Annual Report
2022-23

Central Cotton Research Institute Multan

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

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ANNUAL REPORT

2022-23

CENTRAL COTTON RESEARCH INSTITUE, MULTAN

Pakistan Central Cotton Committee

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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

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Note:

- The reference to some trade names in this report is in no way an endorsement of or discrimination against these products by the Institute.

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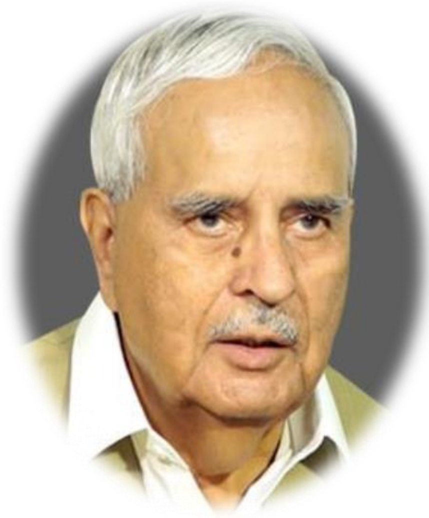
Dedication

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).

ANNUAL REPORT
CENTRAL COTTON RESEARCH INSTITUTE, MULTAN
2022-23

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 recently 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 Secretariate, 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 - 33.0 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.
- 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

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)
- Overseas Development Agency UK
- 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 2022-23 along with estimated cost for each experiment, carried out by various sections are as follows:

AGRONOMY

Sr. No.	Proposed Title of Study/Experiment/project
1	Effect of time of sowing on productivity of advanced genotypes
2	Effect of time of sowing on productivity of transgenic genotypes
3	Impact of nitrogen application on yield performance of newly developed genotypes
4	Yield response to residues management and tillage systems in cotton-wheat cropping system
5	High density planting system (HDPS): Effect on cotton yield and fiber quality
6	Agro-economic feasibility for cotton based intercropping system
7	Effect of planting and picking time on cotton seed quality
8	Genotypes performance at high density planting system (HDPS)-NCVT trial
9	Screening of pre and post-emergence weedicides in cotton

PLANT BREEDING & GENETICS

Sr. No.	Proposed Title of Study / Experiment
1	VT – 1: Evaluation of high yielding, medium long staple Bt-strains equipped with wider adoptability against commercial varieties.
2	VT – 2: Evaluation of medium long staple with high lint %age Bt-strains against cultivar
	VT – 3: Evaluation of high yielding, heat & drought tolerant Bt-strains against a standard variety
	VT – 4: Evaluation of high yielding medium long staple strains with high response to inputs against cultivar
	MVT – 1: Evaluation of high yielding, medium long staple Bt-strains equipped with wider adoptability against commercial varieties
	MVT – 2: Evaluation of medium long staple with high lint %age Bt-strains against cultivar
3	MVT -1-4: Evaluation of newly bulked medium long staple Bt. strains against commercial varieties
4	SVT-1: Evaluation of commercial Non-Bt. varieties at CCRI Multan
5	SVT-2: Evaluation of commercial Bt. varieties at CCRI Multan

6	NCVT-A to B: To test performance of candidate varieties all over Pakistan
7	PCVT 1 to 2: To test performance of candidate varieties all over Punjab
8	F_1 Hybrids: To raise F_2 population for selection according to desirable traits
9	F_{3-5} Generation Block 1-4: To select the segregates for further Filial generation according the desirable traits.
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,
12	Early generation seed (Bt) To produce pre-basic seed of approved commercial varieties of CCRI Multan
13	Early generation seed (Non-Bt): To produce pre-basic seed of approved commercial varieties of CCRI Multan
14	Fresh crosses
15	Maintenance of genetic stock
16	Study of Gene Flow/ out crossing
17	Performance of exotic varieties verses local
18	ICARDA Cotton Project Material Screening of US germplasm for CLCuV resistance/tolerance.
19	Study of phenotypic diversity

CYTOGENETICS

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

ENTOMOLOGY

Sr. No.	Proposed Title of Study/Experiment
1.	Pink bollworm infestation in green bolls in major cotton growing area
2.	Assessment of pesticides based on moth catches of PBW in traps
3.	Management of pink bollworm using attractants and different colored adhesive plastic sheets in relation to its abiotic factors
4.	Studies on Eco-friendly Management of Pink Bollworm
5.	Monitoring of population dynamics of different lepidopterous pests
6.	Impact of sowing period on the Dusky cotton bug infestation
7.	Incidence of arthropods abundance on light and normal green cotton leaves in relation to commercial aspect
8.	Impact of pesticides on the crop physiology/shape/canopy
9.	Monitoring of insecticide resistance
10.	Screening of new and commercially available insecticides

11.	Efficacy of different insecticides at different infestation levels of Whitefly
12.	Rearing of cotton insect pests and natural enemies in labs.

PLANT PHYSIOLOGY / CHEMISTRY SECTION

Sr. No.	Proposed Title of Study/Experiment/project
1.	**Studies on genotype - Environment Interactions**
1.1	Adaptability of genotypes to high temperature stress
1.2	Physiological, biochemical and Molecular analysis to examine the effect of seed priming on heat stress tolerance mechanisms in *Gossypium hirsutum*
1.3	Characterization of cotton germplasm for heat tolerance
2.	**Soil Health and Plant Nutrition**
2.1	Long term effects of reduced tillage on soil health and cotton-wheat productivity
2.2	Does phosphorus application time affect root development and cotton productivity?
2.3	Improving resource use efficiency and soil health by integrating rice crop in cotton
2.4	Enhancing nutrient use efficiency (NUE) by synchronizing application rate and methods
3	**Plant-Water Relationships**
3.1	Adaptability of genotypes to water stress conditions
3.2	Exogenous application of bio-chemicals to improve drought tolerance in cotton
3.3	Seed coating with PGPR's to ameliorate drought stress and enhancing nutrient use efficiency in cotton
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

TRANSFER OF TECHNOLOGY

Sr. No.	Proposed Title of Study/Experiment
1.	Integrated Multi-Media Publicity Campaign
2.	TeleCotton SMS Service

FIBRE TECHNOLOGY

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

FARM MANAGEMENT

Sr. No.	Proposed Title of Study/Experiment
1.	POL
2.	Daily Paid Labour
3.	Fertilizer
4.	Pesticides
5.	Repairs of Tractor & Machinery

ii) **Approval of Cotton Varieties**

The Punjab Seed Council accorded approval of 02 cotton varieties (CIM-343, CIM-537) for commercial cultivation.

Bt.CIM-343	Characteristics	Bt.CIM-537	Characteristics
	Lint %age: 40.3 Staple Length : 31.1 Micronaire: 4.3 Strength: 95.5		Lint %age: 39.8 Staple Length : 28.5 Micronaire: 4.4 Strength: 104.3

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 Room for 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.

ix) Activities under Cotton Research & Development Projects

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. The major activities included registration of 48,319 farmers for BCI practices covering an area 157,030 acres in project areas, 10 farmers training programs, 08 Better Cotton Knowledge Network (BKN) meetings with BCI officials and 24 monthly meetings with BCI staff during the period.

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) 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.

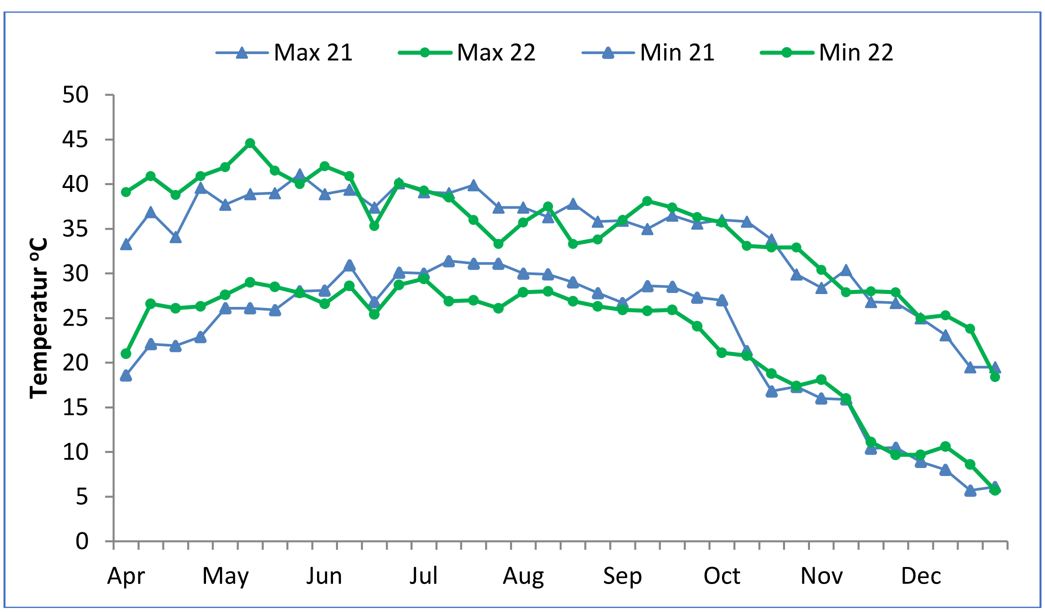
iii) Website & Social Media

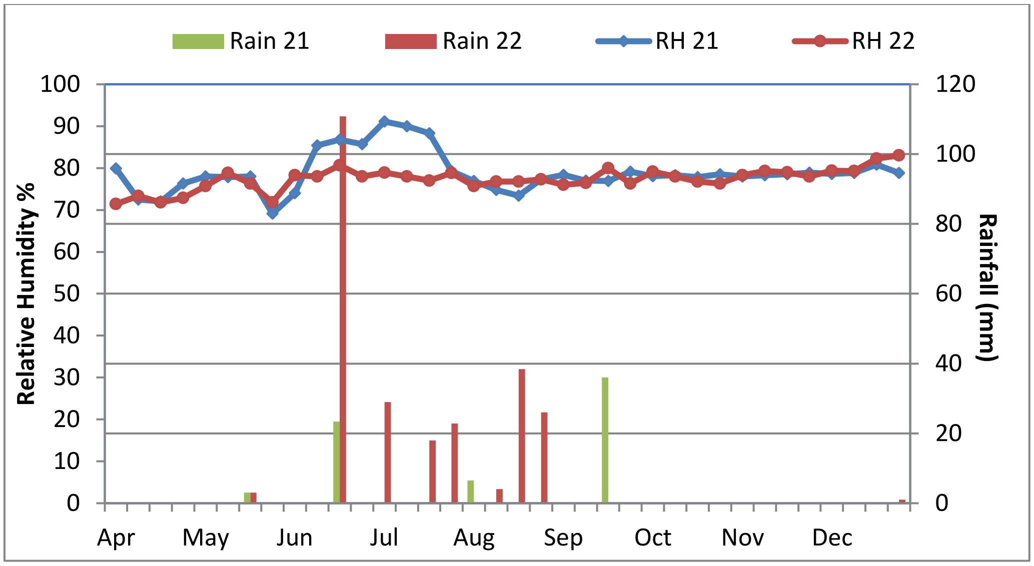
The Institute also initiated highlighting of cotton research and development activities carried out during crop season 2022-23 utilizing social media tools (www.fb.com.pk/CCRIM.PK). This has attracted cotton farmers, researchers, and students very effectively. The followers and members appreciated the 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) COTTON CROP CONDITION

i) Weather Condition

The pattern of maximum temperatures during cotton crop season 2022-23 remained higher especially between June-August. The annual average maximum temperature during 2022-23 remained 35.0°C while it was 34.3°C during last year. Similarly, the annual average minimum temperature during current year remained at 22.5°C while it was 22.8°C during last year. The minimum relative humidity remained 77.3% while it remained 78.9% at maximum level, during current season. A total of 253.0 mm rainfall was recorded during the current crop season as compared to 68.9 mm rainfall during the last year.





ii) Cotton Crop Condition

Cotton crop 2022 drastically damaged due to the climatic changes. Cotton season started with the 7-10^{0}C rise in temperatures from the last few years in March-May coupled with shortage of irrigation water, causing severe heatwave, which affected cotton germination, seedlings growth and leaf wilting problem. Later, the country received heaviest rainfall from July-August (Pakistan: 390.7mm, Punjab: 424mm, Sindh: 697.1mm). Sindh and Balochistan provinces were severely affected due to heavy rains leading to flash floods. Almost the entire crops in these provinces swept away in floods. Rajan Pur, DG Khan and Tounsa was worst hit in the Punjab province damaging 212,000 acres of cotton crop.

Insect pests especially Pink bollworm, Whitefly and Thrips remained prevalent during the season, while cotton diseases including wilting, boll rottening and yellowing of leaves due to stagnant water in fields were observed.

Cotton prices remained all time high; seedcotton/phutti prices ranges Rs.8500-12500 per 40 kgs, while lint prices remained Rs.19,500 to 22,500 per 40 kgs.

Federal government in coordination with the provincial governments taking strenuous measures for relief and rehabilitation measures in the flood affected areas. Efforts would be made to save the remaining each single boll and plant to get maximum yield.

Cotton Area Target Vs Sowing 2022

Province	Target 2022-23	Area Sown		% Change Over	
		2022-23	2021-22	Target	Last Year
Punjab	1.821	1.485	1.279	81.5%	**+16.1**
Sindh	0.640	0.515	0.592	80.5%	**-13.0**
Khyber Pakhtunkhwa	0.0022	0.000171	0.00017	7.8%	**-6.0**
Balochistan	0.0700	0.0650	0.0637	92.9%	**+2.04**
Total	**2.5333**	**2.065**	**1.935**	**81.5%**	**+6.7**

Source: DMR, PCCC

Cotton Arrivals 2022-23

Province	2022-23	2021-22	% Change
Punjab	2,996,203	3,928,690	- 23.74
Sindh	1,879,019	3,513,143	- 46.51
PAKISTAN	**4,878,222**	**7,441,833**	**- 34.49**

Source: PCGA 3rd March, 2023

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1. AGRONOMY

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 addition to these, performance of genotypes is being tested in high density planting system (HDPS). The feasibility study on mung bean, sesame, 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 weed control efficiency of the of registered and candidate herbicides is also being tested. 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.Phil and Ph.D 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., Cyto-231, Cyto-232 and CIM-610 were tested at five sowing dates starting from April 01st to May 30th 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	Cyto-231	124.6	23	2.47	2288	13.4
	Cyto-232	113.0	25	2.48	2452	18.3
	CIM-610	118.2	26	2.58	2570	44.3
April 15	Cyto-231	122.3	19	2.52	1862	41.8
	Cyto-232	109.8	20	2.54	1994	42.7
	CIM-610	114.7	24	2.60	2444	48.8
May 01	Cyto-231	118.2	17	2.58	1688	100.0
	Cyto-232	103.9	14	2.60	1394	100.0
	CIM-610	114.2	18	2.62	1776	100.0
May 15	Cyto-231	112.0	10	2.66	1056	100.0
	Cyto-232	93.4	10	2.65	1050	100.0
	CIM-610	96.0	12	2.67	1232	100.0
May 30	Cyto-231	87.4	9	2.70	934	100.0
	Cyto-232	78.0	9	2.67	920	100.0
	CIM-610	80.6	10	2.74	1088	100.0

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	118.6	25	2.51	2437	25.3
April 15	115.6	21	2.55	2100	44.4
May 01	112.1	16	2.60	1619	100.0
May 15	100.5	11	2.66	1113	100.0
May 30	82.0	9	2.70	981	100.0

Genotypes	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (Kg ha^{-1})	CLCuD incidence (%) at 90 DAS
Cyto-231	112.9	16	2.59	1566	71.0
Cyto-232	99.6	16	2.59	1562	72.2
CIM-610	104.7	18	2.64	1822	78.6

C.D 5%

Sowing date (SD)	10.09	2.79	ns	279.01	9.98
Genotype (G)	3.51	0.38	ns	40.91	3.81
SD x G	ns	2.88	ns	288.74	12.11

The data presented in Table 1.1 indicated that on overall basis of sowing dates, genotype CIM-610 produced significantly higher seed cotton yield as compared to Cyto-231 and Cyto-232. The genotype CIM-610 produced 16.3% and 16.6% higher seed cotton yields than Cyto-231 and Cyto-232, 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 (2.70 g) was produced from May 30 sown crop. The maximum bolls per plant (25) and seed cotton yield (2437 kg ha^{-1}) were harvested from April 01 sown crop.

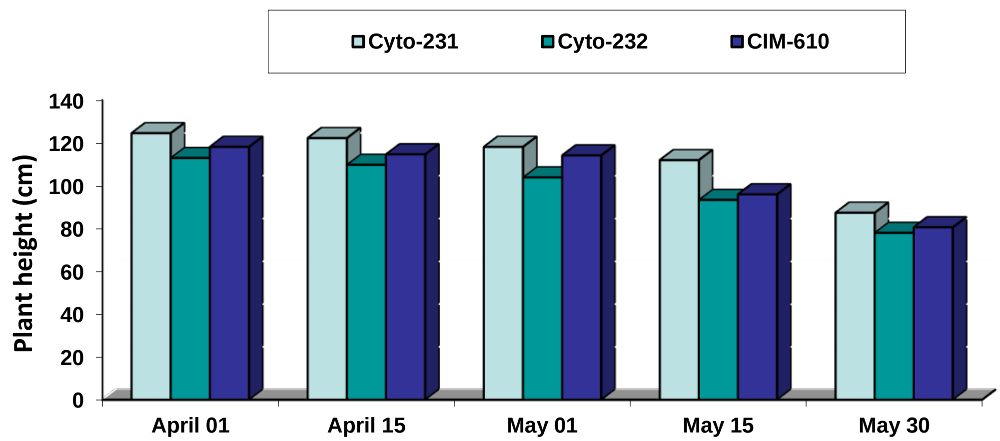


Fig. 1 Plant height as affected by interactive effects of sowing dates and genotypes

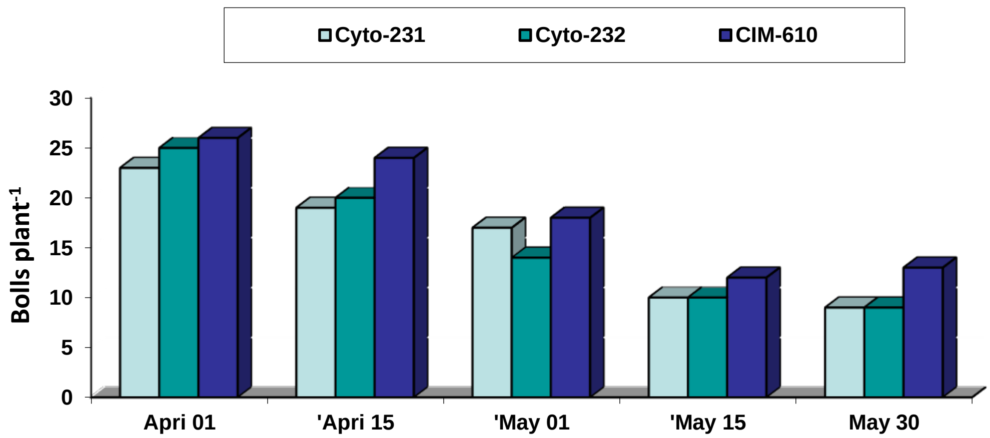


Fig. 2 Bolls plant^{-1} as affected by interactive effects of sowing dates and genotypes

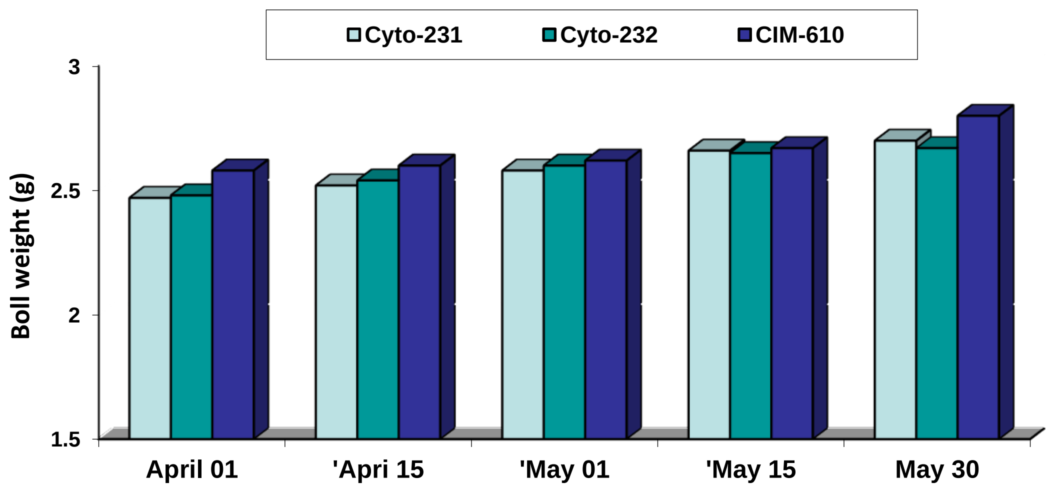


Fig. 3 Boll weight as affected by interactive effects of sowing dates and genotypes

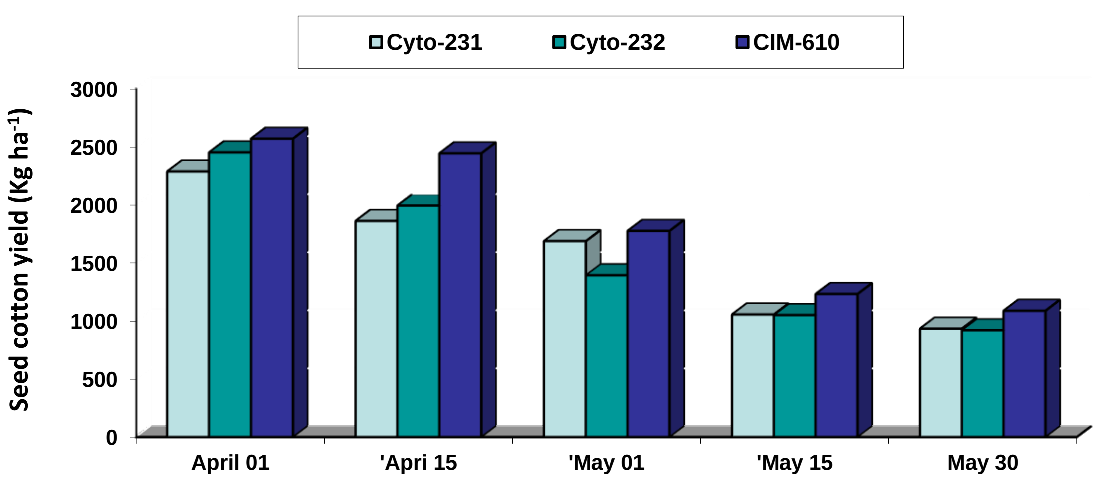


Fig. 4 Seed cotton yield as affected by interactive effects of sowing dates and genotypes

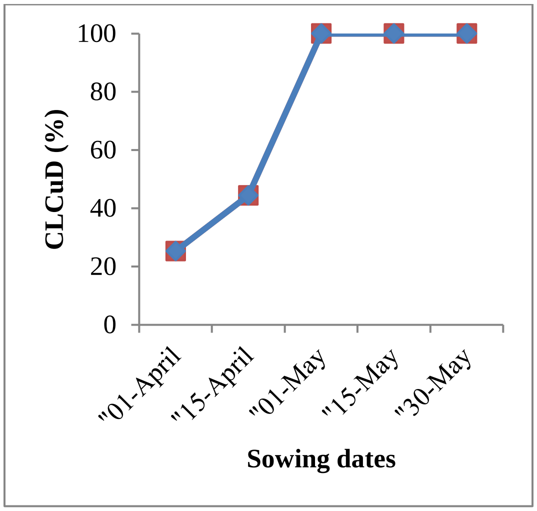


Fig. 5 CLCuD incidence in different sowing dates at 90 DAS

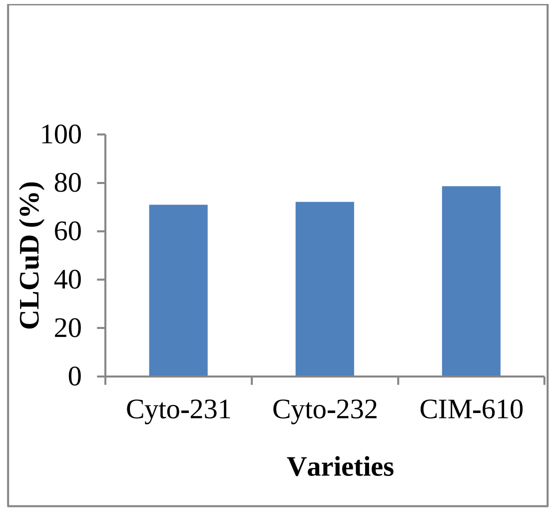


Fig. 6 CLCuD incidence in different genotypes at 90 DAS

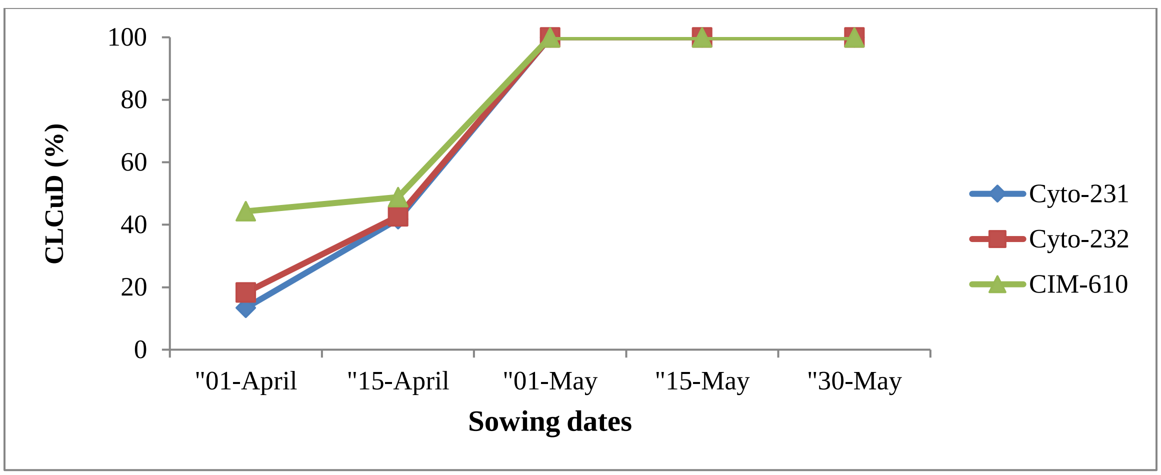


Fig. 7. Interactive affect of sowing dates and genotypes on CLCuD incidence at 90 DAS

The data on CLCuD showed that the disease incidence increased as the sowing was delayed from April 01 up to May 30. The maximum incidence of CLCuD 100% at 90 days after sowing was observed in May 01, May 15 and May 30 sown crops. Whereas April 01 and April 15 sown crops showed 25.3% and 44.4% virus infestation, respectively (Fig. 5). On the average basis of sowing dates, genotype Cyto-231 showed 1.2% and 7.6% less CLCuD incidence than Cyto-232 and CIM-610, 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

Four transgenic cotton genotypes i.e., *Bt.* Cyto-541, *Bt.* Cyto-545, *Bt.*CIM-975 and *Bt.*CIM-990, with one standard *Bt.*CIM-663 were evaluated at six different sowing dates starting from March 15 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 20 ft x 30 ft. 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.

