasites could play their role to suppress the pest population.
✪ Pyrethroids or their combinations should be avoided at early stage of the crop.
✪ Pesticides application should be on the pest scouting basis at the following economic threshold levels (ETL).
✪ Insect growth regulators (IGRs) are most effective against whitefly at immature stages (whitefly nymphs).
✪ Leftover bolls are the main source of pink bollworm for the next cotton crop. Therefore, the cotton field should be grazed after picking to reduce the number of left over bolls. It is better if the cotton sticks are shredded and incorporated into the soil which will improve the physical condition of the soil. In case the cotton sticks are to be kept for fuel purpose, these should be kept in bundles and top portion should be directed towards sun and should be used by mid-February.
✪ Removal of leftover bolls after picking with Pink Bollworm Manager (PBWM) machine is an effective strategy that will not only manage or reduce Pink bollworm but also save sticks to be used by the farmers for fuel purpose.
✪ Spray machines must be in order and properly calibrated. Use hollow cone nozzles with uniform flow rate, fine mist and keep the nozzle at 1.5 to 2 feet height from the plant canopy to ensure better coverage of the crop.
✪ Use right dose of right insecticide at appropriate time with clean water for better results. Spray in the morning or late in the afternoon. Do not spray when rain is expected. If the rain has

affected spray application, it should be repeated. Pest scouting should also be done after 3-4 days of spray to assess efficacy of the pesticide.

Economic Threshold Levels of Different Pests

Name of insects	Economic threshold levels
Jassid	1 adults/nymphs per leaf
Whitefly	5 adults/nymphs or both per leaf
Thrips	10 adults/nymphs per leaf
Spotted bollworm	3 larvae/25 plants
Pink bollworm	5 % bolls damage
American bollworm	5 brown eggs or 3 larvae or collectively 5/25 plants
Armyworm	On appearance

CONTROL OF DISEASES

- The seed should be treated with fungicides for seed rot and seedling diseases during early planting.
- Previous year's cotton stubs should be removed from the fields. The reason being that new sprout from diseased stubs is the source of Cotton Leaf Curl Virus (CLCuD) transmission to the newly planted crop.
- Always plant more than one virus resistant/tolerant variety to create genetic barrier.
- Use healthy and delinted seed.
- Avoid the late planting of cotton to minimize the CLCuD incidence.
- The seed should also be treated with systemic insecticide to protect the crop against whitefly which is the vector of CLCuV.
- Whitefly is the vector of CLCuD. It should be managed and controlled at economic threshold level.
- Reduce the whitefly population during mid-June to end-August and other pests to manage CLCuD.
- The diseased and weak seedlings should be removed at thinning stage and buried.
- Weeds in and around cotton fields, water channels and field bunds should be eradicated. Reduce the whitefly population during mid-June to end of August and other pests to manage CLCuD.
- Judicious use of fertilizer and irrigation helps in the management of CLCuD.
- Application of fertilizer and irrigation should be given in accordance with recommendations. Excessive use of these inputs increases the incidence of boll rot of cotton.
- Good drainage / proper irrigation helps to grow healthy plants and show more resistance against wilt and boll rot diseases.

PICKING

- Seed cotton on the plant is a precious silver fiber. Maintaining its quality during picking, storage and transportation from the field to store or from store to the ginning factories ensures reasonable price.
- Pick seed cotton when 60-70% bolls are opened. Avoid picking under adverse weather conditions when the sky is cloudy or rain is expected. After rain, pick seed cotton when it is dry.
- Do not start picking early in the morning when there is dew on the crop. Let the dew dry and then start picking.
- Start picking from the bottom of the plant and go upward to the top. Pick well opened and fluffy bolls. Seed cotton should be free from weeds and crop trash.
- Use cotton cloth bags for transportation. Do not use plastic or gunny bags.
- Do not keep picked cotton on moist soils in the field.
- Store seed cotton in ventilated stores in heaps of pyramid shape for proper aeration. The floor of the store should be of concrete and free from moisture.

- Moisture content in the seed cotton should be less than 12% otherwise the seed cotton will be heated in the stores. This will deteriorate lint as well as cotton seed quality.

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Annexure-I

Comparative Monthly Meteorological Data Recorded at CCRI, Multan during 2020 and 2021

Month	Air Temperature (ºC)				Relative Humidity				Average Wind Speed (Km h⁻¹)		Rainfall (mm)		Evapo-transpiration (cm day)		Soil Temperature (ºC)	
	Minimum		Maximum		Minimum		Maximum								0 cm	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
January	7.1	5.8	15.5	20.6	73	67	97	93	3.8	3.2	25.1	0.0	0.10	0.12	9.5	9.3
February	11.3	12.7	23.3	26.1	56	57	89	86	4.5	3.7	4.6	0.0	0.38	0.53	12.4	15.3
March	14.7	17.4	23.8	30.5	60	56	89	79	6.4	5.8	88.4	16.9	0.45	0.65	14.5	21.7
April	21.1	21.4	33.8	35.9	56	53	86	75	6.4	6.3	39.5	0.0	0.53	0.78	24.8	25.7
May	25.3	26.5	38.0	39.2	51	46	85	76	6.1	6.8	44.7	3.0	0.74	0.89	29.8	29.0
June	29.0	29.0	39.9	38.9	50	55	82	83	5.8	6.9	24.0	23.4	0.91	0.93	31.3	34.0
July	29.7	30.9	38.0	38.8	62	57	87	87	6.2	6.5	64.4	0.0	0.97	0.98	32.8	36.1
August	30.8	29.1	37.1	36.8	72	54	91	76	6.1	5.9	108.2	6.5	0.91	0.80	34.1	34.6
September	26.5	27.8	36.4	35.7	64	53	86	78	3.6	4.6	0.0	36.0	0.57	0.76	29.5	31.6
October	18.6	20.4	33.9	33.8	58	58	81	78	2.3	3.7	0.0	0.0	0.58	0.68	23.5	26.8
November	13.1	13.2	25.9	28.1	59	48	83	78	2.7	2.3	0.0	0.0	0.26	0.55	16.6	18.4
December	7.4	7.1	21.4	21.7	67	49	91	79	2.5	1.6	0.0	0.0	0.15	0.44	10.6	12.8