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 100 DAS*
March 15	*Bt*.Cyto-541	134.2	32	2.80	3168	22.5
	Bt.Cyto-545	125.5	35	2.77	3498	14.9
	Bt.CIM-975	139.2	36	2.75	3565	19.6
	Bt.CIM-990	158.0	37	2.81	3736	0.0
	Bt.CIM-663	144.4	33	2.84	3328	13.6
April 01	*Bt*.Cyto-541	124.8	29	2.84	2890	50.7
	Bt.Cyto-545	116.2	34	2.80	3406	76.8
	Bt.CIM-975	134.4	36	2.77	3580	82.7
	Bt.CIM-990	143.0	33	2.86	3348	39.3
	Bt.CIM-663	132.2	31	2.87	3110	81.9
April 15	*Bt*.Cyto-541	122.5	28	2.86	2840	100.0
	Bt.Cyto-545	97.0	32	2.84	3202	100.0
	Bt.CIM-975	134.0	32	2.80	3170	100.0
	Bt.CIM-990	128.6	29	2.91	2935	100.0
	Bt.CIM-663	99.5	31	2.90	3130	100.0
May 01	*Bt*.Cyto-541	97.4	16	2.90	1590	100.0
	Bt.Cyto-545	96.5	27	2.88	2660	100.0
	Bt.CIM-975	110.2	21	2.86	2062	100.0
	Bt.CIM-990	121.2	17	2.94	1704	100.0
	Bt.CIM-663	99.0	16	2.96	1624	100.0
May 15	*Bt*.Cyto-541	87.2	10	2.94	1008	100.0
	Bt.Cyto-545	92.0	12	2.93	1196	100.0
	Bt.CIM-975	102.0	13	2.91	1286	100.0
	Bt.CIM-990	94.6	12	3.00	1240	100.0
	Bt.CIM-663	75.4	11	2.99	1118	100.0
May 30	*Bt*.Cyto-541	80.0	9	2.97	923	100.0
	Bt.Cyto-545	71.3	9	2.96	918	100.0
	Bt.CIM-975	82.5	11	2.95	1102	100.0
	Bt.CIM-990	93.3	10	3.01	1038	100.0
	Bt.CIM-663	72.0	8	3.00	818	100.0

*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 100 DAS
March 15	140.3	35	2.79	3459	14.1
April 01	130.**1**	33	2.83	3269	66.3
April 15	116.3	30	2.86	3055	100.0
May 01	104.9	19	2.91	1928	100.0
May 15	90.2	12	2.95	1170	100.0
May 30	79.8	9	2.98	960	100.0
Genotypes					
Bt.Cyto-541	107.7	21	2.89	2070	78.9

Bt.Cyto-545	99.8	25	2.86	2480	82.0
Bt.CIM-975	117.1	25	2.84	2461	83.7
Bt.CIM-990	123.1	23	2.92	2334	73.2
Bt.CIM-663	103.8	22	2.93	2188	82.6
C.D 5%					
Sowing date (SD)	10.03	3.16	ns	311.29	7.38
Genotype (G)	4.07	1.42	ns	142.60	6.02
SD x G	12.02	4.43	ns	440.57	11.10

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 (140.3 cm), bolls plant^{-1} (35) and seed cotton yield (3459 kg ha^{-1}) were harvested from March 15 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.*Cyto-545 produced 0.8%, 6.3%, 13.3% and 19.8% significantly more seed cotton yield than *Bt*.CIM-975, *Bt*.CIM-990, *Bt*.CIM-663 and *Bt*.Cyto-541 respectively.

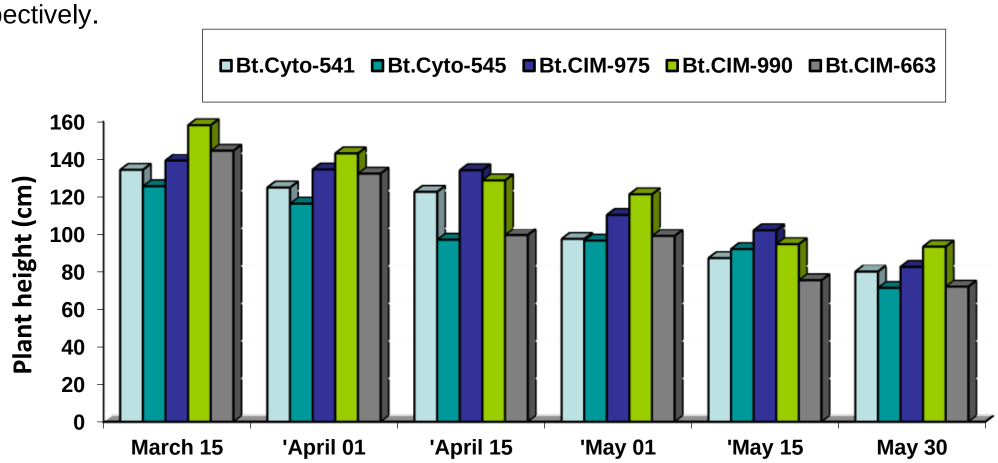


Fig. 8 Plant height as affected by interactive effects of sowing dates and genotypes

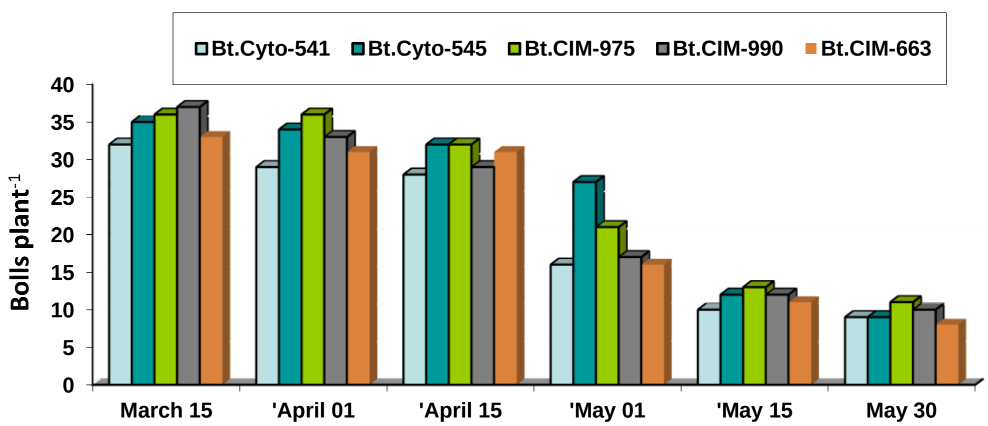


Fig. 9 Bolls plant^{-1} as affected by interactive effects of sowing dates and genotypes

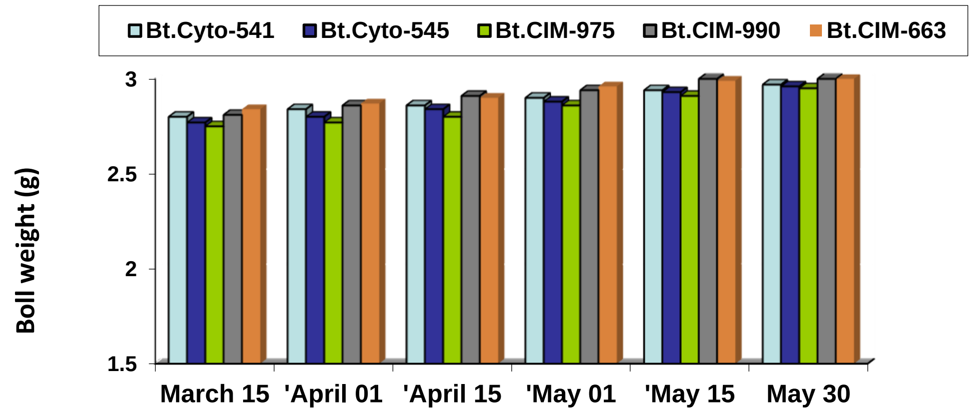


Fig. 10 Boll weight as affected by interactive effects of sowing dates and genotypes

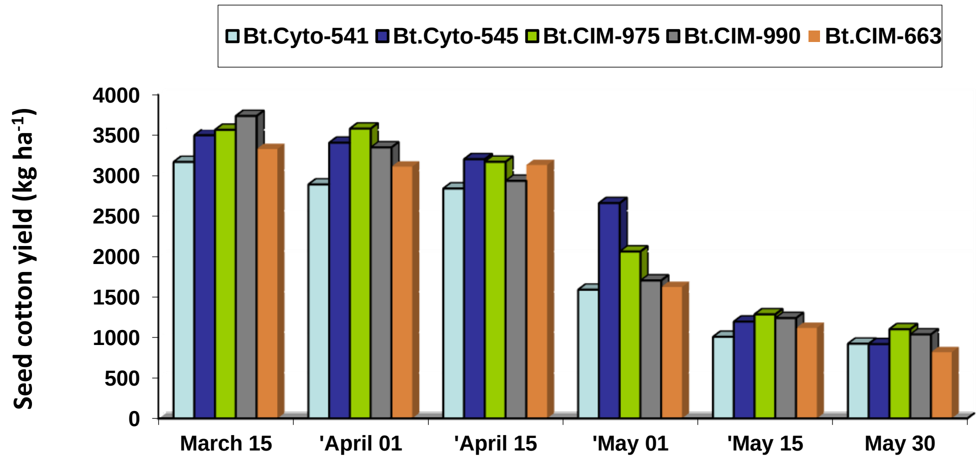
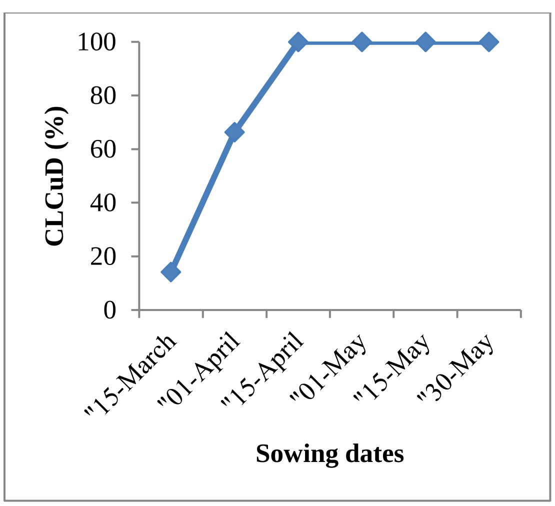


Fig. 11 Seed cotton yield as affected by interactive effects of sowing dates and genotypes



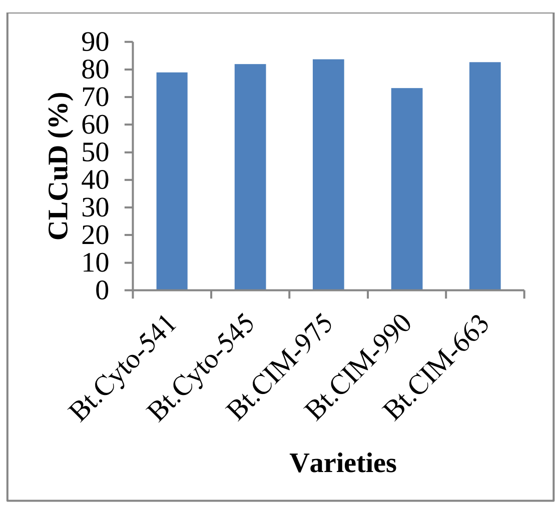


Fig. 12. CLCuD incidence in different sowing dates at 100 DAS

Fig. 13. CLCuD incidence in different genotypes at 100 DAS

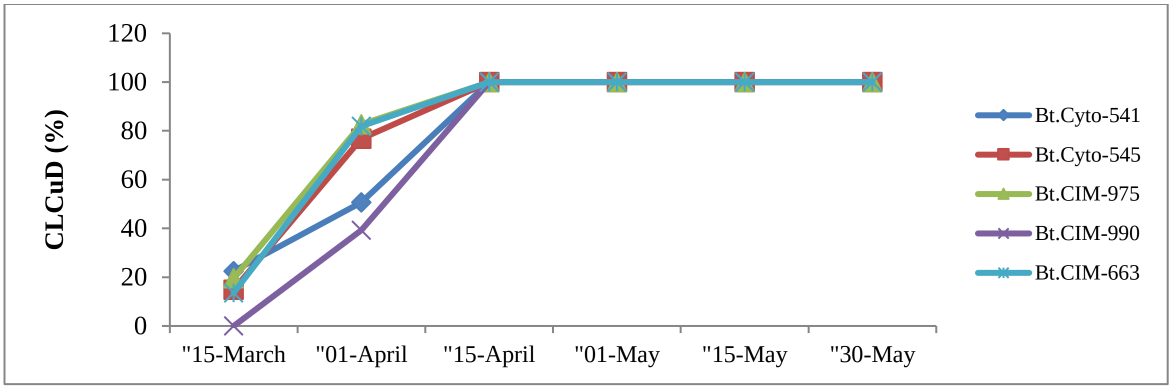


Fig. 14. Interactive effects of sowing dates and genotypes on CLCuD incidence at 100 DAS

The data on CLCuD indicated that the disease incidence increased as the sowing was delayed from March 15 to May 30. The incidence of CLCuD at 100 days old crop was observed 100% in April 15, May 01, May 15 and May 30 sown crop. While March 15 and April 01 sown crops showed 14.1% and 66.3% virus infestation, respectively at 100 days old crop (Fig.12). On the average basis of sowing dates, genotype *Bt.*CIM-990 showed 5.7%, 8.8%, 9.4% and 10.5% less incidence of CLCuD than *Bt*.Cyto-541, *Bt*.Cyto-545, *Bt.*CIM-663, and *Bt*.CIM-975, respectively (Fig.13). The interaction between sowing dates and genotypes is illustrated in Fig.14.

1.3 Impact of nitrogen application on yield performance of newly developed genotypes

The nitrogen is the one of essential element in crop nutrition due to its deficiency in the soil. The nitrogen requirement may vary in different genotypes. Therefore, the present field experiment was conducted to evaluate the impact of three levels of nitrogen (100,150 and 200 kg ha^{-1}) on *Bt.* CIM-975 and *Bt.* Cyto-541 genotype. These nitrogen applications were further splitted as 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 treatments were arranged according to Randomized Complete Block Design with spli-split plot layout. The genotypes were allocated to main plots, the nitrogen levels in sub-plot and application strategies were kept in sub-sub plots. Each treatment was replicated three times and individual plot size measured was 10 × 70 ft. The crop was sown on 22nd March 2022 in bed furrow planting system. The seeds were dibbled in dry beds, followed by irrigation. The Dual Gold 960 EC @ 2L per hectare was applied as pre-emergence weedicide on moist beds within 24 hours after sowing. The gap filling, irrigation, weeding, hoeing and spraying practices was performed as per need of the crop. The basal dose of nitrogen was applied just before bed formation. The fertilizer application at squaring, flowering and peak flowering was completed on 24th May 2022, 06th September, 2022 and 21st September, 2022, respectively. 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. The seed cotton from all the open bolls of 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 (a-d).

The data presented in Table 1.3 a showed interaction between genotypes and nitrogen levels. It showed significant impact only for number of bolls per plant. The number of bolls did not improve with the increase in nitrogen rates for the genotype *Bt*. Cyto-541. However, the number of bolls per plant were initially increased in *Bt*. CIM-975 with the increase in nitrogen from 100 to 150 kg ha^{-1}. The data regarding interactive effects of the genotypes and application strategies is given in the table 1.3b which significant interaction for seed cotton only. The application strategy (T3) produced the highest seed cotton yield in *Bt*. CIM-975, while the T4 application strategy resulted the highest seed cotton yield in the genotype *Bt*. Cyto-541. The seed cotton values were statistically similar for the T2, T3 and T4 in genotype *Bt*. CIM-975. Similarly, the variation in seed cotton yield of genotypes *Bt*. Cyto-541 were statistically similar for T1, T2 and T3. The data regarding the interaction between nitrogen levels and application strategies was statistically non-significant for the recorded parameters (Table 1.3c). Similarly, three-way interaction of genotype × nitrogen levels × application strategies (G × N × AS) was also non-significant (Table 1.3d). The treatments mean showed that number of bolls per plant and seed cotton yield was significantly improved by increasing nitrogen from 100 to 150 kg ha^{-1}. The genotype *Bt*. CIM-975 exceeded the *Bt*. Cyto-541 in seed cotton yield because of a greater number of bolls per plant. The application strategy T4 produced higher seed cotton yield but statistically similar to the T3.

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. CIM-975	100	126.3	23.9 b	2.46	2325.2
	150	129.0	28.5 a	2.48	2777.9
	200	132.8	28.3 a	2.49	2767.9
Bt. Cyto-541	100	122.8	16.8 c	2.81	1866.8
	150	125.6	17.7 c	2.83	1971.6
	200	126.7	18.2 c	2.84	2030.8

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. CIM-975	T1	125.9	25.4	2.48	2475.0
	T2	131.8	26.9	2.45	2591.0
	T3	127.2	28.0	2.48	2732.0
	T4	132.5	27.4	2.49	2696.7
Bt. Cyto-541	T1	122.7	17.9	2.81	1984.3
	T2	125.1	17.1	2.78	1870.2
	T3	124.4	17.0	2.77	1850.4
	T4	127.9	18.4	2.93	2120.7

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})
100	T1	121.0	19.8	2.63	2037.4
	T2	126.3	19.5	2.60	1967.3
	T3	122.1	20.9	2.61	2127.7
	T4	129.0	21.4	2.69	2251.7
150	T1	123.6	22.9	2.65	2354.6
	T2	128.9	24.1	2.62	2446.8
	T3	127.3	22.4	2.63	2277.8
	T4	129.6	23.1	2.71	2419.9
200	T1	128.4	22.4	2.66	2297.0
	T2	130.4	22.3	2.63	2277.8
	T3	128.2	24.2	2.64	2468.1
	T4	132.2	24.2	2.72	2554.6

Table 1.3 (d) Interactive effects of nitrogen (N), genotypes (G) and application strategies (AS) 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. CIM-975	100	T1	120.7	21.4	2.46	2075.9
		T2	130.7	23.6	2.43	2256.5
		T3	123.2	25.8	2.47	2521.8
		T4	130.7	24.9	2.47	2446.8
	150	T1	124.7	27.8	2.48	2723.6
		T2	131.5	29.8	2.45	2873.5
		T3	128.8	28.5	2.48	2783.2
		T4	131.1	27.9	2.49	2731.3
	200	T1	132.5	27.0	2.49	2625.7
		T2	133.4	27.2	2.47	2643.0
		T3	129.6	29.6	2.49	2890.9
		T4	135.9	29.5	2.50	2912.1
Bt. Cyto-541	100	T1	121.3	18.2	2.79	1999.0
		T2	121.8	15.4	2.77	1678.0
		T3	120.9	15.9	2.75	1733.7
		T4	127.3	17.8	2.91	2056.6
	150	T1	122.4	17.9	2.82	1985.5
		T2	126.2	18.4	2.79	2020.1
		T3	125.7	16.3	2.77	1772.2
		T4	128.0	18.3	2.93	2108.5
	200	T1	124.3	17.7	2.83	1968.3
		T2	127.4	17.4	2.79	1912.6
		T3	126.7	18.8	2.78	2045.2
		T4	128.4	19.0	2.94	2197.1

Sub-effects

Nitrogen rates (kg ha^{-1})	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})
100	124.6	20.4	2.63	2096.0
150	127.3	23.1	2.65	2374.7
200	129.8	23.3	2.66	2399.4

Genotypes	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Bt. CIM-975	129.4	26.9	2.47	2623.7
Bt. Cyto-541	125.0	17.6	2.82	1956.4

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	124.3	21.7	2.65	2229.7
T2 = 25% at basal, 25% at squaring, 25% at flowering and 25% at peak flowering	128.5	22.0	2.62	2230.6
T3 = No basal, 25% at squaring, 25% at flowering and 50% at peak flowering	125.8	22.5	2.62	2291.2
T4 = No basal, 33% at squaring, 33% at flowering and 33% at peak flowering	130.2	22.9	2.71	2408.7

C.D 5%

Variables	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Genotypes (G)	ns	2.46	0.20	265.33
Nitrogen (N)	ns	1.34	ns	201.47
Application strategies (AS)	ns	ns	ns	125.44
G × N	ns	1.90	ns	ns
G × AS	ns	ns	ns	177.4
N × AS	ns	ns	ns	ns
G × N × AS	ns	ns	ns	ns

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

The depletion of soil fertility at alarming rate is the most common problem of the wheat-cotton cropping system. Both the cotton sticks and wheat straw contain reasonable amount of the nutrients. These should be incorporated rather to burning in the field to improve fertility and safeguarding the environment quality. The depth of the incorporation is critical factor to harvest maximum benefits of the residue incorporation. The use of tillage implements during residues incorporation process would determine the depth of residues in the soil. Therefore, the long-term study (2019-2023) was planned to quantify the impacts of various residues incorporation and tillage treatments on the soil fertility. The treatments included were cotton sticks incorporation (T_1), cotton sticks & wheat straw incorporation (T_2) and wheat straw incorporation (T_3) and no residue incorporation (T_4). The tillage treatments i.e. chisel along conventional tillage and conventional tillage alone was applied for residue incorporation after harvesting of both wheat and cotton. All the plant material following the picking was rotavated and weight of sticks was measured from taking a fresh weight of post picking plants from an area of 50 m^2. It was converted into dry matter after drying the sub-sample in an oven. During this year, the cotton sticks from T1 with chiseling along conventional and conventional alone was incorporated at the rate of 3229 and 2153 kg ha^{-1}, respectively. The respective values for T2 were 4306 and 2691 kg ha-1. Whereas, the wheat straw in T2 with combination of chisel along conventional tillage and conventional alone was 2620 and 2505 kg ha^{-1}. The corresponding values for the T3 were 2566 and 2445 kg ha^{-1}. The cotton cultivar *Bt.* CIM-343 was planted on 17th May, 2022 on bed furrow planting system. The plant height of five representative plants was measured with height scale and the boll numbers were also counted from these plants. All the open bolls from five plants were picked and weighed to get the average boll weight. The whole plot was manually picked, weighted and yield was converted on hectare basis. The recorded data was arranged according to Randomized Complete Block Design (RCBD) with split plot arrangement. The data on various parameters is given in Table 1.4a.

The data presented in Table 1.5a showed the significant impact of residues on recorded parameters. However, the tillage system resulted a significant variation in the seed cotton yield only. The combination of wheat straw and cotton sticks incorporation resulted maximum values followed by cotton sticks incorporation. The seed cotton yield obtained from combination of wheat straw and cotton sticks was statistically similar to the cotton sticks incorporation. The wheat straw did not produce statistically higher yield over control. The combination of conventional and chisel ploughing produced 90 kg ha^{-1} additional seed cotton yield. The interactive effects of tillage × residue was non-significant for recorded observations. The composite soil samples were collected. The wheat was sown on 29th November, 2022 following the cotton.

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 7.5% and 1.7%, respectively. It increased organic matter, available phosphorus and potassium by 18.2%, 4.6% and 10.0%, respectively.

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

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	83.0	14.0	2.75	1356.0
	Cotton sticks and wheat straw	86.0	15.0	2.84	1478.0
	Wheat straw	73.0	12.1	2.75	1186.0
	No residue	59.0	10.1	2.69	1024.0
Conventional tillage	Cotton sticks	66.0	11.9	2.70	1166.0
	Cotton sticks and wheat straw	77.0	14.1	2.80	1376.0
	Wheat straw	66.4	10.9	2.72	1146.0
	No residue	55.0	9.8	2.65	996.0

Sub-effects

Tillage	Plant height (cm)	Number of bolls $plant^{-1}$	Boll weight (g)	Seed cotton yield ($kg\ ha^{-1}$)
Chisel and conventional tillage	75.3	12.8	2.76	1261.0 a
Conventional tillage	66.1	11.7	2.72	1171.0 b

Residues	Plant height (cm)	Number of bolls $plant^{-1}$	Boll weight (g)	Seed cotton yield ($kg\ ha^{-1}$)
Cotton sticks	74.5	13.0	2.73	1261
Cotton sticks and wheat straw	81.5	14.5	2.82	1427
Wheat straw	69.7	11.5	2.74	1166
No residue	57.0	10.0	2.67	1010

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	51.5
Residue (R)	10.01	2.66	0.09	185.1
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	40.5	3.72	8.13	0.82	8.08	258.2
Cotton sticks and wheat straw	Loam	40.8	3.81	8.11	0.78	8.20	270.5
Wheat straw	Loam	40.2	3.84	8.14	0.75	7.96	252.6
No residue	Loam	39.5	4.12	8.25	0.66	7.84	246.0

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

The high density planting system has been recognized as one of promising approach of improving the yield of the cotton in the world. However, it has still not been tested in Pakistan for its adaptability. In this trial, the performance of two genotypes including *Bt.* CIM-663 and *Bt.* Cyto-535 at various planting geometries was tested. The plant spacings were 15.0, 22.5 and 30.0 cm, while row spacings were 45, 60, 75 and 90 cm. The experiment was laid out in Randomized Complete Block Design (RCBD) with split-split arrangement with three replications. The main plots were comprised of genotypes, sub-plot were row spaces and sub-sub plots were plant spaces. The plot width was variable to adjust the number of rows and plot length was 18 ft. The seeds were sown on 30th March, 2022 and seed rate was adjusted as per required planting scheme. 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. All the cultural practices were carried out as per standard. The data on plant population, plant height, number of bolls (m^{-2}) and boll weight was recorded before picking. All the plants from each plot were counted and converted to find out number of plants on hectare basis. The five representative plants from individual plants were randomly selected for measuring plant height with height measuring scale. The number of bolls (m^{-2}) was recorded by counting all the bolls from all plants in an area of one meter sq. 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 for seed cotton, weighted and converted on hectare basis.

The data pertaining to impact of impact of various row and plant spacing on *Bt*. CIM-663 and *Bt*. Cyto-535 is presented in tables 1.5 (a-d). The genotypes did not differ significantly for various recorded parameters. The main effects of the row and plant spacing were significant for all recorded traits except the boll weight. The interaction between row and plant spacing were significant for plant population, bolls (m^{-2}) and seed cotton yield. The plant height was gradually increased with increasing plant space and opposite response was recorded from increasing plant spaces. The maximum plant population, bolls (m^{-2}) and seed cotton yield were achieved from 45 cm row spacing and 15.0 cm plant spacing. The reduction in plant spacing from 30.0 cm to 15.0 cm resulted an additional seed cotton yield of 604.5, 441.9, 268.8 and 314.3 kg ha^{-1}. The interactive effects of genotypes (G), row spacing (RS) and plant spacing (PS) were non-significant for all recorded parameters. The data on fibre quality is given in Tables (1.5e-h). The fibre quality of *Bt*. Cyto-535 was superior than the *Bt*. CIM-663. The row spacing 60.0 cm produced higher fibre strength and 75.0 cm produced higher values of fibre length and uniformity index. The poor fibre length was recorded from 22.5 cm plant space.

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	90509.4	106.1	109.3	2.81	2684.3
	60	67217.6	114.8	104.3	2.85	2596.9
	75	53109.7	120.5	86.8	2.86	2174.9
	90	46029.8	127.2	69.9	2.88	1756.4
Bt. Cyto-535	45	88885.2	100.0	107.9	2.92	2745.9
	60	66719.3	110.6	108.3	2.96	2797.5
	75	52799.6	118.3	90.2	2.97	2347.3
	90	44221.1	121.1	68.6	2.99	1790.2

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	86070.6	124.1	99.9	2.83	2465.6
	22.5	60628.7	115.9	94.7	2.85	2355.0
	30.0	45950.5	111.4	83.2	2.88	2088.8
Bt. Cyto-535	15.0	86593.9	117.1	102.1	2.94	2614.9
	22.5	58330.9	113.2	95.5	2.96	2468.8
	30.0	44544.1	107.1	83.6	2.98	2177.0

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	121478.9	105.8	119.9	2.84	2963.1
	22.5	84381.9	103.3	112.7	2.87	2823.5
	30.0	63231.1	100.1	93.2	2.89	2358.6
60	15.0	91275.3	118.5	114.0	2.88	2871.7
	22.5	61293.2	112.5	109.8	2.91	2790.1

	30.0	48336.9	107.0	95.0	2.93	2429.8
75	15.0	71890.7	125.5	94.1	2.90	2390.6
	22.5	49831.8	119.6	88.9	2.92	2270.8
	30.0	37141.3	113.1	82.6	2.94	2121.8
90	15.0	60684.1	132.7	76.0	2.91	1935.6
	22.5	42412.4	122.9	68.9	2.94	1763.1
	30.0	32280.0	116.8	62.8	2.95	1621.3

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	121368.2	109.6	120.2	2.78	2914.0
		22.5	87261.1	105.3	114.0	2.82	2801.1
		30.0	62898.8	103.5	93.8	2.85	2337.6
	60	15.0	90361.7	121.0	109.6	2.82	2712.4
		22.5	61791.5	116.6	108.4	2.86	2698.8
		30.0	49499.6	106.7	94.9	2.88	2379.6
	75	15.0	71757.8	128.3	92.8	2.85	2313.5
		22.5	49831.8	117.5	86.7	2.87	2177.3
		30.0	37739.3	115.7	81.0	2.88	2033.8
	90	15.0	60794.8	137.7	76.9	2.86	1922.6
		22.5	43630.5	124.1	69.5	2.88	1742.6
		30.0	33664.2	119.7	63.2	2.90	1604.1
Bt. Cyto-535	45	15.0	121589.7	102.0	119.6	2.89	3012.2
		22.5	81502.7	101.3	111.5	2.92	2845.8
		30.0	63563.3	96.7	92.6	2.94	2379.6
	60	15.0	92188.9	116.0	118.5	2.93	3030.9
		22.5	60794.8	108.3	111.2	2.96	2881.5
		30.0	47174.1	107.3	95.2	2.98	2480.0
	75	15.0	72023.6	122.6	95.3	2.96	2467.7
		22.5	49831.8	121.7	91.1	2.97	2364.3
		30.0	36543.3	110.5	84.3	2.99	2209.8
	90	15.0	60573.4	127.7	75.1	2.97	1948.6
		22.5	41194.3	121.7	68.3	2.99	1783.5
		30.0	30895.7	114.0	62.4	3.00	1638.5

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	64216.6	117.1	92.6	2.85	2303.1
Bt. Cyto-535	63156.3	112.5	93.7	2.96	2420.2

Row spacing (cm)	Plant population (ha^{-1})	Plant height (cm)	Bolls (m^{-2})	Boll weight (g)	Seed cotton yield (kg ha^{-1})
45	89697.3	103.1	108.6	2.87	2715.1
60	66968.4	112.7	106.3	2.91	2697.2
75	52954.6	119.4	88.5	2.92	2261.1
90	45125.5	124.1	69.2	2.93	1773.3
Plant spacing (cm)					
15.0	86332.3	120.6	101.0	2.88	2540.2
22.5	59479.8	114.6	95.1	2.91	2411.9
30.0	45247.3	109.3	83.4	2.93	2132.9

C.D 5%

Variables	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	ns
Row spacing (RS)	1727.1	9.97	5.32	ns	122.59
Plant spacing (PS)	1314.0	7.30	3.51	ns	80.03
G x RS	ns	ns	ns	ns	ns
G x PS	ns	ns	ns	ns	ns
RS x PS	2628.0	ns	7.01	ns	160.06
G x RS x PS	ns	ns	ns	ns	ns

Table 1.5 (e): Interactive effects of genotypes and row spacing on fibre quality

Genotypes	Row spacing (cm)	Fibre length (mm)	Fibre strength (g/tex)	Uniformity index (%)	Micronaire
Bt. CIM-663	45	25.8	26.5	81.9	4.2
	60	25.5	26.4	81.8	4.6
	75	25.1	24.7	82.4	5.0
	90	25.4	25.9	82.2	4.8
Bt. Cyto-535	45	25.6	26.2	82.2	4.5
	60	26.6	27.7	81.6	4.1
	75	27.1	27.8	83.5	4.6
	90	26.4	27.5	82.7	4.4

Table 1.5 (f): Interactive effects of genotypes and plant spacing on fibre quality

Genotypes	Plant spacing (cm)	Fibre length (mm)	Fibre strength (g/tex)	Uniformity index (%)	Micronaire
Bt. CIM-663	15.0	25.7	26.2	82.5	4.7
	22.5	25.4	25.8	82.1	4.6
	30.0	25.3	25.6	81.6	4.5
Bt. Cyto-535	15.0	26.2	26.9	82.4	4.4
	22.5	26.3	27.1	82.7	4.4
	30.0	26.7	27.8	82.4	4.3

Table 1.5 (g): Interactive effects of row and plant spacing on fibre quality

Row spacing (cm)	Plant spacing (cm)	Fibre length (mm)	Fibre strength (g/tex)	Uniformity index (%)	Micronaire
45	15.0	25.8	26.4	82.7	4.4
	22.5	25.4	26.0	81.5	4.4
	30.0	25.9	26.7	81.9	4.2
60	15.0	25.8	26.7	81.9	4.3
	22.5	26.1	27.0	82.4	4.3
	30.0	26.2	27.5	80.8	4.3

75	15.0	26.1	26.0	83.1	5.0
	22.5	26.1	26.2	82.9	4.7
	30.0	26.1	26.5	82.9	4.6
90	15.0	26.1	27.3	82.1	4.6
	22.5	25.8	26.7	82.8	4.7
	30.0	25.8	26.2	82.4	4.6

Table 1.5 (h): Interactive effects of genotypes, row and plant spacing on fibre quality

Genotypes	Row spacing (cm)	Fibre length (mm)	Fibre strength (g/tex)	Uniformity index (%)	Micronaire
Bt. CIM-663	45	25.4	26.6	82.7	4.3
		25.4	25.9	81.4	4.25
		26.55	27.2	81.7	4.0
	60	25.5	26.4	82.1	4.6
		25.65	26.4	82.4	4.6
		25.4	26.5	80.9	4.5
	75	25.5	24.8	83.0	5.2
		25.35	25.2	82.3	4.9
		24.5	24.2	81.9	4.75
	90	26.4	27.3	82.2	4.7
		25.05	25.8	82.3	4.7
		24.8	24.7	82.1	4.9
Bt. Cyto-535	45	26.15	26.3	82.8	4.45
		25.45	26.1	81.6	4.5
		25.2	26.2	82.2	4.4
	60	26.15	27.0	81.8	4.05
		26.5	27.7	82.5	4.05
		27	28.5	80.7	4.1
	75	26.7	27.2	83.2	4.7
		26.8	27.2	83.5	4.5
		27.7	28.9	83.8	4.45
	90	25.85	27.3	82.1	4.4
		26.5	27.5	83.3	4.6
		26.85	27.7	82.8	4.25

Sub-effects

Genotypes	Fibre length (mm)	Fibre strength (g/tex)	Uniformity index (%)	Micronaire
Bt. CIM-663	25.5	25.9	82.1	4.6
Bt. Cyto-535	26.4	27.3	82.5	4.4

Row spacing (cm)	Fibre length (mm)	Fibre strength (g/tex)	Uniformity index (%)	Micronaire
45	25.7	26.3	82.0	4.3
60	26.0	27.1	81.7	4.3
75	26.1	26.2	82.9	4.8
90	25.9	26.7	82.4	4.6

Plant spacing (cm)	Fibre length (mm)	Fibre strength (g/tex)	Uniformity index (%)	Micronaire
15.0	26.0	26.6	82.5	4.6
22.5	25.8	26.5	82.4	4.5
30.0	26.0	26.7	82.0	4.4

1.6 Agro-economic feasibility for cotton based intercropping systems.

The cotton genotype *Bt*.Cyto-535 was sown on 6th April 2022 to evaluate the impact of various intercrops including mung bean (AZRI-06), sesame (T-6) and fodder maize (SGF-2020). The experimental design was randomized complete block design. The net plot size was 24 ft x 75 ft. Bed-furrows were prepared after land preparation in dry condition by employing 60 cm distance in rows. Cotton delinted seeds and intercrops' seed were sown at 22.5 cm and 15.0 cm plant to plant distance respectively 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 weights were converted on hectare basis. Soon after the harvest of mung bean and sesame, the corn was planted during July at the same piece of land along with standing cotton. While, after the harvest of fodder maize again fodder maize was planted. The data on plant height, number of bolls, boll weight, intercrop yield (biological and economical) and seed cotton yield are given in Table 1.6.

Table 1.6 Impact of different intercrops on plant height, number of bolls, boll weight and seed cotton yield

Intercrops	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield (Kg ha^{-1})
Cotton alone	110.2	24	2.80	2533
Cotton + Mung bean + Corn	140.4	18	2.84	1905
Cotton + Sesame + Corn	150.3	20	2.86	2085
Cotton + Fodder Maize + Fodder Maize	100.8	12	2.75	1180
C.D.5%	16.0	2.29	0.009	113.39

Table 1.6 (a) Impact of different intercroppings on economic returns

Intercrops	Seed cotton yield (Kg ha^{-1})	Intercrop yield (Kg ha^{-1})	Income (Rs. ha^{-1})		Total income (Rs. ha^{-1})	Cost (Rs. ha^{-1})		Total cost (Rs. ha^{-1})	Net Income
			Cotton	Intercrops		Cotton	Intercrops		
Cotton alone	2533	-	569925	-	569925	242983	-	242983	326942
Cotton + Mung bean + Corn	1905	598 + 5382	428625	119600 + 301392	849617	121492	62000 +90000	273492	576125
Cotton + Sesame + Corn	2085	506 + 6279	469125	126500 + 351624	947249	121492	72000+ 90000	283492	663757
Cotton + Fodder Maize + Fodder Maize	1180	17297 + 16856	265500	86485 + 84280	436265	121492	64000+ 55000	240492	195773

The data presented in Table 1.6 (a) revealed that among all the treatments, the maximum plant height, boll weight and seed cotton yield were observed in cotton + sesame + corn while, the maximum bolls per plant was observed in cotton alone. Among the intercrops, cotton alone produced 21.5%, 33.0% and 114.7% higher seed cotton yield as compared to cotton + sesame + corn, cotton + mung bean + corn and cotton + fodder maize + fodder maize intercrops, respectively. The cotton alone produced significantly higher seed cotton yield as compared to all other treatments. As far as the economic returns of intercrops are concerned, sesame and corn produced the highest economic returns with the yields of (506 & 6279 kg ha^{-1} respectively) with the highest income of (Rs.126500/- + Rs. 351624/- respectively) as compared to all other intercropping options under study. However, as for as the performance of different intercropping system is concerned, cotton + sesame + corn produced 15.2%, 102.0% and 239.0% high income as compared to cotton + mung bean + corn, cotton alone and cotton + fodder maize +fodder maize, respectively.

1.7 Screening of pre-emergence weedicides in cotton

Study was conducted to evaluate the efficiency of various weedicides on weed management in bed furrow planting system. The following pre-emergence weedicides Invert 51% EC @ 1000 ml $acre^{-1}$ and Phaser 84.8% EC @ 750 ml $acre^{-1}$, Top Max 96% EC @ 900 ml $acre^{-1}$, Pre-act 960 EC 900 ml $acre^{-1}$, Dual Gold 960 EC @ 800 ml $acre^{-1}$ were compared along with one control plot. All weed treatments were arranged in randomized complete block design. Cotton cultivar *Bt.*Cyto-535 was dibbled on 14th April, 2022 manually. All these weedicides were sprayed within 24 hours of planting in their respective plots as per product recommendation. The cultural practices were carried out as per need of the crop. The net plot size was 20 ft x 30 ft with three repeats. Bed-furrows were prepared after land preparation in dry condition. Sowing was done with delinted seeds by dibbling method followed by irrigation. 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. Data on plant height, boll number, boll weight, seed cotton yield and dry weight of weeds are given in table 1.7.

1.7 Effect of various weedicides on plant height, bolls per plant, boll weight and seed cotton yield

Weedicides	Plant height (cm)	Bolls $plant^{-1}$	Boll weight (g)	Seed cotton yield (Kg ha^{-1})	Increase over untreated (%)
Invert 51% EC @ 1000 ml ac^{-1}	145.7	18	2.50	1722	28.9
Phaser 84.8% EC @ 750ml ac^{-1}	165.4	22	2.54	2188	63.8
Dual Gold 960 EC @ 800ml ac^{-1}	140.1	20	2.53	1978	48.1
Top Max 96% EC @ 900ml ac^{-1}	142.6	21	2.54	2082	55.8
Pre-act 960 EC @ 900ml ac^{-1}	135.2	19	2.53	1830	37.0
Control	120.3	14	2.46	1336	-
C.D.5%	ns	1.79	ns	188.45	-

The data presented in table 1.7 displayed that all the weedicide applications resulted higher plant height over control. Among the treatments, the maximum plant height was observed in Phaser 84.8% EC while minimum plant height was observed in control. Phaser 84.8% EC produced 5.1%, 10.6%, 19.6, 27.1% and 63.8% higher seed cotton yield than Top Max 96% EC, Dual Gold 960 EC, Pre-act 960 EC, Invert 51% EC and control respectively.

Table 1.7a Dry weight of weeds (gm^{-2}) and percent weed control at 30 days after sowing

Weedicides	Dry weight of weeds (gm^{-2})		Percent weed control	
	Broad leaves	Narrow leaves	Broad leaves	Narrow leaves
Invert 51% EC@ 1000ml ac^{-1}	28.8	22.3	78.9	76.6
Phaser 84.8% EC@ 750ml ac^{-1}	34.5	15.7	74.7	83.6
Dual Gold 960 EC@ 800ml ac^{-1}	36.2	11.4	73.5	88.1
Top Max 96% EC@ 900ml ac^{-1}	31.9	17.6	76.6	81.6
Pre-act 960 EC@ 900ml ac^{-1}	22.5	19.5	83.5	79.6
Control	136.6	95.5	-	-
C.D.5%	9.31	5.04	-	-

Table 1.7b Dry weight of weeds (gm^{-2}) and percent weed control at 60 days after sowing

Weedicides	Dry weight of weeds (gm^{-2})		Percent weed control	
	Broad leaves	Narrow leaves	Broad leaves	Narrow leaves
Invert 51% EC@ 1000ml ac^{-1}	98.7	74.5	62.2	52.4
Phaser 84.8% EC@ 750ml ac^{-1}	105.3	48.2	59.7	69.2
Dual Gold 960 EC@ 800ml ac^{-1}	104.5	42.5	60.0	72.8
Top Max 96% EC@ 900ml ac^{-1}	101.4	57.3	61.2	63.4
Pre-act 960 EC@ 900ml ac^{-1}	88.9	60.9	66.0	61.1
Control	261.2	156.4	-	-
C.D.5%	13.57	10.72	-	-

The data presented in table 1.7a and 1.7b showed that all weedicide treatments significantly suppressed the weeds population over control. Pre-act 960 EC exhibited (83.5% and 66.0%) of robust control of broad leave weeds at 30 and 60 days after sowing while Dual Gold 960 EC showed (88.1% and 72.8%) of strong control of narrow leave weeds at 30 and 60 days after sowing. The dry weight of weeds at 30 days after sowing for Phaser 84.8% EC was recorded 74.7 and 83.6% in broad and narrow leave weeds over control, Top Max 96% EC resulted in 76.6 and 81.6% broad and narrow leave weeds over control and Invert 51% EC resulted in 78.9 and 76.6% broad and narrow leave weeds over untreated as it is evident in table 1.7a. The dry weight of weeds at 60 days after sowing for Phaser 84.8% EC was recorded 59.7 and 69.2% in broad and narrow leave weeds over control, Top Max 96% EC resulted in 61.2 and 63.4% broad and narrow leave weeds over control and Invert 51% EC resulted in 62.2 and 52.4% broad and narrow leave weeds over untreated as it is shown in table 1.7b.

1.8 Internship

Agronomy Section provided research facilities to one Ph.D. scholar from faculty of Agricultural Science and Technology, Bahauddin Zakariya University. In addition, this facility was extended to ten students of B.Sc. (Hons.) Agriculture (Agronomy) from Bahauddin Zakariya University. These students participated in ongoing research activities and availed internship training under the supervision of experts.

1.9 Cost of production of one acre cotton for the year 2022-23 is given below

Sr. No.	Operations and Inputs	Number/ Quantity	Rate (Rs)	Amount (Rs.)
1.	Seedbed Preparation			**8620**
	a) Cultivation (Ploughing + planking)	4	1000/cultivation	4000.00
	b) Leveling	1	1000/leveling	1000.00
	c) Bed and furrow making	1	2000/acre	2000.00
	d) Pre-emergence Weedicides	800ml	1500/800 ml	1500.00
	e) Bund making	1	120/acre	120.00
2.	Seed			**2170.00**
	a. Cost	8 kg.	10000/40 kg	2000.00
	b. Transportation	-	50/40 kg	10.00
	c. Delinting	-	800/40 kg	160.00
3.	Sowing	2 men day	1554/acre	**1554.00**
4.	Thinning	2 men day	1554/acre	**1554.00**
5.	Interculturing and earthing up	4	1000/acre	**4000.00**
6.	Irrigation			**18041.00**
	a. Land preparation (3 hours)	1/3 canal		
	b. *Rouni*(4 hours)	2/3 tubewell	800/hour of tubewell	14933.00
	c. Post planting irrigation (21hours)			
	d. Cleaning of water channel and labour charges for irrigation	4 man day	777/man day	3108.00
7.	*Abiana* (Water rates)	-	125/acre	**125.00**
8.	Fertilizer			**19237.00**
	a. DAP (Di-Amonium Phosphate)	1 bag	12000/bag	12000.00
	b. Urea	3.0 bags	2100/bag	6300.00
	c. Transportation	4.0 bags	40/bag	160.00
	d. Fertilizer Application Charges	1man day	777/day	777.00
9.	Plant Protection			**14400.00**
	a. Sucking	6	2000/spray	12000.00
	b. Bollworm	2	1200/spray	2400.00
10.	Harvesting (Picking charges)	800 Kg	20.0/kg	**16000.00**
11	Stick Cutting	2 men day	777/man day	+1554.00
11a	Value of cotton sticks			-1554.00
12.	Managerial Charges for 1 acre	7 months	35000/month/100 acre	**2450.00**
13.	Land Rent	7 months	40,000/acre/annum	**23,333.00**
14.	Unforeseen Expenses	-	3500/acre	**3500.00**

15.	Production Expenditure a. Including Land Rent b. Excluding Land Rent	-	-	 **114984.00** **91651.00**
16.	Mark-up on Investment a. Including Land Rent b. Excluding Land Rent	7 months	12.5% for one year	 **8384.00** **6683.00**
17.	Total Expenditure a. Including Land Rent b. Excluding Land Rent	--		 **123368.00** **98334.00**
18.	Income of Seed Cotton	800 kg	9000/40 kg	**180000. 00**
19.	Market expenses	800 kg	160/40 kg	**3200. 00**
20.	Cost of Production at Farm level a. Including Land Rent b. Excluding Land Rent	-	 Per 40 kg	 **6168.00** **4917.00**
21.	Cost of production at Market a. Including Land Rent. b. Excluding Land Rent.	-	 Per 40 kg	 **6328.00** **5076.00**

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2. PLANT BREEDING & GENETICS SECTION

Plant Breeding & Genetics Section develops new cotton varieties or lines with desirable fibre traits equipped with inbuilt resistance/tolerance against insect-pest and diseases by utilizing purposeful breeding (crossing) of closely or distantly related genotypes. Plants are cross-bred to introduce traits/genes from one variety or line into a new genetic background.

The promising hybrids, *Bt.* and non-*Bt*. strains (in coded form) of all the cotton breeders of the country were evaluated under National Coordinated Variety Testing (NCVT) Program of Pakistan Central Cotton Committee. The prominent commercial varieties (*Bt.* and non-*Bt.*) were also tested for their performance under the local agro-climatic conditions of Multan zone in standard varietal trials. The breeding materials in different filial generations were screened out for selection into next generation. Major emphasis was laid on the selection of material having resistance/tolerance against biotic (Cotton Leaf Curl Virus (CLCuV), Pink boll worm etc. and abiotic factors (tolerance against heat-drought and weedicides etc.) with excellent fibre characteristics. The genetic stock of World Cotton collections comprising of 6243 cultivars of four cultivated species of *Gossypium* genus from 41 countries of the World are being preserved for short (25 years), medium (50 years) and long (100 years) duration as well as for utilization in breeding program by cotton breeders in the country and abroad. Promising lines e.g., *Bt*.CIM-990 and *Bt*.CIM-909 developed by utilizing USDA and local cotton germplasm. These were tested for first years in NCVT 2022-23. Trainings were also imparted to small farmers, progressive growers from core and non-core zones of the cotton belts along with technical staffs of different seed companies. Students from different universities were also trained through internship training program. Summary of above mentioned activities are given below.

2.1 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., *Bt.*CIM-793 to *Bt.*CIM-801, were evaluated against one commercial variety *Bt.*CIM-663 at CCRI, Multan. Data of seed cotton yield and other parameters are given in **Table 2.1.**

The strain *Bt.*CIM-798 produced the highest seed cotton yield of 2475 kg ha^{-1} followed by *Bt.*CIM-795 having yield 2341 kg ha^{-1} while the standard variety *Bt.*CIM-663 yielded 1956 kg ha^{-1} **(Table 2.1).**

The new strain *Bt.*CIM-800 produced the highest lint percentage of 42.4 followed by *Bt.*CIM-801 having lint percentage values of 41.2 compared with the standard *Bt.*CIM-663 i.e. 39.0 (**Table 2.1**). The new strain *Bt.*CIM-795 produced the maximum staple of 28.7 mm, followed by *Bt.*CIM-793 with 28.6mm while the standard *Bt.*CIM-663 produced 27.2 mm of staple length **(Table 2.1).**

All the new strains possess desirable micronaire value ranging from 4.0 to 4.9 in comparison to *Bt.*CIM-663 with 4.9.The fiber strength of all the new strains and standard are in the desirable range, i.e., 26.2 to 28.7 g/tex **(Table 2.1).**

Table 2.1 Performance of advanced strains in Varietal Trial-1 at CCRI, Multan

Sr. #	Strains	Seed Cotton 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-793	1845	38.5	28.6	4.8	27.8	3.2	28604
2.	*Bt.* CIM-794	1749	39.3	28.3	4.5	27.8	3.2	32639
3.	*Bt.* CIM-795	2341	38.0	28.7	4.0	27.5	2.8	28693
4.	*Bt.* CIM-796	2025	40.4	27.8	4.9	26.8	2.9	32011
5.	*Bt.* CIM-797	2114	39.9	27.5	4.1	28.7	2.5	30397
6.	*Bt.* CIM-798	2475	37.7	27.5	4.5	26.2	2.7	28693
7.	*Bt.* CIM-799	2213	40.2	27.6	4.8	27.0	2.9	34611
8.	*Bt.* CIM-800	1980	42.4	26.8	4.9	26.2	2.6	26183
9.	*Bt.* CIM-801	2049	41.2	28.1	4.8	28.5	2.9	35060
10.	*Bt.* CIM-663	1956	39.0	27.2	4.9	25.9	3.0	35060

Sowing date 01.04.2022, CD (5%) for seed cotton: Strains =356.65; CV % =10.75

2.1.2 Varietal Trial-2

Objective: Testing and evaluation of promising strains with high ginning out turn for the Development of commercial varieties

Nine new strains with medium-long staple viz., *Bt*.CIM-782, *Bt*.CIM-783, *Bt*.CIM-784, *Bt*.CIM-787, *Bt*.CIM-802, *Bt*.CIM-803, *Bt*.CIM-804, *Bt*.CIM-805, *Bt*.CIM-806 and *Bt*.CIM-663 were tested at CCRI, Multan against a commercial variety *Bt*.CIM-663.

Data presented in **Table 2.2** showed that the new strain *Bt*.CIM-782 produced the highest seed cotton yield of 2367 kg ha^{-1}, followed by *Bt*.CIM-806 with 2128 kg ha^{-1} while the standard varieties *Bt*.CIM-663 produced 777 kgha-^{1}.

The strain *Bt*.CIM-804 had the highest lint percentage of 44.3, followed by 43.4% of *Bt*.CIM-782 in comparison to the commercial varieties *Bt*.CIM-663 produced 43.3 lint percentages. The strain *Bt*.CIM-802 produced the longest staple of 29.8 mm followed by *Bt*.CIM-787 having 29.5 mm **(Table 2.2)** while standard *Bt*.CIM-663 produced 27.8 mm staple length.

All the strains possess desirable micronaire value ranging from 4.0 to 4.8 The fibre strength of the strains ranged from 26.0 to 28.5 g/tex **(Table 2.2).**

Table 2.2 Performance of advanced strains in Varietal Trial-2

Sr. #	Strains	Seed Cotton 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-782	2367	43.4	28.3	4.8	26.6	2.9	33356
2.	Bt CIM-783	1728	42.8	28.1	4.5	27.1	3.4	19996
3.	Bt CIM-784	1527	39.1	28.5	4.0	26.9	2.9	26900
4.	Bt CIM-787	1703	42.3	29.5	4.5	28.5	4.3	25107
5.	Bt CIM-802	1795	42.1	29.8	4.7	26.8	3.3	30756
6	Bt CIM-803	1616	42.7	29.4	4.4	28.4	3.1	28873
7	Bt CIM-804	1289	44.3	29.1	4.2	28.3	3.3	23493
8	Bt CIM-805	1649	43.0	28.9	4.4	27.5	3.5	23941
9	Bt CIM-806	2128	42.3	29.3	4.3	28.5	3.1	29859
10	Bt CIM-663	777	43.3	27.8	4.7	26.0	3.0	23672

Sowing date 01.04.2022, CD (5%) for seed cotton: Strains =360.65; CV %=10.75

2.1.3 Varietal Trial-3

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

Seven medium staple promising *Bt*. Strains *Bt*.CIM-807, *Bt.*CIM-808, *Bt*.CIM-809, *Bt.*CIM-810, *Bt*.CIM-811, *Bt.*CIM-812, *Bt*.CIM-813 were evaluated against commercial variety *Bt.*CIM-663 at CCRI, Multan. Data on seed cotton yield and other parameters are given in **Tables 2.3.**

The strain *Bt*.CIM-810 produced the highest seed cotton yield of 2182 kg ha^{-1} followed by *Bt*.CIM-807 having yield of 1912 kg ha^{-1} while the standards *Bt.*CIM-663 produced yield of 923 kg ha^{-1} **(Table 2.3).**

Table 2.3 Performance of advanced strains in Varietal Trial-3

Sr. #	Strains	Plant Pop. (ha^{-1})	SCY (Kg/ha)	Av. Boll Weight (g)	GOT %	Staple Length (mm)	Uniformity Index %	Micro naire	Fiber Strength (g/tex) 1/8"
1.	CIM-807	27795	1912	3.0	41.9	28.1	83.3	4.7	29.0
2.	CIM-808	24119	1418	2.8	43.4	24.4	81.5	6.1	21.7
3.	CIM-809	25105	1238	2.7	42.7	25.8	82.2	5.5	23.0
4.	CIM-810	37120	2182	3.2	43.2	28.3	84.2	5.1	27.1
5.	CIM-811	30485	1685	2.5	40.5	25.7	82.9	5.0	25.4
6.	CIM-812	17663	1146	2.4	36.0	27.9	83.8	4.2	28.0
7.	CIM-813	15242	1147	2.6	42.0	27.0	83.6	5.0	26.7
8.	CIM-663	30126	923	2.6	36.9	25.0	81.9	4.9	24.3

Sowing date 15.04.2022, CD (5%) for seed cotton: Strains =492.08; CV %=19.30

The new strains *Bt*.CIM-808 produced the highest GOT% of 43.4, followed by *Bt*.CIM-810 having lint percentage value of 43.2 (Table 2.7). *Bt.*CIM-810 produced the longest staple of 28.3 mm, followed by *Bt*.CIM-807 with 28.1 mm while the standards *Bt*.CIM-663 produced 25.0 mm staple length **(Table 2.3).**

All the new strains possess desirable micronaire values ranging from 4.2 to 5.1 except *Bt*.CIM-808 and *Bt*.CIM-809 The fibre strength of all the new strains and standard is in the range of 21.7 to 29.0 g/tex **(Table 2.3).**

2.1.4 Varietal Trial-4

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

Seven medium staple promising *Bt.* Strains *Bt.*CIM-785, *Bt*.CIM-759, *Bt*.CIM-778, *Bt*.CIM-762, *Bt*.CIM-792, *Bt*.CIM-781, and *Bt*.CIM-782, were evaluated against commercial variety *Bt*.CIM-663 at CCRI, Multan. Data on seed cotton yield and other parameters are given in **Table 2.4**.

Averaged across location, the strain *Bt.*CIM-792 produced the highest seed cotton yield of 3536 kg ha^{-1} followed by *Bt*.CIM-782 having yield of 3201 kg ha^{-1} while the standard *Bt.*CIM-663 produced 2366 kg ha^{-1} yield **(Table 2.4).**

Table 2.4 Performance of advanced strains in Varietal Trial-4 at Central Cotton Research Institute, Multan

Sr. #	Strains	Plant Pop. (ha^{-1})	SCY (Kg/ha)	Av. Boll Weight (g)	GOT%	Staple Length (mm)	Micron aire	Fiber Strength (g/tex) 1/8"
1.	CIM-758	26181	2893	3.2	40.3	28.8	4.9	27.3
2.	CIM-759	25064	2812	3.1	40.7	29.0	4.8	27.5
3.	CIM-778	27169	2560	3.2	40.2	27.0	4.7	28.1
4.	CIM-762	39543	2508	3.0	41.4	27.6	4.8	27.1
5.	CIM-792	32818	3536	3.0	39.0	29.4	4.5	28.7
6.	CIM-781	33087	2509	3.1	40.6	26.9	5.6	24.6
7.	CIM-782	36584	3201	3.2	40.8	28.2	4.8	25.1
8.	CIM-663	32011	2366	3.2	39.4	27.8	5.0	25.4

* Sowing date =16.04.2022 CV = 6.7%, CD (5%) for seed cotton: =148.73;

The new strains *Bt*.CIM-672 produced the highest lint percentage of 41.4, followed by *Bt.*CIM-782 having lint percentage value of 40.8 **(Table 2.4).** The new strains *Bt*.CIM-792 produced the longest staple of 29.4 mm, followed by *Bt.*CIM-759 with 29.0 mm while the standard *Bt.*CIM-663 produced 27.8 mm staple length **(Table 2.4).**

All the new strains possess desirable micronaire values ranging from 4.8 to 5.0 including the standard *Bt*.CIM-663. The fibre strength of all the new strains and standard is in the desirable range. **(Table 2.4).**

2.2.1 Micro Varietal Trial-1

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

Nine newly bulked strains numbering from MV-1/22 to MV-9/22 were tested against commercial variety *Bt.*CIM-663 at CCRI, Multan for the second year. The strain MV-4/22 surpassed all the strains and standard variety in seed cotton yield by producing 2582 kg ha^{-1} followed by MV-1/22 with 2264 kg ha^{-1} compared with 1469 kg ha^{-1} of *Bt.*CIM-663 **(Table 2.5).**

The strain MV-7/22 produced the highest GOT% of 44.2 followed by 42.9 percent in MV-2/22 and MV-4/22 while the commercial variety *Bt*.CIM-663 produced the GOT% of 40.1. The strain MV-1/22 and MV-7/22 produced the longest staple of 28.5 mm, followed by 28.0 mm in MV-4/22 compared with the fibre length of 25.2 mm in commercial variety *Bt.*CIM-663. Micronaire values of all the strains are in acceptable limit except MV-2-5/22. The strain MV-7/22 maintained the maximum fibre strength of 29.5 g/tex, followed by 29.3 g/tex in MV-1/22 while standard *Bt.*CIM-663 had 25.5 g/tex.

Table 2.5 Performance of advanced strains in Micro Varietal Trial-1 at CCRI, Multan

Sr. #	Strains	SCY (Kg/ha)	GOT%	Staple Length (mm)	Mike	Fiber Strength (g/tex) 1/8"	Av. Boll weight (g)	Plant Pop. (ha^{-1})
1.	MV-1	2264	41.7	28.5	4.3	29.3	2.7	39809
2.	MV-2	1784	42.9	24.2	5.6	22.0	2.6	37299
3.	MV-3	1547	42.8	27.4	5.3	24.4	2.7	32816
4.	MV-4	2582	42.9	28.0	5.0	26.1	2.5	42679
5.	MV-5	1988	41.5	27.3	5.1	26.0	3.0	35685
6.	MV-6	2099	40.8	25.6	4.9	25.3	2.3	37837
7.	MV-7	1497	44.2	28.5	4.7	29.5	2.6	30485
8.	MV-8	1543	35.4	27.1	3.9	28.0	2.4	28692
9.	MV-9	1483	35.4	27.1	3.9	28.0	2.7	24029
10.	CIM-663	1469	40.1	25.2	4.8	25.5	2.9	39809

Sowing date 30.03.2022 CD (5%) for seed cotton: Strains =474.08; CV %=15.14

2.2.2 Micro Varietal Trial-2

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

Nine newly bulked strains numbering from MV-10/22 to MV-18/22 were tested against commercial variety *Bt*.CIM-663 at CCRI, Multan. The new strain MV-16/22 surpassed all the strains and standard variety in seed cotton yield by producing 2315 kg ha^{-1}, followed by MV-14/22 with 2269 kg ha^{-1} compared with 1281 kg ha^{-1} of *Bt.*CIM-663 **(Table 2.6).**

The strain MV-10/22 produced the highest lint percentage of 43.4 followed by 42.6 percent lint in MV-18/22 while the commercial variety *Bt*.CIM-663 produced the lint percentage of 41.3. The strain MV-17/22 produced the longest staple of 29.2 mm, followed by 29.1 mm in MV-11/22 compared with the fibre length of 26.1 mm in commercial variety *Bt*.CIM-663. All the strains have desirable micronaire except MV-15 of MV-16, while fiber strength values are in desirable range.

Table 2.6. Performance of advanced strains in Micro-Varietal Trial-2 at CCRI, Multan

Sr. #	Strains	Seed Cotton 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	1828	43.4	28.0	4.3	28.0	2.9	30128
2.	MV-11	1971	41.8	29.1	4.6	29.8	2.6	31921
3.	MV-12	1575	39.5	27.5	4.9	27.4	3.7	30307
4.	MV-13	1980	40.8	27.5	4.3	27.9	3.1	29052
5.	MV-14	2269	39.6	28.8	4.7	28.9	3.3	23134
6.	MV-15	1597	42.1	27.3	5.1	27.7	2.7	21879
7.	MV-16	2315	39.6	28.4	5.0	27.5	3.5	23313
8.	MV-17	1944	42.2	29.2	4.6	30.3	2.6	28693
9.	MV-18	2099	42.6	28.3	4.7	28.5	2.8	22775
10.	CIM-663	1281	41.3	26.1	5.0	26.8	2.9	25107

Sowing date 31.03.2022, CD (5%) for seed cotton = 286, CV. % = 7.80

2.2.3 Micro Varietal Trial-3

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

Nine newly bulked strains numbering from MV-19/22 to MV-27/22 were tested against commercial variety *Bt.*CIM-663 at CCRI, Multan. Data presented in **Table 2.7** indicated that the new strain MV-25/22 surpassed all the new strains yielding 2344 kg ha^{-1}, followed by strains MV-22/22 produced 2263 kg ha^{-1} while the standard *Bt.*CIM-663 yielding 975 kg ha^{-1}. The new strain MV-24/22 produced the lint percentage of 44.4 followed by MV-22/22 with 43.4 % in comparison to *Bt.*CIM-663 having 42.6 lint percentages. The strains MV-20/22 has the longest staple of 29.8 mm followed by MV-19/22 and MV-26/22 with the staple of 29.1 mm compared with the staple length of 26.5 mm in standard variety *Bt.*CIM-663. All the genotypes have desirable micronaire value except MV-23 and MV- 27 where as fineness of standard CIM-663 is also undesirable. All the strains were showing fibre strengths ranging from 26.3 to 30.3 g/tex.

Table 2.7. Performance of advanced strains in Micro-Varietal Trial-3 at CCRI, Multan

Sr. #	Strains	Seed cotton yield (kg ha-1)	Lint (% age)	Staple Lengt h (mm)	Micro naire value	Fibre Strength (g/tex)	Av. boll weight (g)	Plant Pop. (ha-1)
1.	MV-19	2160	40.7	29.1	3.8	29.4	3.2	39274
2.	MV-20	2008	39.8	29.8	4.0	30.3	3.2	38915
3.	MV-21	2161	37.5	28.9	4.3	28.6	3.0	38019
4.	MV-22	2263	43.4	28.2	4.9	26.7	3.6	38019
5.	MV-23	1421	42.5	28.2	5.0	26.9	2.9	32459
6.	MV-24	2219	44.4	29.0	4.8	28.4	2.8	38377
7.	MV-25	2344	41.9	27.8	4.8	28.0	3.7	35508
8.	MV-26	1808	40.5	29.1	4.7	29.3	3.1	38915
9.	MV-27	1145	41.0	28.4	5.1	27.1	2.9	26362
10.	CIM-663	975	42.6	26.5	5.2	26.3	2.9	29052

Sowing date = 01.04.2022, CD (5%) for seed cotton: 320.230, CV% = 10.85

2.2.4 Micro-Varietal Trial-4

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

Seven newly bulked elite *Bt.* strains from MV-28/22 to MV-34/22 were tested against commercial variety *Bt.*CIM-663 at CCRI, Multan. Data on yield and other parameters are presented in **Table 2.8**.

The strain MV-28/22 out-yielded all the strains and standard variety by producing 2893 kg ha^{-1} seed cotton, followed by MV-29/22 having seed cotton yields of 2812 kgha^{-1} against commercial variety *Bt.*CIM-663 which produced 2066 kg ha^{-1} seed cotton. The strain MV-28/22 produced the higher lint percentage of 42.9 followed by MV-34/22 with 42.1% compared with that of 41.4% by *Bt.*CIM-663.

The strain MV-33/22 produced the longest staple of 28.6 mm, followed by the 28.4 mm of strain MV-34/22 compared with the 28.4 mm of *Bt.*CIM-663. All the strains have desirable micronaire values ranging from 4.0 to 4.8. The fibre strength of all the new strains was observed within the range i.e. 26.0 to 28.0.

Table 2.8. Performance of advanced strains in Micro-Varietal Trial-4 at CCRI, Multan

Sr.#	Strains	Seed Cotton Yield (kg ha^{-1})	Lint (% age)	Staple Length (mm)	Micronaire value	Fibre Strength (g/tex)	Av. boll weight (g)	Plant Pop. (ha^{-1})
1.	MV-28/22	2893	42.9	28.1	4.8	26.8	2.9	36584
2.	MV-29/22	2812	41.7	28.3	4.7	26.3	2.7	23313
3.	MV-30/22	2560	39.1	27.6	4.8	28.0	2.7	32280
4.	MV-31/22	2508	40.0	27.1	4.6	27.6	3.3	35867
5.	MV-32/22	2236	39.2	27.6	4.8	27.9	3.1	37839
6.	MV-33/22	2509	41.8	28.6	4.0	27.2	2.5	35508
7.	MV-34/22	2201	42.1	28.4	4.2	27.1	2.8	32459
8.	*Bt.*CIM-663	2066	41.4	28.4	4.2	26.0	2.4	30307

Sowing date 01.04.2022, CD (5%) for seed cotton 212.65 CV. % = 9.18

2.2.5 Micro-Varietal Trial-5

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

Eight newly bulked elite strains MV-36/22 to MV-42/22 were tested against commercial variety *Bt.*CIM-663 at CCRI, Multan. Data on yield and other parameters are in **Table 2.9.**

The strain MV-39/22 out-yielded all the strains and standard variety by producing 2479 kg ha^{-1} seed cotton followed by MV-38/22 having seed cotton yields of 2250 kg ha^{-1} against commercial variety *Bt.*CIM-663 which produced 1845 kg ha^{-1} seed cotton. The strains MV-42/22 produced the higher lint percentage values of 42.1% followed by MV-41/22 with 42.0% compared with that of 40.2% by *Bt.*CIM-663.

The strain MV-36/22 and MV-41/22 produced the longest staple of 28.9 mm, followed by 28.8 mm in MV-38/22 compared with the fibre length of 27.8 mm in commercial variety *Bt.*CIM-663. All strains have desirable micronaire values ranging from 4.0 to 4.8. The strain MV-39/22 maintained the maximum fibre strength of 28.5 g/tex followed by MV-35/22 and MV-38/22 with 27.8 g/tex and 27.5 g/tex while standard *Bt.*CIM-663 had 26.7 g/tex fibre strength.

Table 2.9 Performance of advanced strains in Micro-Varietal Trial-5 at CCRI, Multan

Sr. #	Strains	Seed Cotton 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-35/22	1780	40.2	28.1	4.0	27.7	2.9	40529
2.	MV-36/22	2044	40.5	28.9	4.1	26.7	2.6	31563
3.	MV-37/22	1493	41.9	27.9	4.5	26.2	2.8	38198
4.	MV-38/22	2250	40.0	28.8	4.8	27.5	2.6	39812
5.	MV-39/22	2479	41.8	28.1	4.8	28.5	2.5	40529
6.	MV-40/22	2094	40.8	28.2	4.4	27.2	2.6	39991
7.	MV-41/22	2240	42.0	28.9	4.0	26.3	2.5	41067
8.	MV-42/22	1875	42.1	28.8	4.6	26.3	2.6	39812
9.	Bt.CIM-663	1845	40.2	27.8	4.2	26.7	2.4	35149

Sowing date = 01.04.2022; CD (5%) for seed cotton = 383.01; CV. % = 11.23

2.3 Coordinated Variety Testing Program

2.3.1 National Coordinated Varietal Trials (Set-B)

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

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

The data presented in **Table 2.10** showed that the Shara-Klean-10 produced the highest seed cotton yield of 1600 kg ha^{-1}, followed by CEMB-AAS-3 having 1479 kg ha^{-1} seed cotton yield while *Bt*.CIM-600 produced lowest yield 662 kg ha^{-1}.

Data also revealed that the strain VH-447 produced the highest lint percentage of 42.2, followed by KZ-111 with 42.1%. Strain IR-NIBGE-17 produced the longest staple with 27.9 mm length followed by Bahar-GTG-155 with 27.8 mm.

All strains have micronaire values ranging from 4.2 to 5.6. Maximum fibre strength was maintained by CEMB-AAS-3 having 28.4 g/tex, followed by TIPU-10 with 27.9 g/tex.

Table 2.10 Performance of different Bt. Strains of public Sector in National Coordinated Varietal Trial (Set-B) at CCRI, Multan

Sr.#	Strains	Seed-cotton Yield (kg ha-1)	Lint (%age)	Staple length (mm)	Micronaire value	Fibre strength (g/tex)	Boll Weight	Plant Pop. (ha-1)
1.	IUB-4	1467	41.6	26.3	4.7	26.8	2.8	42482
2.	Bahar-GTG-155	1225	39.6	27.8	4.8	26.4	2.2	39370
3.	FH-189	1263	40.4	24.5	4.3	21.5	2.3	42003
4.	Sahara-Klean-10	1022	40.9	25.8	5.3	22.5	2.6	43170
5.	VH-447	1489	42.2	25.9	5.6	20.4	2.5	42362
6.	KZ-181	1600	37.8	26.6	5.1	22.9	2.3	42362
7.	IUB-23	975	40.7	27.6	4.6	26.6	2.5	42003
8.	RH-Bagh-O-Bahar	1204	39.0	26.9	4.6	25.1	2.6	39131
9.	Silver-Queen-33	1158	38.1	26.6	4.6	25.3	2.5	42601
10.	Captain-300	915	40.0	27.7	4.2	26.9	2.3	38413
11.	IR-NIBGE-17	1084	39.9	27.9	4.6	26.6	2.3	40447
12.	KZ-111	1026	42.1	26.1	5.2	22.6	2.6	42482
13.	CEMB-AAS-3	1386	35.7	27.3	4.5	28.4	2.5	42483
14.	Silver-Queen-44	951	41.8	25.1	5.5	20.6	2.3	38533
15.	PC-2234	1181	40.9	25.9	4.3	23.7	2.2	42721
16.	**CIM-600 (Bt. Standard)**	1203	41.3	25.1	4.5	23.8	2.1	42242
17.	NIAB-868	1084	40.1	26.6	4.9	25.3	2.6	42362
18.	RH-Gold-1	832	42.0	25.4	5.5	21.8	2.5	42721
19.	Tipu-10	963	41.6	26.7	4.7	27.9	2.3	42362
20.	Diamond-2024	965	41.3	27.5	4.9	25.5	2.4	42242
21.	PC-2237	680	38.9	26.0	5.2	22.6	2.7	42721
22.	FH-415	682	38.0	26.3	4.7	24.5	2.4	38543
23.	IR-NIBGE-20	807	40.9	27.3	5.1	24.7	2.9	41046

Sowing date : 30-04-2022

2.4 Testing of Commercial Varieties

2.4.1. Standard Varietal Trial-1

Objective: To test the performance of commercial varieties of Pakistan under the agro-climatic conditions of Multan

Seven commercial Non *Bt.* varieties of the country were tested at CCRI, Multan. Data recorded on seed cotton yield and other parameters are presented in **Table 2.11**. The results indicated that varieties CIM-496 and CIM-482 excelled among all varieties by producing seed cotton yield 1421 kg ha^{-1} followed by the variety CIM-608 with 1396 kg. ha^{-1} seed cotton production. Variety CIM-608 had the highest lint percentage of 42.6, followed by variety Cyto-

124 having lint percentage of 41.5 The variety CIM-608 maintained the staple length of 28.7 mm, followed by the variety the CIM-124 with 27.9 mm staple length.

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

Table 2.11 Performance of commercial varieties in Standard Varietal Trial-I at CCRI, Multan

Sr. #	Varieties	Year of released	Seed Cotton 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	1421	39.9	27.0	4.7	27.7	2.4	29590
2.	CIM-496	2005	1421	39.0	26.3	4.1	27.3	2.5	28155
3.	CIM-573	2012	1236	40.2	26.3	4.7	25.3	2.6	29590
4.	CIM-608	2013	1396	42.6	28.7	4.8	29.5	2.6	40171
5.	Cyto-124	2015	1326	41.5	27.9	4.8	28.3	2.8	34073
6.	CIM-620	2016	1025	40.2	27.1	4.4	27.7	2.5	27976
7.	CIM-610	2018	1243	40.0	27.0	4.8	27.8	2.6	30128

Sowing date = 01.04.2022, CD (5%) for seed cotton: 295.35, CV% = 9.90

2.4.2. Standard Varietal Trial-2

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

Ten *Bt.* commercial varieties of the country were tested at CCRI, Multan. Data recorded on seed cotton yield and other parameters are presented in **Table 2.12**. The results indicated that variety *Bt.*CIM-678 excelled among all varieties by producing seed cotton yield of 2433 kg ha^{-1}, followed by the variety *Bt.*CIM-600 with 2151 kg ha^{-1} while *Bt.*CIM-598 produced lowest (1181 kg ha^{-1}) seed cotton production. *Bt*.Cyto-179 had the highest GOT% of 42.9, followed by *Bt.*CIM-678 showing 42.3%. Longest staple length of 28.9 observed in *Bt*.Cyto-535. Micronaire and fiber strength of all the varieties were up to the standard.

Table 2.12 Performance of commercial varieties in Standard Varietal Trial-2 at CCRI, Multan

Sr.#	Strains	Plant Pop. (ha^{-1})	SCY (Kg/ha)	Av. Boll weight (g)	GOT %	Staple Length (mm)	Uniformity Index %	Micronaire	Fiber Strength (g/tex) 1/8"
1.	*Bt.* CIM-663	38853	1619	2.6	40.3	25.3	82.0	5.3	24.3
2.	*Bt.* CIM-602	35984	1874	2.3	38.0	27.6	80.7	4.4	28.0
3.	*Bt.* CIM-600	35267	2151	2.6	35.9	28.0	80.4	4.4	28.6
4.	*Bt.* CIM-598	39570	1181	2.4	41.6	28.2	81.0	4.5	29.0
5.	*Bt.* Cyto-179	41244	1717	2.8	42.9	25.3	81.2	4.8	26.1
6.	*Bt.* Cyto-535	24746	1734	3.4	41.0	28.9	82.7	4.6	29.7
7.	*Bt.* CRIS-508	41125	1459	2.0	31.8	25.8	80.8	3.3	27.5
8.	*Bt.* CIM-632	27855	1560	2.6	42.1	28.0	81.2	4.7	28.1
9.	*Bt.* CIM-785	38973	1836	2.8	41.7	27.7	81.8	5.0	27.4
10.	*Bt.* CIM-678	39331	2433	2.7	42.3	28.0	80.9	4.3	28.6

Sowing date = 30.03.2022

2.5 Breeding Material

2.5.1 Selection from Breeding Material

Single plants were selected from the filial generation in different segregating populations for further testing and screening against biotic and a biotic stresses. Details of breeding material planted and number of plants selected during 2022-23 are given in **Table 2.13**.

Table 2.13 Detail of single plants selected from breeding material

Generation/Trial	No. of plants Selected	Range	
		Lint (%age)	Staple length (mm)
VT	302	37.7-43.5	28.3-30.2
MVT	422	39.3-43.7	28.1-30.9
F_6 single lines	773	38.2-44.6	28.2-30.2
F_5 single lines	913	38.0-42.2	28.2-30.2
F_4 generation	1199	38.7-42.5	28.7-30.5
F_3 generation	1922	37.2-42.5	27.1-30.5
F_2 generation	2475	36.9-42.9	27.6-31.5
Others	637	37.3-45.6	27.1-32.7

2.5.2. Hybridization program

Detail of the crossing program of the Section for the development of breeding material to evolve cotton varieties of high yield potential equipped with desirable fibre traits and wider adoptability along with inbuilt resistance/tolerance against insect-pest and weedicides. Details are given in Table-2.14 to 2.18.

Table-2.14. Cross Reference Chart F_1 Hb-1 Of Breeding And Genetics Section At Central Cotton Research Institute, Multan During 2022-23

Hybrid No.	Parentage	Hybrid No.	Parentage
H-2294	SS-102 x CKC-6	H-2299	Cyto-535 x CKC-5
H-2296	SS-32 x CKC-6	H-2300	CKC-6 x B-2240
H-2295	SS-32 x CKC-5	H-2301	CKC-5 x B-2240
H-2297	SS-102 x CKC-5	H-2302	CKC-3 x B-2240
H-2298	Cyto-535 x CKC-6	H-2303	FH-333 x CKC-6

Table-2.15. Cross reference chart f_1 hb-2 of breeding and genetics section at central cotton research institute, multan during 2022-23

Hybrid No.	Parentage	Hybrid No.	Parentage
H-2303	H-2371 x H-2240	H-2311	H-2378 x CM-11/23
H-2304	H-2372 x CKC-6	H-2312	H-2371 x CM-19/23
H-2305	H-2373 x CIM-790		
H-2306	H-2373 x CIM-791 (Big Boll)	H-2313	H-2372 x Cyto-547
H-2307	H-2374 x CIM-790	H-2314	H-2373 x H-2377
H-2308	H-2375 x H-2385	H-2315	CIM-651 x Cyto-547
H-2309	H-2376 x H-2377	H-2316	CIM-651 x H-2373
H-2310	H-2377 x Okara Leaf	H-2317	CIM-651 x Okara Leaf

Table-2.16. Cross reference chart f_1 hb-3 of breeding and genetics section at central cotton research institute, multan during 2022-23

Sr. No.	Parentage	Sr. No.	Parentage
H-2318	Pronto X GH-Uhud	H-2329	GH-Sanabal x G. Okra
H-2319	SAS-1 x GH-Sanabal	H-2330	FH-189 x Cyto-537
H-2320	Pronto x GH-Sultan	H-2331	GH-Sanabal x MNH-1090
H-2321	CKC-2 x MNH-1090	H-2332	GH-Sultan x MNH-1090
H-2322	NIAB-868 x Cyto-537	H-2333	NIAB-868 x GH-Snabal
H-2323	NIAB-868 x Cyto-537	H-2334	Cyto-533 x MNH-1090
H-2324	GH-Sanabal x GH-Hamalia	H-2335	SAS-1 x GH-Hadi
H-2325	GH-Sanabal x MNH-1090	H-2336	SAS-1 x GH-Sanabal
H-2326	SASI x Cyto-537	H-2337	Cyto-535 x MNH-1090
H-2327	GH-Sanabal x MNH-1090	H-2338	GH-Hadi x Cyto-533
H-2328	GH-Sanabal x CIM-343		

Table-2.17. Cross reference chart f_1 hb-3 of breeding and genetics section at central cotton research institute, multan during 2022-23

Hybrid No.	Origin	Hybrid No.	Origin
H-2339	CIM-343 x MNH-1090	H-2344	431/SDK x MNH-1050
H-2340	CIM-785 x MNH-1090	H-2345	MNH-1050 x CIM-663
H-2341	CIM-789 x MNH-1090	H-2346	MNH-1090 x CIM-506
H-2342	Cyto-511 x MNH-1090	H-2347	MNH-1090 x Samroz-317
H-2343	CIM-663 x MNH-1050	H-2348	Okra x MNH-1090

Table-2.18. Cross reference chart f_1 hb-5 of breeding and genetics section at central cotton research institute, multan during 2022-23

Hybrid No.	Origin	Hybrid No.	Origin
H-2349	CIM-632 x CKC6	H-2354	CIM-990 x FH-333
H-2350	CKC3 x 2240	H-2355	CIM-995 x FH333
H-2351	CIM-632 x FH-333	H-2356	CKC6 x C-22
H-2352	MNH-1090 x CKC3	H-2357	SLAD-115 xC-22
H-2353	CM-28 x Super Gold	H-2358	CIM-221 x C20

2.6 Maintenance of Genetic Stock of World Cotton Collection

2.6.1 Maintenance/Preservation of Cotton Genetic Stock at CCRI Multan

Six thousand one hundred and fourty three genotypes are being maintained at the Cold Room of CCRI Multan for Long (100 years), medium (50 years) and short term (25 years). One third of the seed was planted in the field for production of fresh seed as well as to utilize in the hybridization program. Detail of genetic stock is given in **Table 2.19.** 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 2.19.**

Table 2.19 Detail of Genetic Stock of World Cotton Collection

Local genotypes	1310
Exotic genotypes	4933
Total	**6243**
Species-Wise Detail	
Gossypium herbaceum L.	556
Gossypium arboreum L.	1025
Gossypium hirsutum L.	4553
Gossypium barbadense L.	109
Total Accessions	**6243**

2.7. Comparison of exotic versus local cotton varieties at the agro-climatic condition of Multan, Pakistan.

Twelve cotton genotypes including six local and six exotic were tested in the climatic conditions of Multan. The local genotypes produced higher yields than that of the exotic genotypes. Highest yield (2654 Kg ha^{-1}) produced by Israr Shaheed variety of Dera Ismail Khan.

Table 2.20 Comparison of exotic versus local cotton varieties at the agro-climatic condition of Multan

Sr. No.	Name of varieties	Name of country	Seed cotton yield (Kg ha^{-1})
1	MNH-1035	Pakistan (Punjab)	1148
2	Israr Shaheed DIK	Pakistan (K.P.)	2654
3	CIM-663	Pakistan (Punjab)	1148
4	SLH-Chandi	Pakistan (Sindh)	1419
5	Sindh-1	Pakistan (Sindh)	1435
6	GH-Sultan	Pakistan (Sindh)	646
7	USA Acala-5-918	USA	717
8	USSR SA-71	Russia	739
9	Turkey Carolina Queen	Turkey	574

10	Brazil BPA	Brazil	857
11	France BJA-HC-27-B/163	France	736
12	Samroz-317	Turkey	837

2.8. Study of Phenotypic diversity

The *Gossypium hirsutum* L. species has much more phenotypic diversity that needs to be explored. An experiment designed to observe the most diverse genotypes of *G. hirsutum* L. Observed data is presented in the **Table 2.21**.

Table 2.21 Phenotypic diversity

Sr. #	Genotype	Peculiar Characters
1	Acala 63-69	Open Bushy type plant
2	Acala SJ4	Open Bushy type plant
3	BW-76-31DH	Open Bushy type plant
4	Coker-310	Open type plant
5	Gumbo Okra	Okra Leaf
6	HG-11	Nectariless
7	LA-23897	Frego Bract and Nectariless
8	LB-609	Open type plant with long sympodia
9	NCN-2-65	Open type plant
10	PD-695	Open type plant
11	Red Leaf Cotton	Red plant color with red leaves
12	Stoneville	Nectariless and Low Gossypol
13	Green Lint	Green colored lint
14	Khaki Cotton	Brown colored lint
15	Chure 2A-121	Long Sympodia
16	DPL-61	Okra Leaf
17	Pronto	Okra leaf with susceptibility to drought
18	Reshmi	Thick leaf open type
19	Xiao YiMian	Open type plant with long sympodia
20	H88-8-J-69-J-70	Open type plant with long sympodia

Table 2.22: List of scientists/researchers whom received (Locally) the cotton germplasm 2022-23

Name of Scientist / Research Institute	No. of Stocks
Chairman, Department of Plant Pathology University of Agriculture, Faisalabad.	30
Dr. Ahmad Saleem Akhter, General Manager (R&D),Tara Group, Pakistan.	20
Dr. Muhammad Asif Saleem, Supervisor/Assistant Professor, Department of Plant Breeding & Genetics, Bahauddin Zakariya University, Multan.	50
Dr. Muhammad Asif Saleem, Supervisor / Assistant Professor, Department of Plant Breeding & Genetics, Bahauddin Zakariya University, Multan.	80
Dr. Rao Sohail Ahamd Khan Assistant Professor, Centre of Agriculture Biochemistry and Biotechnology (CABB), University of Agriculture, Faisalabad.	28
Dr. Tariq Mahmud Shah, DCS/Director, Nuclear Institute for Agriculture & Biology (NIAB),Jhang Road, Faisalabad, Pakistan.	50
Dr. Ummad-ud-Din Umar, Associate Professor, Department of Plant Pathology, Bahauddin Zakariya University, Multan.	03
Dr. Waqas Malik, Associate Professor, Department of Plant Breeding and Genetics, Faculty of Agriculture Sciences and Technology Bahauddin Zakariya University, Multan.	56
Furqan Ahmad (Lec), Institute of Plant Breeding &Biotechnology, Muhammad Nawaz Shareef University of Agriculture, Multan.	68
Muhammad Kashif Shehzad Sarwar, PhD Scholar IPBB MNS, University of Agriculture, Multan.	50
Miss Shanza Malik, M. Phil Scholar, Department of Entomology, Bahauddin Zakariya University,.	03
Mr. Muhammad Saad Khalil, Department of Plant Pathology, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan.	02
Prof. Dr. Zulifqar Ali, Principal officer Institute of Plant Breeding & Biotechnology, Muhammad Nawaz Shareef University of Agriculture, Multan.	24
Syed Muhammad Arshad, Scientific Officer (Plant Breeder)Four Brothers Group, Seed Corporation, Pakistan.	12
Total Accessions	**476**

Table 2.23: List of scientists/researchers whom received (Abroad) the cotton germplasm 2022-23

Dr Paul S Saidia (PhD) Centre Director Tari Ukiriguru Tanzania Agriculture Research Institute, Tanzania.	35

2.7. 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 of pure seed. The selected plants will be sown next year. The detail about pre basic seed develop in this trial are given in **Table 2.23**.

Table 2.24 Detail of pre-basic seed produced during 2022-23

Sr. #	Variety	Total Families	Seed weight (Kg)
1	Bt.CIM-632	39	22
2	Bt.CIM-785	26	70
3	Bt.CIM-678	39	75
4	Bt.CIM-602	26	36
5	Bt.CIM-600	26	31
6	CIM-554	13	06
7	CIM-620	13	05
8	CIM-610	13	06

2.8 Study of gene flow in Cotton crop.

2.8.1 Three cotton varieties viz. CIM-496, *Bt*.CIM-632 and Russian red leaf with distinguishable morphological traits (Lear color normal green and red colors) were sown. Normal plant protection and agronomic practices were adopted to get normally formed bolls. Bolls were ginned and the seed will sown next year to study the gene flow/out crossing.

2.9 Pak-US ICARDA Cotton Project CCRI Multan Component

2.10 Ratooning of resistant/tolerant USA cotton germplasm for flower induction

44 accessions of US germplasm were ratooned for the last 6-8 years at the research farm CCRI Multan. Out of these 44 accessions square formation and flower induction were started in only few accessions in the month of December 2022 as detailed in Table 2.24. In Set-D accessions USG-1087/13 one boll was formed. While in Set K only one accession USG-618/14 having flowers and bolls formations were observed. In Set N in only one accession i.e. USG-2269/14 buds formation and flower induction were observed. The seed formed in all bolls were found non-viable due to the harsh climatic condition of this year.

Table 2.22 Ratoon crop of resistant accessions of 2022-23 having bud and flower formation

Sr. No.	Set No.	Year	No of total Accessions	Resistant accessions	Accessions having buds and flower formation
1.	C	2013	200	3	0
2.	D	2013	200	10	01
3.	K	2014	200	3	01
4.	N	2014	600	28	01
		Total	**1200**	**46**	**03**

Besides the above facts Breeding and Genetics were made successes by developing to high yielding strains i.e. *Bt.*CIM-990 and *Bt*.CIM-909 (First year) were tested in NCVT of Pakistan Central Cotton Committee trails.

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3. CYTOGENETICS SECTION

Over the last decade or so, the area under cotton cultivation has declined and has been replaced by competing crops like sugarcane, maize, potato and rice. Sowing area was 20% less than the target. More importantly, unfavorable weather conditions such as rain or heat stress undermined the production per unit. To cope these climate changes, development of climate resilient verities is the need of the day. Such verities should be developed that have greater recovery capacity and are less vulnerable to pest attacks and weather misadventures. Cytogenetics section is continuously working on variety development through interspecific and intraspecific hybridization with conventional and molecular approaches. Cytogenetics section has developed single to triple gene Bt cotton varieties that are climate-smart, resistant against bollworms attack, survive amid low water availability, and are able to tackle weeds problems to give yield as high as 50+ maunds per acre. The newly developed varieties, including Cyto-545, Cyto-537, Cyto-535 and Cyto-547 can survive the shock of climate change and can counter the attack by bollworms, including American bollworm, spotted bollworm, armyworm, and pink bollworm. 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 are:

- 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

Twenty eight 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 2022-23

Sr. No.	Species Name	Genome	Habit
1	*G. hirsutum* L.	AD1	Cultivated
2	*G. barbadense* L.	AD2	Cultivated
3	*G. tomentosum*	AD3	Wild
4	*G. darwinii*	AD5	Wild
5	*G. herbaceum* L.	A1	Cultivated
6	*G. arboreum* L.	A2	Cultivated
7	*G. anomalum*	B1	Wild
8	*G. capitis-viridis*	B4	Wild
9	*G. sturtianum*	C1	Wild
10	*G. nandewarense*	C1-n	Wild
11	*G. australe*	C3	Wild
12	*G. thurberi*	D1	Wild
13	*G. harknessii*	D2-2	Wild
14	*G. davidsonii*	D3-d	Wild
15	*G. klotzschianum*	D3-k	Wild
16	*G. aridum*	D4	Wild
17	*G. gossypioides*	D6	Wild
18	*G. lobatum*	D7	Wild
19	*G. laxum*	D8	Wild
20	*G. stocksii*	E1	Wild
21	*G. somalense*	E2	Wild
22	*G. areysianum*	E3	Wild
23	*G. incanum*	E4	Wild
24	*G. longicalyx*	F1	Wild
25	*G. bickii*	G1	Wild
26	*G. australe*	G2	Wild
27	*G. nelsonii*	G3	Wild
28	*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-two wild species were germinated in an incubator at 28 ± 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

Sr. No.	Name of Species	No. of seeds planted	No. of seeds germinated
1	*G. arboreum*	10	4
2	*G. anomalum*	15	8
3	*G. capitis-viridis*	8	4
4	*G. thurberi*	22	8
5	*G. harknessii*	11	2
6	*G. davidsonii*	10	3
7	*G. klotzschianum*	7	5
8	*G. aridum*	12	3
9	*G. gossypioides*	22	4
10	*G. laxum*	19	2
11	*G. stocksii*	30	9
12	*G. somalense*	13	4
13	*G. areysianum*	24	4
14	*G. incanum*	17	2
15	*G. longicalyx*	16	2
16	*G. bickii*	24	5
17	*G. herbaceum* (Red)	15	3
18	*G. herbaceum* (Green)	15	5
19	*G. darwinii*	13	6
20	*G. nelsonii*	26	5
21	*G. raimondii*	10	3
22	*G. barbadense*	10	4
Total		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)*	10
2	*G.capitis veridis*	6
3	*G. lobatum*	4
4	*G. laxum*	4
5	*G. gossipoides*	7
6	*G. longicalyx*	9
7	*G. bickii*	7
8	*G. incanum*	5
9	*G. somalense*	4
10	*G. tomentosum*	7

11	*G. stocksii*	4
12	*G. anomalum*	8
13	*G. areysianum*	5
14	*G. nelsonii*	5
15	*2(G. arbo. X G. somalense)* 2n	8
16	*(G. hirs. X G. arbo.)* 3n	7
17	*2(G. hirs. X G. ano.)* X *G. barba.4*n	9
18	*G. barba* X *2(G. arbo. X G. stockii) 5*n	6
19	*G. barba* X *2(G. arbo. X G. stockii) 6*n	4
Total		**119**

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

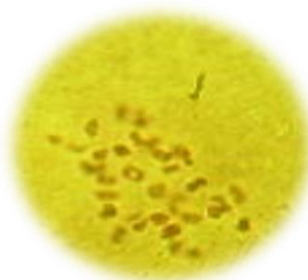
Sr. No.	Name of species	No. of Cuttings
1	*G. laxum*	19
2	*G. stocksii*	18
3	*G. laxum*	22
4	*G. lanceolatum*	12
5	*G. areysianum*	10
6	*G. lobatum*	10
7	*G. tomentosum*	10
8	*G. anomalum*	12
9	*G. harknessii*	17
10	*G. klotzschianum*	11
11	*2(G.hirsutum* x *G.anomalum)*	15
12	*2(G.hirsutum* x *G.anomalum)* x *G.barbadense* (5n)	10
13	*2(G.arbo.* x *G.anomalum)* x *G.hirsutum* (5n)	10
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)	18
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)	12
28	*(G.arboreum* x *G.thurberii*) (2n)	12
29	*G.hirsutum* x *G.herkensii* (3n)	12
30	*2(G.hirsutum* x *G.stockii)* (4n)	10
31	*G.hirsutum* x *G.gossypiodes* (3n)	15
32	*G.barbadense*	10
Total		**451**

Fig.3.1. Maintenance of wild species during 2022

Chromosal Studies

Flowering buds of *G.arboreum*, (*G. hirsutum* x.*G. tomentosum),.* 2(*G. hirs*. x *G. stocksii*) and *G. hirsutum*. x *G. arboreum* were fixed in Carnoy:s fixative ,preserved in 70% alcohol and screened at metaphase-1. The Chromosomal configurations in *Gossypium* species and species hybrids are given below.

G.arboreum
13 bivalents at MI=26



2(*G. hirsutum*) x.*G.tomentosum*.
52

2(*G.hirs*.x *G. stocksii*)
=78

G. hirsutum x G. arboreum
=39

Fig-3.3 Chromosomal configurations in *Gossypium* species and species hybrids.

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 100 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	100	4013
Inter-specific hybridization	6	310

3.4. Selection from Breeding Material

Single plants were selected 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 2022 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	201	39.1-42.9	28.1-30.9
MVT	323	37.5-43.5	27.9-30.3
F_6 single lines	119	39.1-44.6	28.5-33.2
F_5 single lines	463	38.7-43.8	28.1-31.7
F_4 generation	1983	37.2-43.2	27.9-31.0
F_3 generation	377	37.9-42.1	28.1-32.4
F_2 generation	699	35.5-43.7	27.7-32.7

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-535 as standard. The performance of this material is shown in Table 3.9.

Table 3.9 Performance of Cyto-strains in Micro Varietal Trial -1 during 2022-23

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	2456	42888	3.0	37.5	28.2	3.9	29.8
MV-2	2581	41612	2.7	40.4	29.2	4.0	28.9
MV-3	1793	43047	2.7	39.9	29.1	3.9	29.9
MV-4	2501	42250	3.2	41.6	28.1	4.2	29.7
MV-5	2307	44163	2.8	40.0	28.9	4.3	29.1
MV-6	2669	42090	3.1	40.9	28.5	3.9	30.0
Cyto-535	2261	42888	3.0	38.3	28.7	3.9	28.8

Maximum seed cotton yield was produced by MV-6 (2669 kg ha^{-1}) followed by MV-2 (2581 kg ha^{-1}) and MV-4 (2501 kg ha^{-1}) compared with standard (2261 kg ha^{-1}) Table 3.9. The line MV-4 was found to have highest lint% (41.6%) followed by MV-6 (40.9%) compared with standard Cyto-535 (38.3%). The line MV-2 produced the medium long staple of 29.2 mm followed by MV-3 (29.1 mm) compared with 28.7 mm of Cyto-535. All the strains have desirable micronaire values ranging from 3.9 to 4.3 µg $inch^{-1}$. The maximum fibre strength (30.0 g tex^{-1})) was produced in MV-6 followed by MV-3 (29.9 g tex^{-1}) compared with 28.8 g tex^{-1} of standard Cyto-535.

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-535 as standard. Data presented in Table-3.10 exhibited that maximum seed cotton yield was produced by MV-11 (2885 kg ha^{-1}) followed by MV-7 (2746kg ha^{-1}) compared with Cyto-535 (2045 kg ha^{-1}). Maximum lint % was produced by MV-7 (43.5%) followed by MV-12 (41.4%) compared with standard Cyto-179 (37.7%). The line MV-7 produced the medium long staple of 30.7 mm followed by MV-8 (29.8 mm) compared with 28.3 mm of Cyto-535. All the strains have desirable micronaire values ranging from 3.7 to 4.3 µg $inch^{-1}$. The maximum fibre strength (31.0 g tex^{-1})) produced in MV8 followed by MV-12 (30.4 g tex^{-1}) compared with 28.8 g tex^{-1} of standard Cyto-535.

Table 3.10 Performance of advanced strains in Micro Varietal Trial-2 during 2022-23

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	2746	39221	3.3	43.5	30.7	4.0	29.3
MV-8	1596	39380	2.8	39.3	29.8	3.9	31.0
MV-9	2341	40815	2.8	39.9	29.1	4.2	29.9
MV-10	2687	40496	3.3	40.4	28.5	4.3	29.2
MV-11	2885	43047	3.4	39.9	28.3	4.0	28.9
MV-12	2164	38902	3.2	41.4	28.2	3.8	30.4
Cyto-535	2045	42409	3.1	39.8	28.3	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-535 as standard. Data presented in Table-3.11 exhibited that maximum seed cotton yield was produced by MV-13 (2709 kg ha^{-1}) followed by MV-14 (2641 kg ha^{-1}) compared with Cyto-535 (2108 kg ha^{-1}). Maximum lint % produced by MV-18 (41.8%) followed by MV-16 (41.4%) compared with standard Cyto-535 (37.8%). The line MV-18 produced the medium long staple of 30.3 mm followed by MV-15 (30.0 mm) compared with 28.6 mm of Cyto-535. All the strains have desirable micronaire values ranging from 3.8 to 4.2 µg $inch^{-1}$. The maximum fibre strength was produced in MV-14 (30.5g tex^{-1}) followed by MV-15 (29.3 g tex^{-1}) compared with 26.1 g tex^{-1} of standard Cyto-535.

Table 3.11 Performance of Cyto-strains in Micro Varietal Trial -3 during 2022-23

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	2709	36032	3.3	39.0	28.4	3.9	28.7
MV-14	2641	43685	2.8	39.9	29.8	3.8	30.5
MV-15	2619	26785	3.6	39.9	30.0	3.8	29.3
MV-16	2416	28698	3.0	41.4	29.2	4.1	29.1
MV-17	2213	39221	3.2	40.0	28.0	4.0	29.0
MV-18	2456	40815	3.0	41.8	30.3	4.2	28.9
Cyto-535	2108	35235	3.3	37.8	28.6	3.9	26.1

3.5.4. Micro Varietal Trial-4

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

Five new Bt strains MV-19, MV-20, MV-21, MV-22 & MV-23 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-23 (2185 kg ha^{-1}) followed by MV-21 (1704 kg ha^{-1}) compared with Cyto-179 (1466 kg ha^{-1}). Maximum lint % produced by MV-20 (40.3%) followed by MV-21 (40.2%) compared with standard Cyto-179 (37.9%). The line MV-22 produced the medium long staple of 29.0 mm followed by MV-21, 20 (28.5 & 28.3mm) compared with 27.0 mm of Cyto-179. All the strains have desirable micronaire values ranging from 3.8 to 4.1

µg inch^{-1}. The maximum fibre strength was produced in MV-20 (30.8 g tex^{-1}) followed by MV-21 & MV-22 (29.3 g tex^{-1}) respectively compared with 27.8 g tex^{-1} of standard Cyto-179.

Table 3.11 Performance of Cyto-strains in Micro Varietal Trial -4 during 2022-23

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	1584	35850	2.8	39.0	28.1	4.0	29.6
MV-20	1694	42064	2.7	40.3	28.3	3.9	30.8
MV-21	1704	40154	2.9	40.2	28.5	3.8	29.3
MV-22	1469	40152	2.3	39.3	29.0	3.9	29.3
MV-23	2185	37284	3.1	40.0	28.0	4.1	28.9
Cyto-179	1466	40158	3.0	37.9	27.0	4.1	27.8

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-24, MV-25, MV-26, MV-27, MV-28 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 (2401 kg ha^{-1}) followed by MV-28 (1965 kg ha^{-1}) compared with Cyto-179 (1845 kg ha^{-1}). Maximum lint % was produced by MV-26 (40.2%) followed by MV-28 (40.0%) compared with standard Cyto-179 (35.2%). The line MV-27 produced the medium long staple of 29.3 mm followed by MV-28 (28.6 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-28 (30.1 g tex^{-1}) followed by MV-25 (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 2022-23

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-24	2401	40152	2.9	39.4	28.4	4.4	29.3
MV-25	1906	41108	2.8	39.8	28.3	4.1	29.7
MV-26	1732	38718	2.8	40.2	27.9	3.8	29.2
MV-27	1804	40391	2.4	39.9	29.3	3.9	29.6
MV-28	1965	40869	2.6	40.0	28.6	3.9	30.1
Cyto-179	1845	42303	2.7	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-535 as standard. The performance of this material is given in Table 3.13. Data presented in Table 3.13 revealed that maximum seed cotton yield was produced by V-3 (2589 kg ha^{-1}) followed by V-4 (2485 kg ha^{-1}) compared with standard Cyto-535 (2235 kg ha^{-1}). Maximum lint % was produced by V-3 (40.4%) and V-6 (39.5%) compared with Cyto-535 (37.4%). The strain V-4 produced the medium long staple of 30.0 mm followed by 28.8 mm of V-5 compared with Cyto-535 (28.0 mm). All strains have desirable micronaire values ranging from 3.8 to 4.5 µg inch^{-1}. The maximum fibre strength (31.0 g tex^{-1}) produced by V-4 followed by V-5 (30.5 g tex^{-1}) compared with 27.2 g tex^{-1}of standard Cyto-535.

Table 3.13 Performance of Cyto-strains in VT-1during 2022-23

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	1922	40018	3.1	38.9	28.1	4.0	29.7
V-2	2278	40815	3.3	38.7	28.4	4.0	30.1
V-3	2589	35235	3.2	40.4	27.9	3.9	30.3
V-4	2485	40815	3.2	38.9	30.0	4.5	31.0

V-5	2314	40177	3.1	38.0	28.8	4.3	30.5
V-6	2186	31090	3.1	39.5	27.7	3.8	30.2
Cyto-535	2235	40656	3.1	37.4	28.0	3.9	27.2

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 20' ×12.5' along with Cyto-535 as standard. The performance of this material is given in Table 3.14. Data showed that maximum seed cotton yield was produced by V-7 (2015 kg ha^{-1}) followed by V-13 (2001 kg ha^{-1}) and V-9 (1925 kg ha^{-1}) compared with standard Cyto-535 (1583kg ha^{-1}). Maximum lint % was produced by V-9 (40.8%) followed by V-13 (40.3%) compared with standard Cyto-535 (36.9%).

Table 3.14 Performance of Cyto-strains in VT-2 during 2022-23

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	2015	39750	2.8	38.0	29.3	4.1	29.8
V-8	1523	39750	2.6	39.2	28.1	3.8	30.1
V-9	1925	37784	3.0	40.8	29.1	3.7	29.7
V-10	1677	38171	2.7	38.7	30.8	4.1	30.2
V-11	1598	40180	2.9	38.0	29.1	3.9	29.2
V-12	1389	37310	2.6	38.7	30.5	3.9	29.0
V-13	2001	40180	2.8	40.3	28.5	3.9	30.6
Cyto-535	1583	37884	3.2	36.9	28.9	4.5	26.7

V-10 produced medium longest staple of 30.8 mm followed by V-12 (30.5 mm) compared with Cyto-535 (28.9 mm). All the strains have desirable micronaire values ranging from 3.7 to 4.1 µg $inch^{-1}$. The maximum fibre strength (30.6 g tex^{-1}) was produced by V-13 followed by V-10 (30.2 g tex^{-1}) in contrast to standard Cyto-535 (26.7 g tex^{-1}).

Coordinated Variety Testing Programme

3.5.9 National Coordinated Varietal Trial (Set-A)

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

The cotton seed of twenty 22 strains under coded numbers was received from Director Research, Pakistan central Cotton Committee (PCCC) for evaluation. Data on seed cotton production and other parameters are presented in **Table 3.16**. The results indicated that the strain PC-2215 produced maximum yield of 1302 kg ha^{-1} followed by PC-2209 with 1248 kg ha^{-1} seed cotton yield. PC-2208 produced lowest yield that is 721 kg ha^{-1}. The strain PC-2203 produced the highest lint percentage of 41.8%, followed by PC-2215 & PC-2204 with 39.8 & & 38.7% respectively. The strain PC-2207 produced the highest value of staple length 27.7 mm, followed by PC-2215 which has staple length of 27.2 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	Seedcotton Yield (kg ha^{-1})	Lint (%age)	Staple length (mm)	Micronaire value	Fibre strength (g/tex)	Boll Weight	Plant Pop. (ha^{-1})
PC-2201	920	38.2	25.2	4.5	26.4	2.5	39493
PC-2202	1109	38.1	27.2	4.6	25.4	2.3	38748
PC-2203	1012	41.8	24.6	5.0	25.3	2.3	39346
PC-2204	995	38.7	25.8	5.0	25.6	3.0	39346
PC-2205	747	36.9	24.0	5.5	24.1	2.3	36954
PC-2206	944	37.6	24.4	5.1	25.6	2.7	42814
PC-2207	1171	38.5	27.7	4.5	27.9	2.4	31214
PC-2208	721	38.5	24.5	4.9	24.6	2.1	38030
PC-2209	1248	37.8	24.8	4.8	24.1	3.1	35998

PC-2210	798	36.7	25.3	5.4	23.1	3.0	41379
PC-2211	961	37.9	25.9	5.1	25.1	2.3	40662
PC-2212	750	38.1	24.5	4.7	25.4	2.0	37433
PC-2213	775	35.6	25.9	3.7	24.7	2.2	37074
PC-2214	771	33.9	25.7	4.6	26.5	2.3	34204
PC-2215	1302	39.8	27.2	4.6	27.1	2.1	35639
PC-2216	855	38.2	25.5	4.6	26.0	2.3	38748
PC-2217	792	37.7	25.7	4.9	25.7	2.1	37313
PC-2218	981	38.2	23.1	4.4	25.1	2.1	36954
PC-2219	868	38.7	26.4	5.0	25.6	2.3	35280
PC-2220	871	36.7	26.5	4.9	25.1	2.1	37546
PC-2221	833	36.4	23.7	5.5	25.1	2.3	39107
PC-2222	860	38.0	27.0	5.1	25.0	2.5	34802

C.D Value 5% 145.0 Sowing date = 11.05.2022

3.6. Mapping population development for Fiber Quality

Objectives: Development of mapping population for Fiber Quality

F_4 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-3.6. DNA isolation

3.7 Early Generation Seed (EGS) System

30 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	03
Cyto-537	05
Cyto-535	07
Cyto-226	01
Cyto-124	02
CIM-608	02

3.8 Cotton Biotechnology

The Biotechnology lab has been established to develop local cultivars with export quality yield and 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 (Family 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.

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.

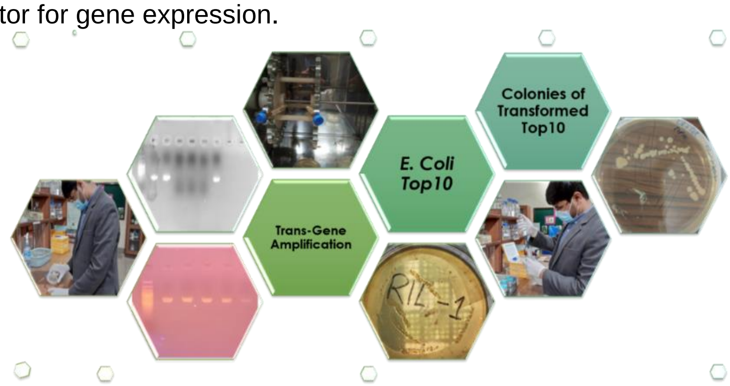


Fig: 3.7: Gene Cloning and Transformation

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 will be cloned into pCAMBIA1309 Plasmid vector, then this construct will be transformed to Agrobacterium for plant transformation.

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.

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4. ENTOMOLOGY SECTION

Studies were carried out on various aspects under field and laboratory conditions including

- Surveys of cotton growing areas for pink bollworm infestation.
- Studies on Eco-friendly management of cotton insect pests.
- Management of pink bollworm using attractants and different colored adhesive-cloths sheets.
- Monitoring of Lepidopterous pests with sex pheromone and light traps,
- National Coordinated Varietal Trials on *Bt.* & non-*Bt.* strains.
- Impact of cotton sowing period on sucking insect pests and their natural enemies' population tendency.
- Incidence of arthropods on light and normal green cotton leaves.
- 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 Dera Ghazi Khan, Rajanpur and Muzaffargarh districts of Punjab were surveyed in September and October, 2022 for damage assessment by pink bollworm in green bolls and infestation levels of sucking insect pests **(Table-4.1).** A total of 25 cotton fields in DGK, 30 in Rajanpur and 55 in Muzaffargarh were observed and mature bolls were collected and examined in the laboratory to record the population of pink bollworm.

Among the sucking insect pests, mean number of jassid, whitefly and thrips were below ETL in all the districts with few patches of mealybug and cotton stainer including small population of dusky cotton bug. An increasing trend in pink bollworm population was observed in October in all districts except DGK.

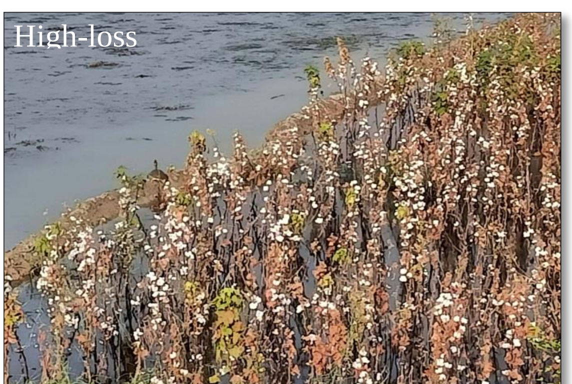


Fig. 4.1. Cotton crop damage caused by flood in Rajanpur district

In Rajanpur, Muzaffargarh and DGK districts, cotton crop fields submerged under flood water followed by monsoon rains that adversely affected seed-cotton yield especially in Rajanpur district in comparison with DG Khan district **(Fig. 4.1).**

Table-4.1 Mean plant and incidence of pink bollworm and sucking in DGK, Rajanpur and Muzaffargarh districts.

Districts	September				October			
	%PBW A. Lar.	Sucking Insect Pests/leaf			%PBW A. Lar.	Sucking Insect Pests/leaf		
		Jassid	Whitefly	Thrips		Jassid	Whitefly	Thrips
Multan	51	0.2	1.97	0.5	69	0.0	1.4	0.2
Khanewal	58	0.3	1.84	0.4	74	0.1	1.2	0.1
Vehari	20	0.2	1.76	0.8	43	0.2	1.35	0.2
Bahawalpur	47	0.4	1.68	0.7	59	0.1	1.28	0.3
Lodhran	60	0.2	1.63	0.5	72	0.1	1.16	0.4
DGK	18.2	0.2	3.0	0.1	26.8	0.1	2.0	0.0
Rajanpur	15.3	0.7	2.5	0.3	31.7	0.6	1.7	0.1
Muzaffargarh	25.4	0.3	2.8	0.2	24.2	0.1	2.0	0.0

***A.Lar =** Alive larvae

4.1.2 Studies on Eco-friendly Management of cotton insect pests

Biocontrol agents against cotton insect pests, especially those of pink bollworm and armyworm were explored to mitigate economic losses and discouraging indiscriminate use of insecticides. For this purpose, one male and two females of *Rhynocoris marginatus* (Hemiptera: Heteroptera, Reduviidae: Harpactorinae), a potential predator of many insect pests, were collected from Swabi district of Khyber Pakhtunkhwa. Sufficient mass production under special care was established on armyworm, pink bollworm, cotton stainer and grain moth (*Sitotroga cerealella*) **(Fig. 4.2),** however, evaluation of different formulations of artificial diets is still in progress. Augmentative releases are planned to be made in the upcoming cotton season (2023) to induce insecticidal and heat resistance ability by direct exposure to the predator and assessment of its bio-control efficacy in the field.

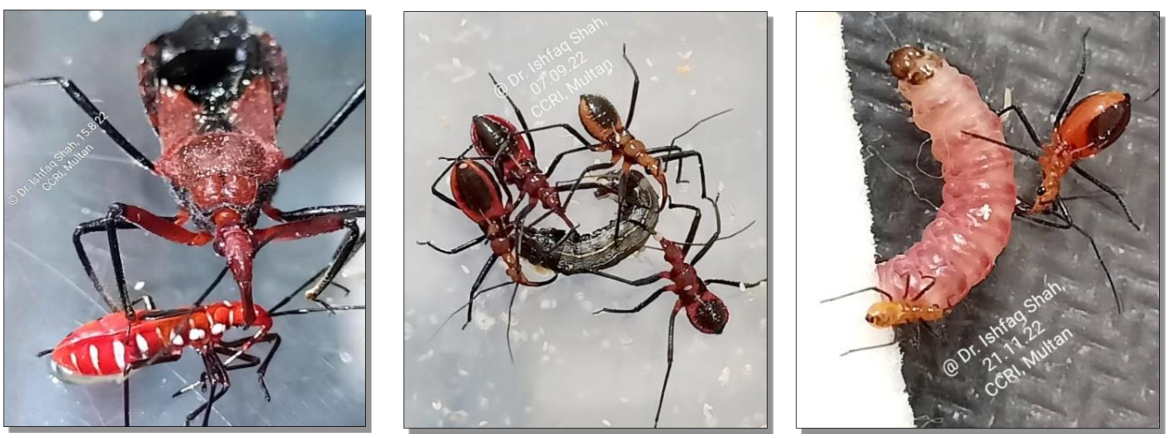


Fig.4.2 ***Rhynocoris marginatus*** **adult and nymphs predating on cotton stainer, armyworm and pink bollworm.**

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

The attraction of pink bollworm moths (both sexes) to green, nevy-blue, black, white, red and yellow adhesive cloths and male moths to pheromone/sex traps was evaluated in the field. The adhesive cloth sheets of 91.44 Sq.cm each were mounted stretched about 3 feet above the ground with the help of two bamboo sticks fixed in soil. 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 15-20 days intervals.

Highest mean moth catches were found in November on red adhesive cloth sheet followed by green in October and pheromone lure trap in November whereas, mean lowest moth catches were recorded on white adhesive cloth sheet followed by yellow in October. Overall, highest moth attraction was observed to green colour followed by red, whereas, highest number of moths were caught in November followed by October and December **(Fig.4.3).**

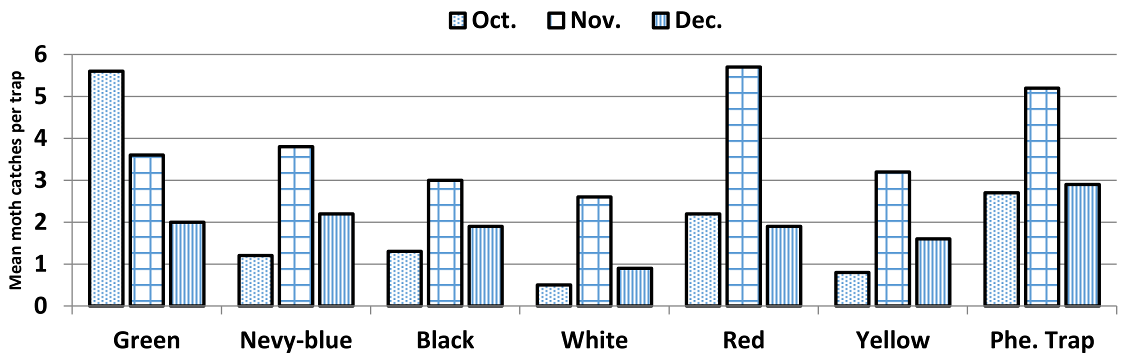


Fig. 4.3 Mean moth catches in different colored adhesive-cloths sheets and sex trap

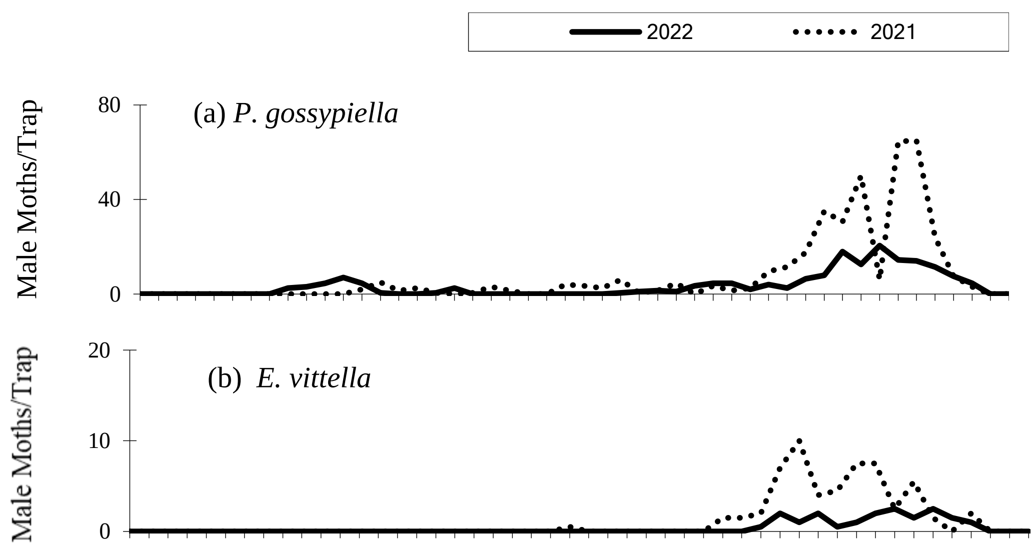
4.2 Monitoring of lepidopterous pests

4.2.1 Monitoring of lepidopterous pests with sex pheromone traps

Male Moth's 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 all lepidopterous pests as compared to last year **(Table-4.2).** Weekly male moth catches are given in **Fig. 4.4 (a-f).**

4.2.1.1 *Pectinophora gossypiella* (Pink bollworm)

Male Moth's activity started in in 1st week of March with fluctuating trend afterwards. Maximum catches were recorded in 1st week of November. **(Fig. 4.4a).** Overall, male moth catches were 54.8% lower than last year **(Table-4.2).**



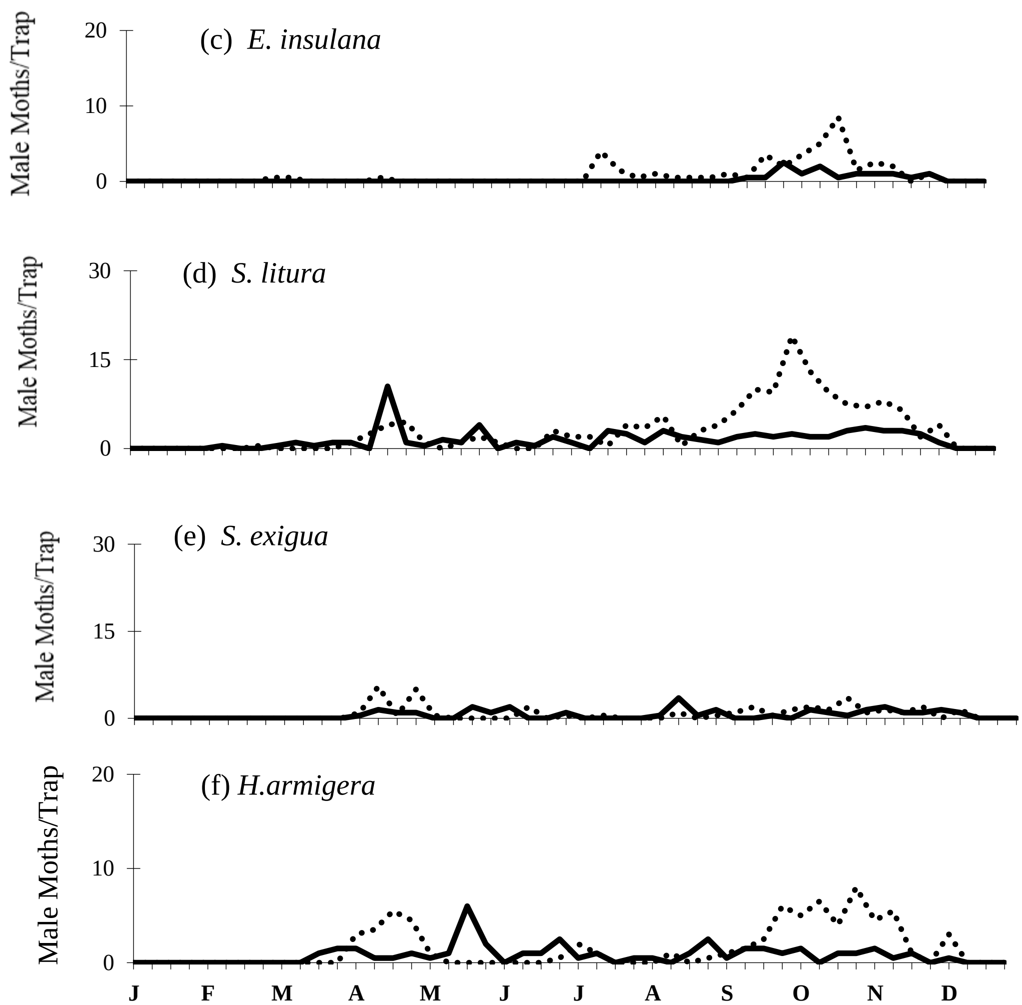


Fig.4.4 Weekly male moth catches of Lepidopterous pests in sex pheromone traps at CCRI, Multan and farmer's field (Khanewal).

4.2.1.2 *Earias vittella* (Spotted bollworm)

Male Moth's catches remained zero upto 1st week of September. Moth's activity started in 2nd week of September with fluctuating trend afterwards. **(Fig. 4.4b).** Overall, male moth catches were 68.7% lower as compared to last year **(Table-4.2).**

4.2.1.3 *Earias insulana* (Spiny bollworm)

Male Moth catches were zero up to 2nd week of September. Moth's activity was not consistent and showed fluctuating trend throughout the season **(Fig. 4.4c).** Total number of moth catches was 72.0% lower than last year **(Table-4.2).**

4.2.1.4 *Spodoptera litura* (Armyworm)

Male Moth's activity started from 2nd week of February and reached at its peak in 3rd week of April with fluctuating trend afterwards **(Fig. 4.4d)**. Overall, male moth catches were 52.4% lower as compared to last year **(Table-4.2).**

4.2.1.5 *Spodoptera exigua* (Beet armyworm)

Male moth's activity remained zero upto 4th week of March and its peak was observed in 2nd week of August **(Fig. 4.4e)**. Total number of male moth catches were about 23.6% lower than the last year **(Table-4.2).**

4.2.1.6 *Helicoverpa armigera* (American bollworm)

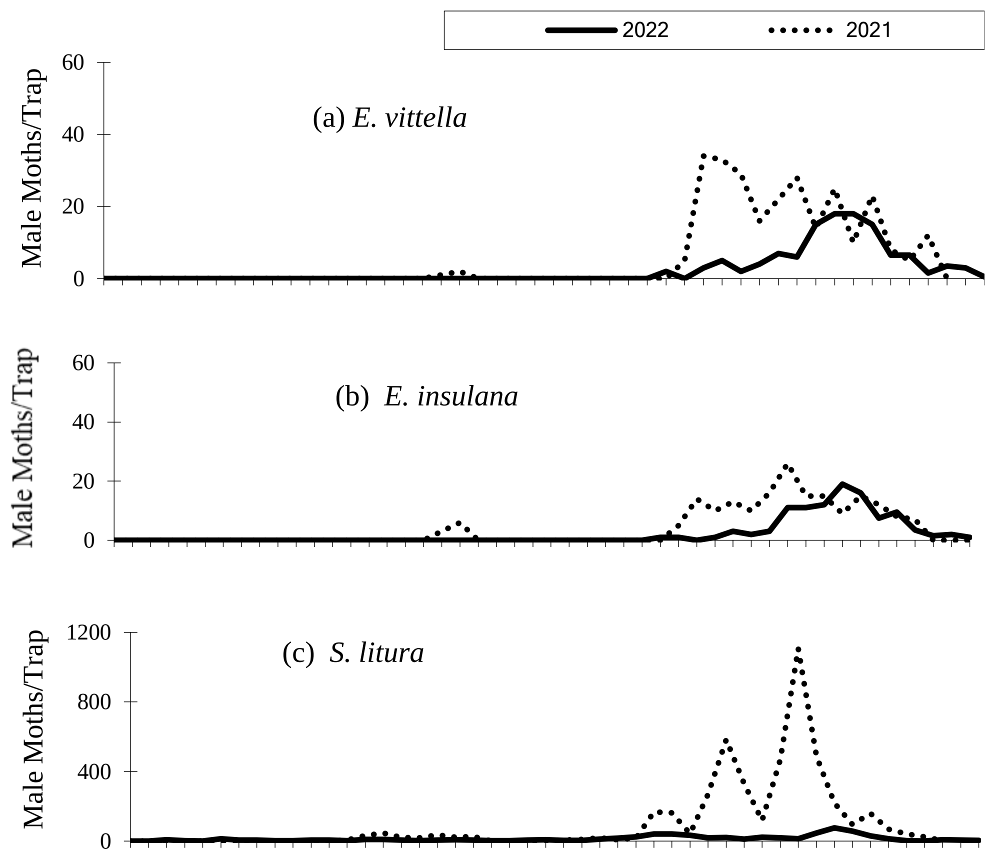
Male moth's activity started in 3rd week of March with inconsistent trend and its peak was observed in 3rd week of May **(Fig. 4.4f)**. Overall, male moth catches were 74.6 lower to that of last year **(Table-4.2).**

Table-4.2 Comparison of male moth catches of lepidopterous pests in sex pheromone traps

Insect pest	CCRI, Multan		
	2021	2022	+ %age
P. gossypiella	370.5	167.5	**-54.8**
E. vittella	57.5	18.0	**-68.7**
E. insulana	41.0	11.5	**-72.0**
S. litura	148.0	70.5	**-52.4**
S. exigua	36.0	27.5	**-23.6**
H. armigera	71.0	18.0	**-74.6**

4.2.2 Monitoring of lepidopterous pests with light traps

Moth's activity of *E. insulana*, *E. vittella*, *S. litura*, *S. exigua* and *H. armigera* was monitored throughout the year with inflorescent light traps at CCRI, Multan. Overall, declining population trend was detected in all lepidopterous pests as compared to last year **(Table-4.3).** Moth catches on weekly basis are given in **Fig. 4.5 (a-e).**



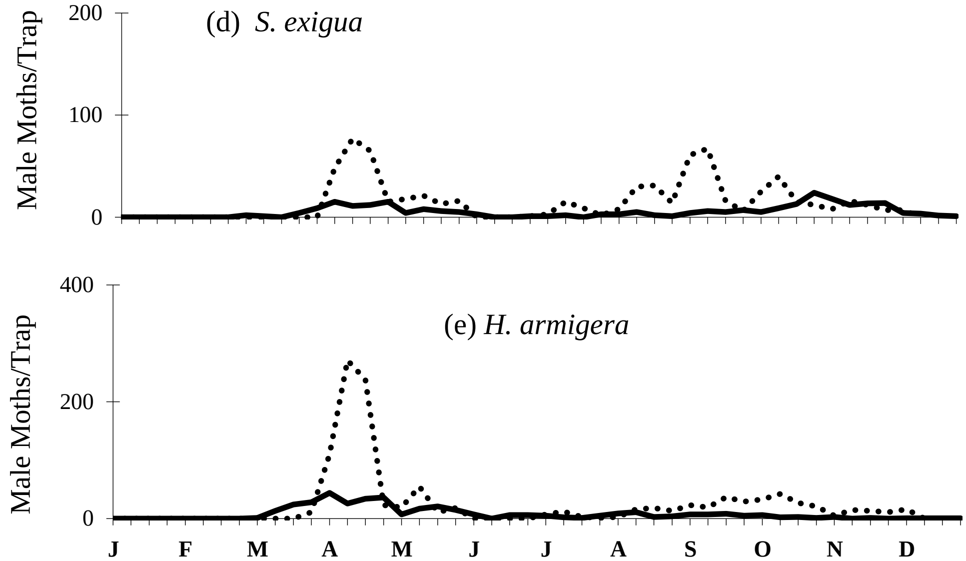


Fig. 4.5 Weekly moth catches of lepidopterous pests in light traps at CCRI, Multan

4.2.2.1 *Earias vittella* (Spotted bollworm)

Moth's activity remained zero from January to 2nd week of August. Population was inconsistent throughout the season and reached to its maximum in 4th week of October **(Fig. 4.5a).** Overall number of moth catches was 56.4% lower as compared to last year **(Table-4.3).**

4.2.2.2 *Earias insulana* (Spiny bollworm)

Moth catches were zero upto 2nd week of August. Afterwards, population increased with fluctuating trend and reached at its peak in 1st week of November **(Fig. 4.5b).** Total number of moth catches was 42.9% lower than last year **(Table-4.3).**

4.2.2.3 *Spodoptera litura* (Armyworm)

Moth's activity started in 3rd week of January with fluctuating trend throughout the season and its peak intensity was observed in 4th week of October **(Fig. 4.5c)**. Total number of moth catches was 86.0% lower than the last year **(Table-4.3).**

4.2.2.4 *Spodoptera exigua* (Beet armyworm)

Moth catches of *S. exigua* appeared in 4th week of February with inconsistent trend and its peak was detected in 4th week of October **(Fig. 4.5d)**. Overall, moth catches were 62.6% lower as compared to last year **(Table-4.3).**

4.2.2.5 *Helicoverpa armigera* (American bollworm)

Moth's activity remained zero upto 4th week of February and reached at its peak in 1st week of April **(Fig. 4.5e)**. Overall, moth catches were 67.0% lower to that of last year **(Table-4.3).**

Table-4.3 Comparison of moth catches of lepidopterous pests in light traps based on total catches during the year/trap

Insect pest	2021	2022	% change (±)
Earias vittella	267.0	116.5	**-56.4**
Earias insulana	184.0	105.0	**-42.9**
Spodoptera litura	4615.5	644.0	**-86.0**
Spodoptera exigua	678.0	253.5	**-62.6**
Helicoverpa armigera	1120.0	370.0	**-67.0**

4.3 National Coordinated Varietal Trials (NCVT)

4.3.1 Pest situation in set-B (B-2223-B-2245)

In this set-B, 23 cotton strains were tested for their tolerance/susceptibility to insect pest complex. During the month of July, jassid population was above ETL while whitefly and thrips populations were below ETL on all tested varieties. During the month of August, jassid and whitefly population were above ETL while thrips populations were below ETL on all tested varieties. During the month of September, jassid and thrip populations were below ETL while whitefly was above ETL on all tested varieties **(Table-4.4)**.

Table-4.4 Seasonal population of sucking insect pests in Set-B

Strains	Number of sucking insect pests per leaf								
	Jassid			Whitefly			Thrips		
	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep
CEMB-AAS-3	3.1	0.2	0.1	7.6	5.3	6.4	0	0.5	0.2
IR-NIBGE-17	1.6	0.1	0	8.0	7.1	5.2	0.8	0.6	0.3
IR-NIBGE-20	2.3	0	0	7.2	6.5	5.5	0	0.1	0
KZ-181	1.4	0.5	0	8.2	4.6	5.1	0	0.3	0.2
NIAB-868	1.7	0.3	0	12.1	9.4	8.4	0	0.4	0.2
Silver-Queen-33	2.2	0.4	0.1	11.2	8.4	6.9	0.6	0	0
CIM-600 (Bt. Std)	2.3	0.1	0	10.9	7.5	6.7	0.7	0	0
IUB-4	2.1	0.2	0.1	11.1	6.4	5.9	0.3	0	0.3
Bahar-GTG-155	2.2	0.1	0	9.5	3.7	4.1	0.3	0.2	0.4
IUB-23	2.5	0	0	10.5	6.9	5.4	0.9	0.5	0.1
Captain-300	2.2	0.3	0.1	13.9	4.5	3.7	0.7	0.3	1.0
PC-2234	4.1	0.4	0.1	8.5	6.1	5.8	1.1	1.0	0.1
VH-447	2.8	0.2	0	9.9	8.4	7.7	1.2	0	0
Tipu-10	1.8	0	0	9.8	7.3	6.8	1.1	0	0.2
PC-2237	2.0	0	0	10.1	6.6	5.6	1.2	0	0.1
FH-415	2.6	0.2	0.1	10.9	8.7	7.2	0.4	0.2	0
Diamond-2024	2.3	0.4	0.3	10.7	10.8	8.7	1.2	0	0
FH-189	1.1	0.1	0	4.5	3.9	2.8	0	0	0.6
Sahara-kleam-10	2.3	0.2	0	10.9	8.8	7.4	0.6	0.3	0.5
RH-Bagh-O-Bahar	1.7	0.1	0	15.2	10.5	9.3	0.6	0.2	0.4
KZ-111	2.0	0.2	0	14.3	11.3	7.5	0.9	0.1	0.2
RH-Gold-1	2.7	0.4	0.2	11.5	9.8	6.4	1.0	0	0.8
Silver-Queen-33	2.2	0	0	15.0	7.6	6.6	1.2	1.0	0

4.3.2 Pest situation in Set (C-2201-C-2222)

In this set-C 22 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 July. During the month of August, jassid and thrip populations were fluctuating on all tested varieties and were below ETL while whitefly was above ETL on all tested varieties. During the month of September, jassid and thrip populations were below ETL while whitefly was above ETL on all tested varieties **(Table-4.5**).

Table-4.5 Seasonal population of sucking insect pests in Set

Strains	Number of sucking insect pests per leaf								
	Jassid			Whitefly			Thrips		
	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep
NIAB-585	1.7	0.1	0	10.8	9.8	6.9	1.2	0.8	0
FH-416	1.8	0	0.1	10.5	7.9	6.7	0.2	0	0.1
CS-303	2.7	0	0.2	11.6	8.8	7.4	0.9	0.5	0
CIM-600 (Bt. Std)	1.8	0	0	12.3	7.6	6.2	0.7	0.2	0
FH-938	2.6	0.2	0.1	10.3	9.4	8.4	0.9	0.7	0.1
ZAR-22	2.2	0.1	0.1	14.9	9.1	7.3	0.3	0.1	0.2
IUB-21	1.4	0	0.2	10.0	8.5	6.5	0.2	0	0.6
PC-2208	2.1	0	0	13.4	7.7	6.8	1.0	0.6	0
NIAB-787	2.1	0.4	0.3	11.8	6.9	5.5	0.8	0.3	0
Super-Sultan-22	1.8	0.3	0.1	9.9	9.7	8.3	1.1	0	0.2

IR-NIBGE-19	1.9	0.9	0.5	10.0	9.2	7.6	0	0	0.6
VH-442	1.3	0.3	0	9.0	8.4	6.5	0.7	0	0.4
Inqalab-101	1.7	0.4	0	10.0	9.5	8.8	0.3	0	0
Tahafuz-2025	1.7	0	0	13.3	8.6	6.4	0	0	0
Sahara-500	1.6	0	0.3	12.7	10.7	9.4	0	0	0.1
IUB-222/111	1.7	0.6	0.1	10.4	9.9	8.2	0.2	0.1	0
Certus-10	1.5	0.4	0	10.2	11.3	8.2	0	0.4	0
FH-333	1.8	0.8	0.3	12.6	10.2	7.8	0	0.1	0
PC-2219	1.6	0	0.1	14.3	11.6	9.9	0.7	0.4	0.2
CS-424	1.8	0	0	13.1	10.7	8.6	1.1	0.6	0.4
MNH-Super-Gold-2022	1.9	0	0.2	8.9	7.5	5.3	0.9	0.7	0.3
ASPL-710	1.4	0.1	0.1	12.6	9.3	4.9	1.1	1.0	0.1

4.4 Impact of cotton sowing period on sucking insect pests and their natural enemies' population tendency

The trial was conducted to assess the effect of different sowing periods of cotton on buildup of sucking insect pests and their natural enemies and to devise their management strategies. The Set-1 (Early-April) was planted on 1st April, Set-II (Early-May) on 2nd May and Set-III (Early-June) on 1st June. Two Bt varieties (Bt.CIM.663 & Bt.CIM-785) and two non Bt varieties (CIM-554 & CIM-620) were planted in split-plot design with three replicates. Main plots were sowing dates whereas varieties were in subplots. Data recording on sucking insect pests and predators was started 20 days after sowings (DAS) at weekly interval.

Prevalence of jassid in Set-1 (Early-April) was detected in May with fluctuating trend throughout the season and its peak intensity was noticed in June. In Set-2 (Early-May), jassid appeared in May with peak infestation just at cotton seedling stage. In Set-3 (Early-June), it remained below ETL throughout season **(Fig. 4.6a).** On the whole, seasonal average incidence of jassid was higher in May **(Fig. 4.7a).** Varieties showed no profound impact on jassid intensity and its maximum population was observed in Set-2 on all the tested varieties. Overall, jassid population was higher in Early- May sown plots as compared to Early-April and Early-June **(Table-4.6).**

Whitefly remained dominant among sucking pests and it appeared during last week of April in Set-1 with peak intensity in June. In Set-2, its prevalence was detected in May with fluctuating trend afterwards. Its peak was observed in August in both Set-2 and Set-3 **(Fig. 4.6b).** Rainfalls severely affected whitefly population buildup in July and overall maximum seasonal average intensity of whitefly was recorded in August followed by June **(Fig. 4.7b).** Varieties showed almost similar response to whitefly with respect to sowing dates. In general, whitefly was lower in Early- May sown plots as compared to Early-April and Early-June **(Table-4.6).** Thrips population remained below ETL throughout the season on all tested varieties in all sowing dates. However, its population was comparatively higher in Early-April sown cotton. **(Fig. 4.6c, 4.7c; Table-4.6).**

Among the natural enemies, the *Chrysoperla carnea, Orius* spp. and spiders were dominant predators. Prevalence of *C. carnea* and spiders was observed in April in Set-1 and in May in Set-2 and their population reached at its peak during August in both sets. *Orius* spp., *Coccinellid* Spp. and *Geocoris* spp. appeared in May and June in Set-1 and set-2, respectively. While, in Set-3 all the noted predators appeared in July. Total number of predators was higher in August in all the three sets **(Fig. 4.8 a-f).** *C. carnea*, spiders, *Orius* spp. *Coccinellid* Spp. and *Geocoris* spp. was comparatively higher in Set-1 than Set-2 and Set-3 **(Fig. 4.8 a-f; Table-4.7)**. Population of predators was low in early stage of the crop because of low sucking insect pests' population. Afterwards, number of predators increased with the increase in sucking pest's population. Similar to the sucking pests, rainfall also affected the predators and caused decline in their population in July. Mean seasonal incidence of *C. carnea* and spiders was higher in August. However, maximum mean seasonal incidence of *Orius* spp. and *Geocoris* spp. was observed in June and *Coccinellid* spp. in September. Overall, mean seasonal incidence of total predator was higher in June and August **(Fig. 4.9 a-f)**.

There was no profound impact of varieties on predator's incidence as their response was almost alike in the respective sowing dates. Overall, predators' number was higher in Early-April sown cotton followed by Early-May while lower in Early-June sown cotton **(Table-4.7).** Though July and August are critical months due to increased pest pressure but natural enemies peak incidence was observed at the same time on cotton so, the farmers are advised to delay the first spray and apply spray keeping in view natural enemies population.

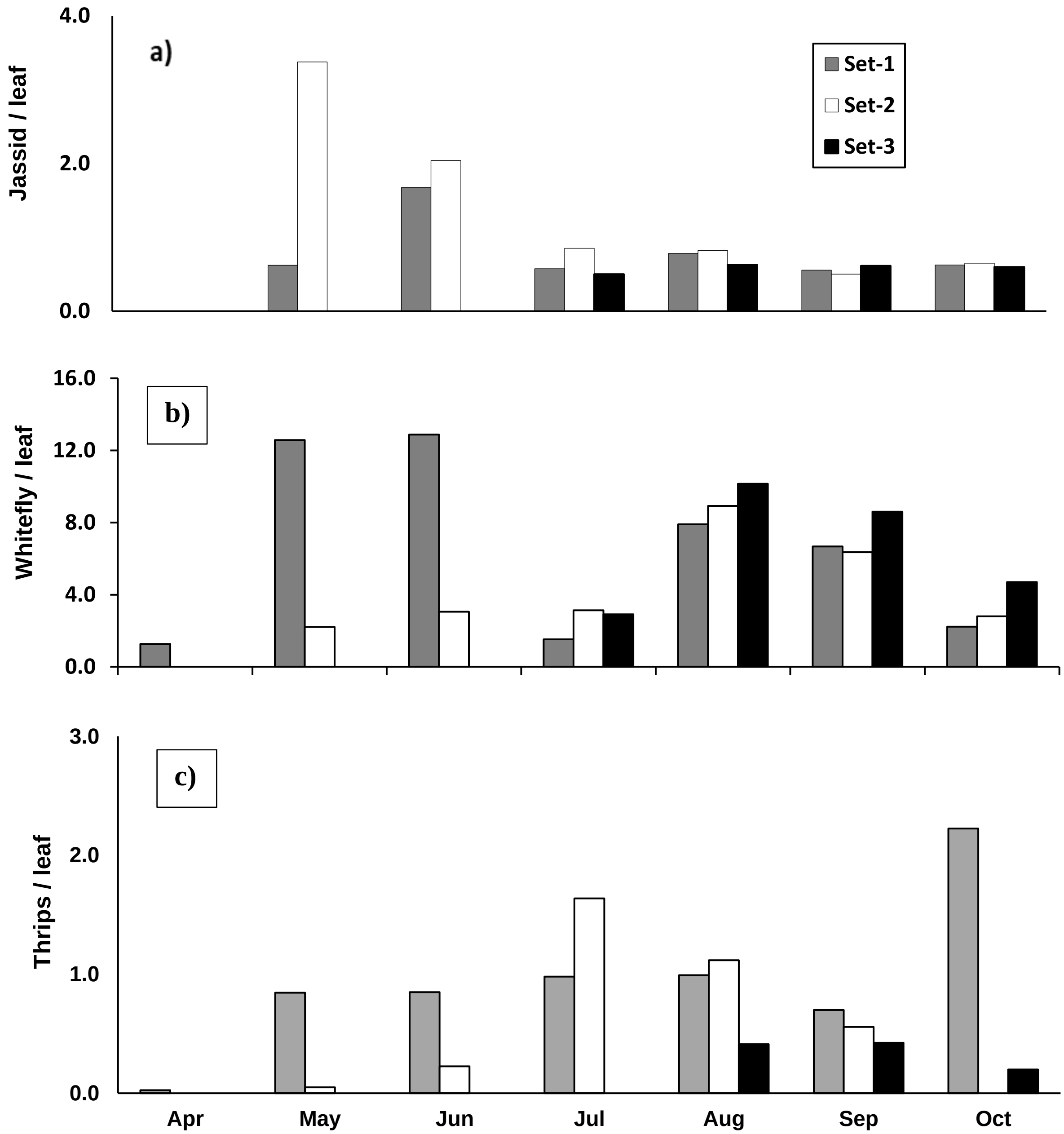


Fig. 4.6 **Impact of cotton sowing period on population dynamics of a) jassid, b) whitefly and c) thrips. Set-1, Set-2 and Set-3 represent Early-April, Early-May and Early-June sowing dates**

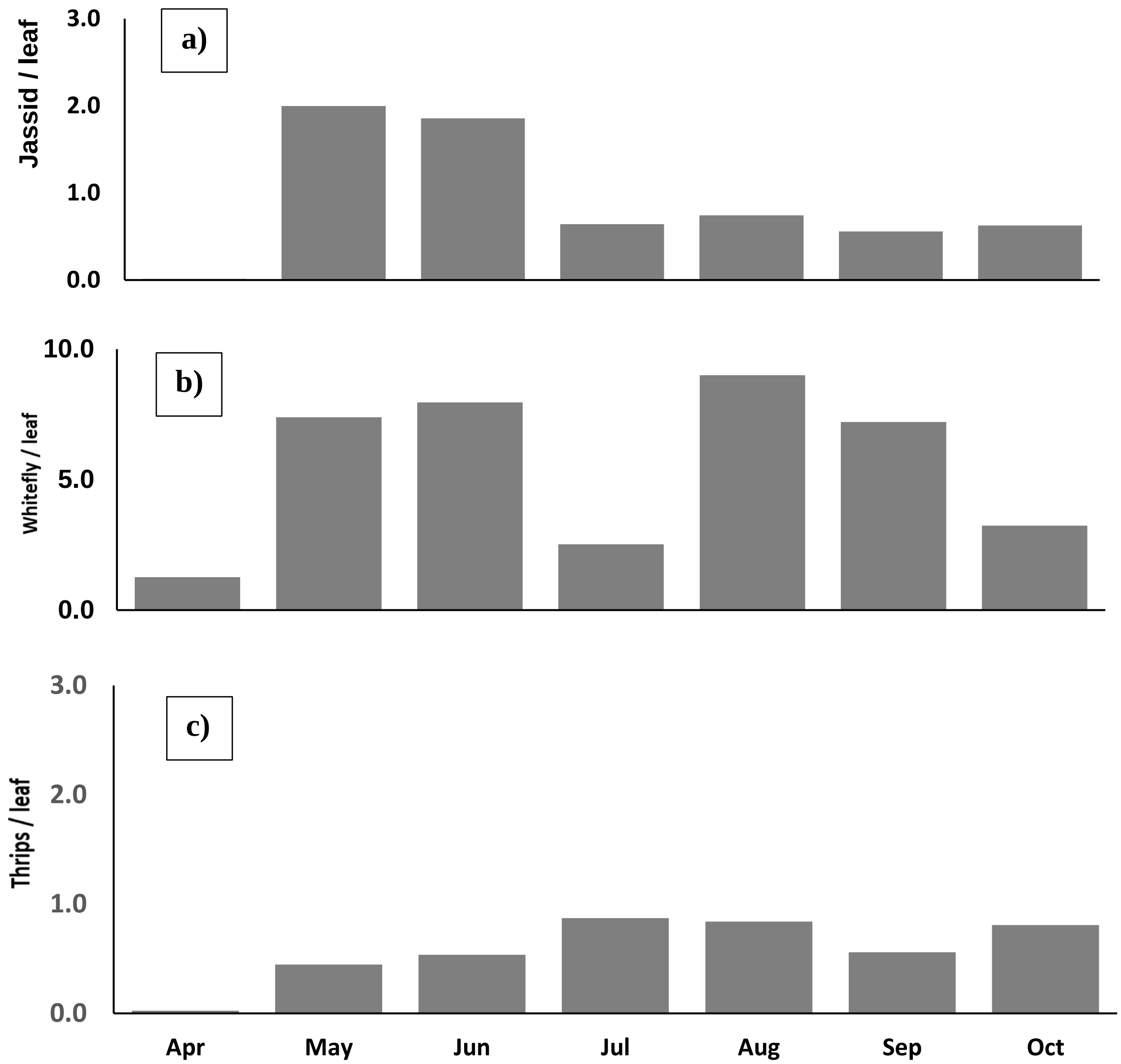
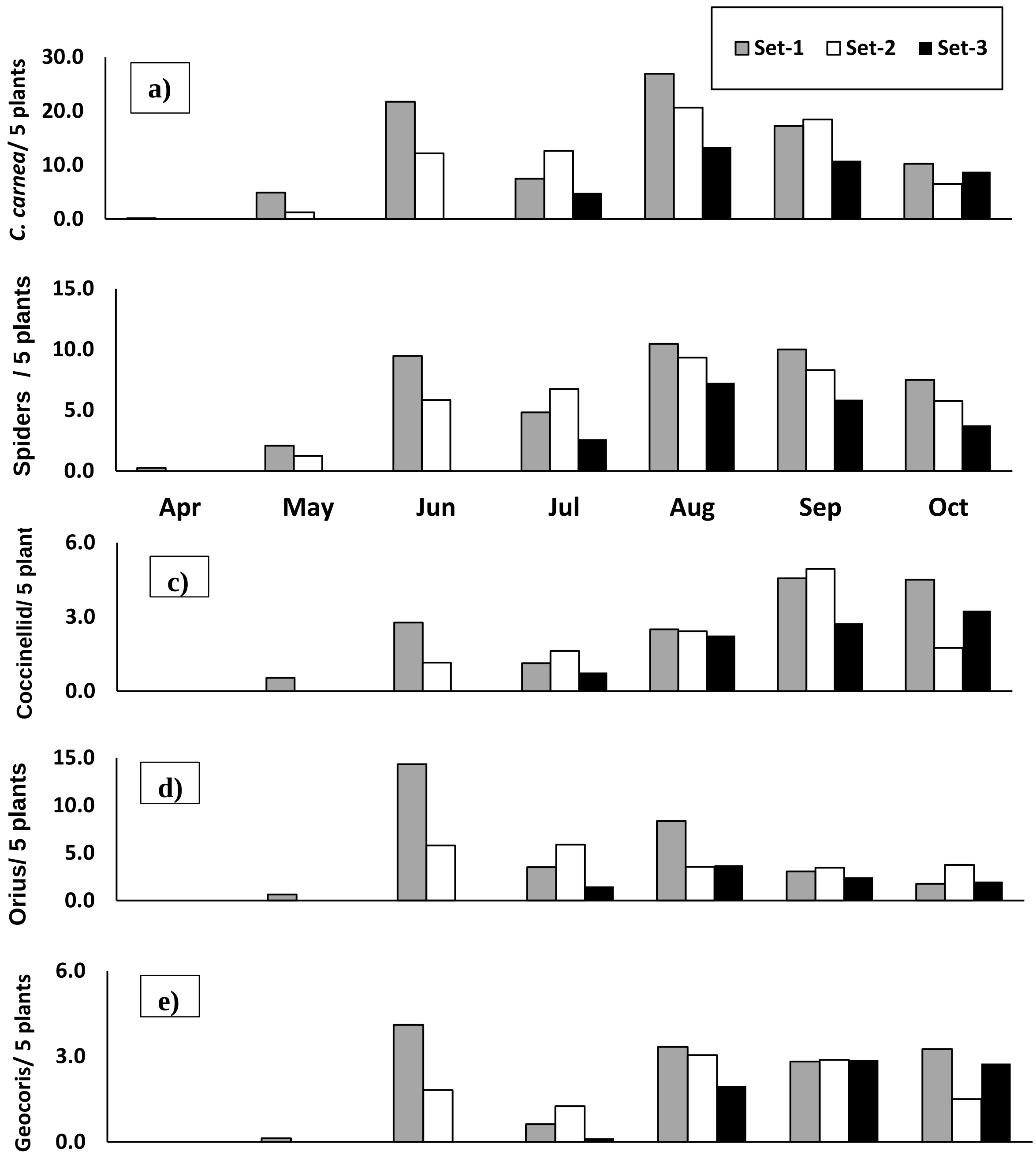


Fig. 4.7 Mean seasonal incidence of a) jassid, b) whitefly and c) thrips

Table-4.6 Interactive impact of sowing date and varieties on sucking pest's intensity

Sowing date	Variety	Sucking pests/leaf		
		Jassid	Whitefly	Thrips
April (Set-1)	Bt.CIM-663	0.7	6.1	0.9
	Bt.CIM-785	0.8	7.0	1
	CIM-554	0.7	6.1	1
	CIM-620	0.7	6.6	1
	Aver.	**0.7**	**6.5**	**1.0**
May (Set-2)	Bt.CIM-663	1.3	4.5	0.4
	Bt.CIM-785	1.6	4.3	0.7
	CIM-554	1.3	4.3	0.5
	CIM-620	1.2	4.5	0.7
	Aver.	**1.4**	**4.4**	**0.6**
June (Set-3)	Bt.CIM-663	0.6	6.8	0.3
	Bt.CIM-785	0.4	6.7	0.2
	CIM-554	0.6	6.2	0.2
	CIM-620	0.5	6.7	0.3
	Aver.	**0.5**	**6.6**	**0.3**


Set-1
Set-2
Set-3
a)
C. carnea/ 5 plants
30.0
20.0
10.0
0.0
Spiders / 5 plants
15.0
10.0
5.0
0.0
Apr
May
Jun
Jul
Aug
Sep
Oct
c)
Coccinellid/ 5 plant
6.0
3.0
0.0
d)
Orius/ 5 plants
15.0
10.0
5.0
0.0
e)
Geocoris/ 5 plants
6.0
3.0
0.0

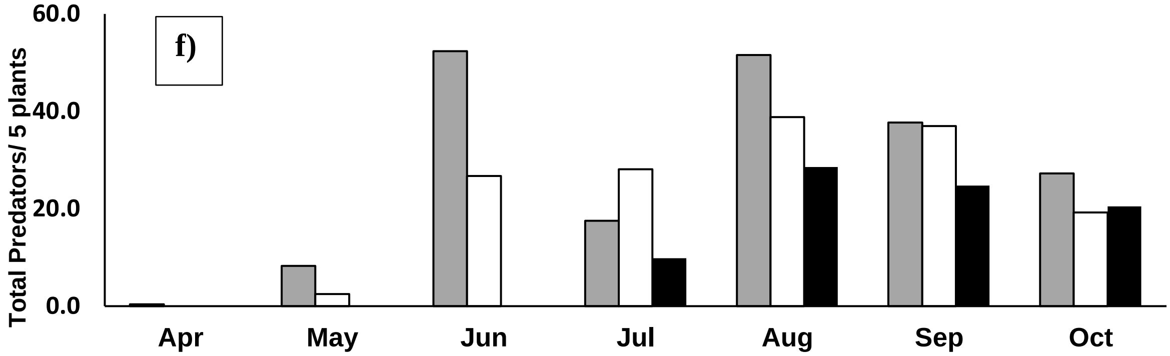
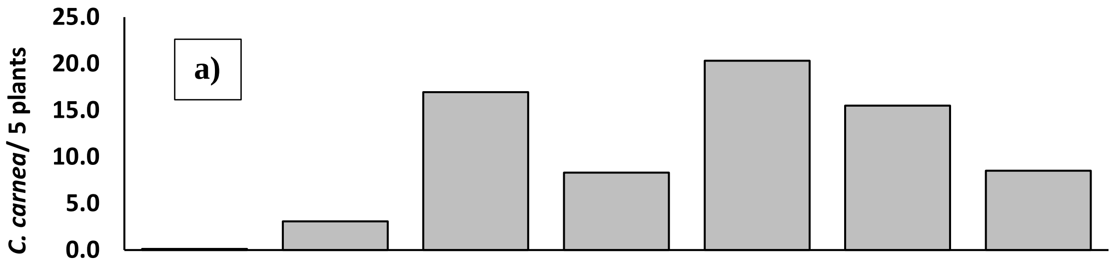
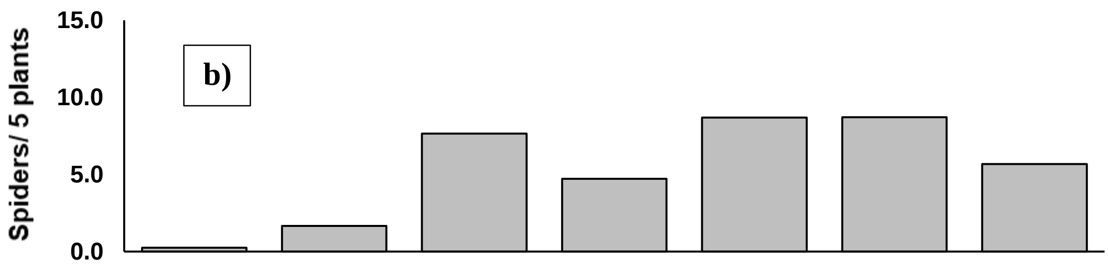


Fig. 4.8 Impact of cotton sowing period on population dynamics of natural enemies a) *Chrysoperla carnea,* b) spiders, c) *Coccinellid* spp., d) *Orius* spp., e) *Geocoris* spp. and f) total predators. Set-1, Set-2 and Set-3 represent Early-April, Early-May and Early-June sowing dates





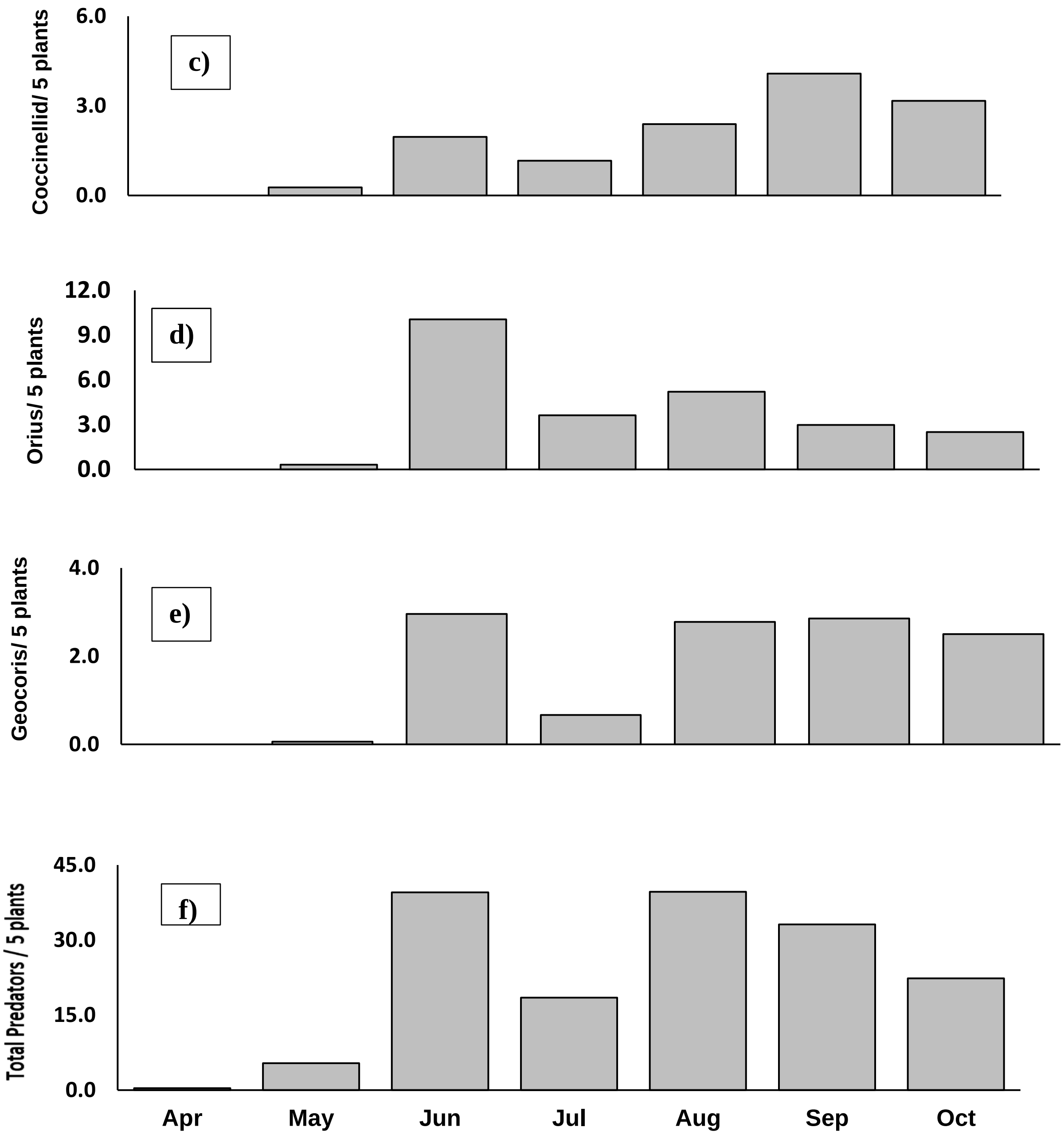


Fig. 4.9 Mean seasonal incidence of natural enemies a) *Chrysoperla carnea,* b) spiders, c) *Coccinellid* spp., d) *Orius* spp., e) *Geocoris* spp. and f) total predators.

Table-4.7 Interactive impact of sowing date and varieties on natural enemies intensity

Sowing date	Variety	Predators/ 5plants					
		C. carnea	Spiders	Coccinellids	Orius	Geocoris	Total
Set-1 (Early-April)	CIM-663	12.2	6.5	2.4	4.6	1.7	27.4
	CIM-785	13.1	6.3	2.1	4.2	2.3	27.9
	CIM-554	11.8	6.6	2.5	4.3	2.2	27.4
	CIM-620	13.6	6.1	2.2	5	1.9	28.8
	Aver.	**12.7**	**6.4**	**2.3**	**4.5**	**2.0**	**27.9**
Set-2 (Early-May)	CIM-663	11.3	7.1	2.2	3.3	2.2	26.1
	CIM-785	12.5	6.3	2.2	3.5	1.6	26.1
	CIM-554	13	6	1.8	3.8	1.4	25.9
	CIM-620	13	6	1.8	3.8	1.4	25.9
	Aver.	**12.4**	**6.3**	**2.0**	**3.6**	**1.6**	**26.0**
Set-3 (Early June)	CIM-663	8	5.2	1.8	1.7	1.9	18.5
	CIM-785	9.8	4.6	2.2	2.7	1.2	20.5
	CIM-554	11	4.6	2.8	2.2	2.5	23.1
	CIM-620	9	5	2.3	3.1	2.1	21.6
	Aver.	**9.5**	**4.9**	**2.3**	**2.4**	**1.9**	**20.9**

4.5 Incidence of arthropods on light and normal green cotton leaves

Light-green (CIM-775, CIM-875 and Sahara-110) and normal-green (CIM-785 and CIM-678) cotton genotypes/varieties were compared under unsprayed and sprayed conditions regarding incidence of sucking insect pests, CLCV disease, beneficial fauna, alive larvae of pink bollworm and seed cotton yield. Plant protection was carried out on the sprayed block when the pests pressure reached ETL, however, at an early stage of the crop, application of insecticide was done due to heavy infestation of jassid and thrips on unsprayed block, whereas, standard agronomical practices were employed uniformly both on unsprayed and sprayed blocks.

4.5.1 Sucking insect-pests

Among the light-green leaf genotypes/varieties, Sahara-110 was recorded as comparatively resistant against jassid and whitefly in both unsprayed and sprayed blocks; whereas, CIM-775 and CIM-875 were recorded marginally below or above ETL in both unsprayed and sprayed blocks **(Fig. 4.10)**. Among normal-green leaf genotypes/varieties, mean number of jassid and whitefly per leaf was recorded above ETL in both unsprayed and sprayed blocks. Overall, number of thrips per leaf was recorded highly below ETL in unsprayed and sprayed blocks on all the six genotypes/varieties.

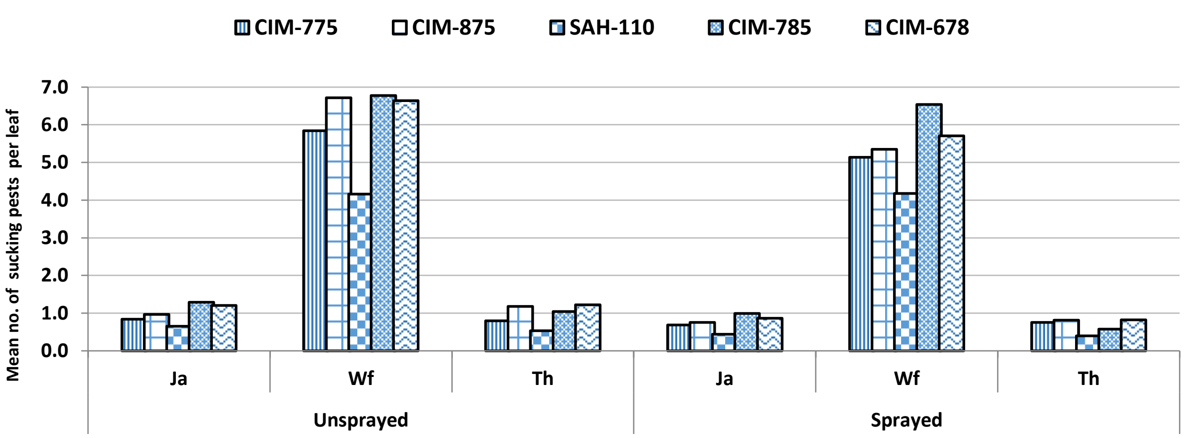


Fig. 4.10 Mean number of jassid, whitefly and thrips on different cotton genotypes/varieties in unsprayed and sprayed conditions.

4.5.2 CLCV disease

The lowest CLCV disease was recorded under sprayed condition on CIM-775 (4.4%) followed by CIM-775 (6.6%) and CIM-875 (7.5%) unsprayed condition at 60DAP, whereas, at 90DAP CIM-775 was comparatively resistant in unsprayed condition (13.1%) as compared with sprayed (16.3%) block **(Fig. 4.11)**. Overall, the most susceptible genotypes/varieties were CIM-785 and CIM-678 with 100% disease outbreak at 90DAP in both unsprayed and sprayed conditions followed by Sahara-110 (84.8%) in unsprayed and (99.1%) in spayed conditions at 120DAP, whereas, the most resistant genotype recorded was CIM-775 with (24.6%) in sprayed and (31.7%) in unsprayed blocks at 120DAP.

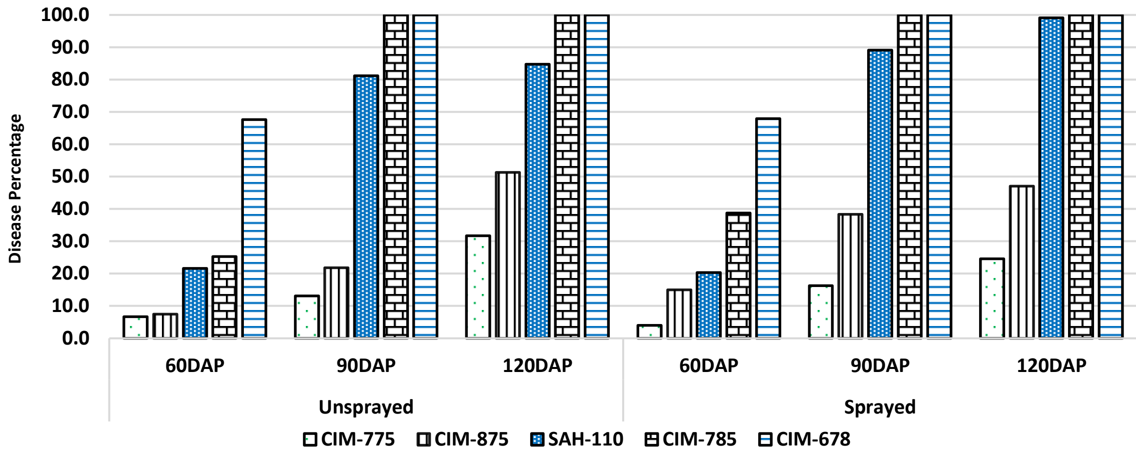


Fig. 4.11 Mean incidence (%) of CLCV disease of jassid on different cotton genotypes/varieties.

4.5.3 Beneficial arthropods

Among the beneficial arthropods, the highest mean number of (3.1/5plants) recorded was that of geocoris in unsprayed conditions followed by spiders 3.0/5plants, however, in sprayed conditions, spiders were comparatively resistant against chemical insecticides being 2.4/5plants followed by geocoris 1.6/5plants. Overall lowest mean numbers of predators were recorded in Shara-110 both unsprayed and sprayed conditions due to light-green leaves showing less attraction for sucking insect pests **(Fig. 4.12).**

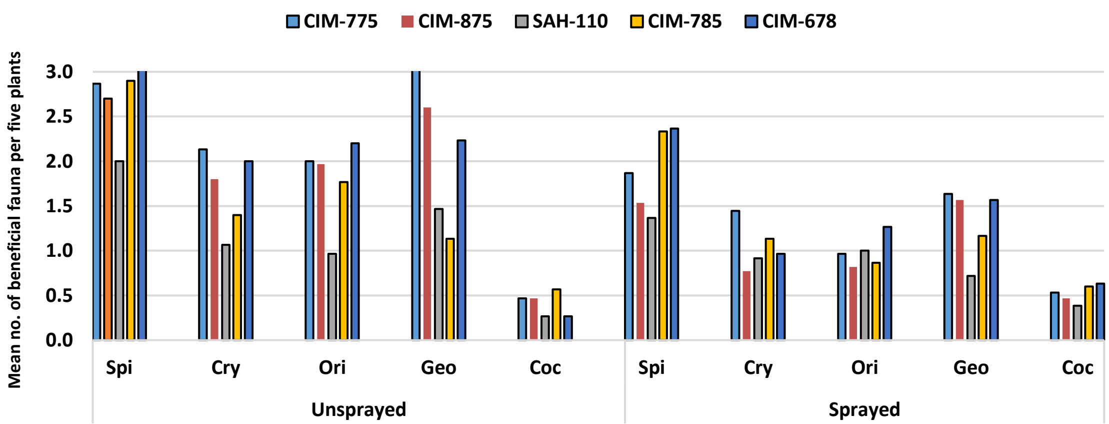


Fig. 4.12: Mean number of predators in unsprayed and sprayed blocks.

4.5.4 Alive larvae of pink bollworm

Overall maximum alive larvae of pink bollworm were recorded in unsprayed as compared with sprayed block. In unsprayed block, mean highest population of alive larvae was recorded on CIM-875 (38.3%) followed by CIM-678 (34.2%), whereas, it was lowest on Sahara-110 (12.5%) followed by CIM-775 (14.2%). Similarly, in sprayed block, highest mean population of alive larvae was recorded on CIM-875 (15.8%) followed by CIM-678 (13.3%), whereas, lowest on Sahara-110 (5.0%) followed by CIM-775(6.7%). The results revealed that Sahara-110 had the maximum capability to resist pink bollworm **(Fig. 4.13)**

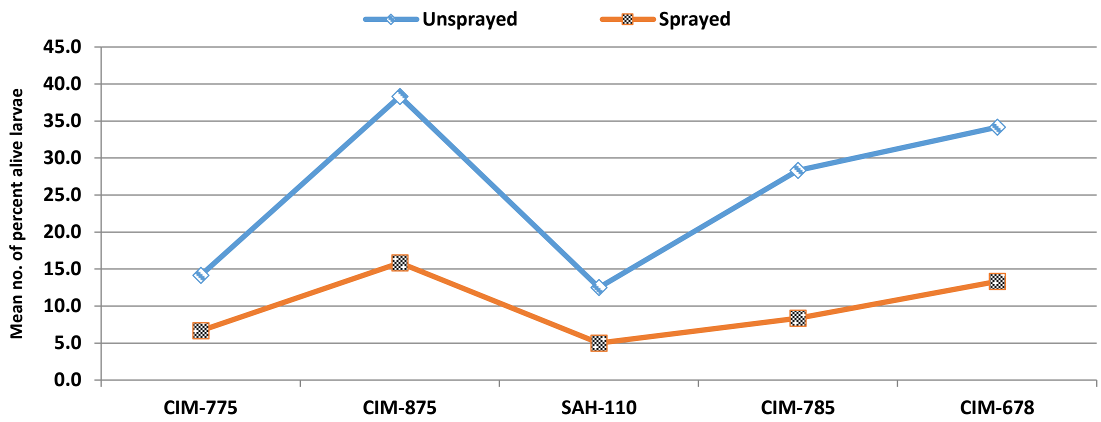


Fig. 4.13 Incidence of pink bollworm in unsprayed and sprayed blocks.

4.5.5 Seed-cotton yield

Almost all the varieties tested proved better under sprayed than unsprayed conditions for all the parameters like plant height, bolls number per plant and seed-cotton yield per hectare. The highest yield was obtained from CIM-785 (2434.0 kg/hectare) followed by CIM-775 (2195.8 kg/hectare) in sprayed conditions **(Table-4.8)**.

Table-4.8 Mean seed cotton yield under unsprayed and sprayed conditions based on different parameters.

Genotypes/ Varieties	Unsprayed				Sprayed			
	Height (m)	No. of Bolls/Plant	Boll Weight(g)	Yield kg ha^{-1}	Height (m)	No. of Bolls/Plant	Boll Weight(g)	Yield kg ha^{-1}
CIM-775	1.41	42.50	2.91	1372.4	1.30	40.5	3.03	2195.8
CIM-875	1.57	27.2	3.04	914.5	1.57	49.9	3.80	1885.1
SAH-110	1.28	20.6	2.65	1079.2	1.29	27.3	2.88	1463.5
CIM-785	1.22	30.2	2.97	1134.1	1.35	40.5	3.31	2434.0
CIM-678	1.36	38.6	2.68	512.7	1.45	40.5	3.0	1427.3

4.6 Insecticide resistance monitoring

4.6.1 Dusky cotton bug *(Oxycarenus hyalinipennis)*

Oxycarenus hyalinipennis, dusky cotton bug collected from cotton fields at Khanewal, Bahawalpur (BWP), Lodhran and Vehari were exposed to six insecticides viz. triazophos, profenophos, chlorpyriphos, bifenthrin, deltamethrin, and cypermethrin 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 **(Table-4.9)**.

Chlorpyriphos showed lower LC^{50} values in all the tested field populations as compared to other insecticides. While, LC50 values of profenophos were very high in field population of Vehari, Lodhran and BWP locations as compared to other insecticides. **(Table-4.11)**. Adoption of insecticide resistance management (IRM) strategies is crucial to manage insecticidal resistance in *O. hyalinipennis*.

Table-4.9 Response of *Oxycarenus hyalinipennis* to different insecticides

Insecticide	Location	Slope ± SE	95% fiducial limits	LC50 (ppm)
Triazophos	Khanewal	1.25 ± 0.28	50.23 - 157.32	78.73
	Bahawalpur	1.99 ± 0.43	59.48 - 126.40	81.87
	Lodhran	1.81 ± 0.33	32.31 - 134.22	59.96
	Vehari	1.54 ± 0.27	164.31 - 331.20	231.49
Profenophos	Khanewal	1.05 ± 0.27	828.18 - 3682.3	1417.20
	BWP	1.04 ± 0.28	1070 - 6258.5	1933.40
	Lodhran	0.87 ± 0.27	1334.9 - 19882	2875.30
	Vehari	1.40 ± 0.29	2181 - 5771	3257.00
Chlorpyriphos	Khanewal	2.22 ± 0.36	0.31 - 0.89	0.54
	BWP	2.11 ± 0.35	0.55 - 1.61	0.90
	Lodhran	1.92 ± 0.33	0.47 - 1.64	0.84
	Vehari	1.58 ± 0.29	0.45 - 0.92	0.64
Bifenthrin	Khanewal	1.05 ± 0.26	722.84 - 2916.13	1214.79
	BWP	1.10 ± 0.28	969.54 - 4461	1664.60
	Lodhran	1.16 ± 0.27	712.04 - 2385.37	1142.09
	Vehari	1.48 ± 0.28	443.88 - 974.89	640.02
Deltamethrin	Khanewal	1.94 ± 0.33	63.19 - 120.21	88.83
	BWP	1.21 ± 0.26	106.21 - 263.44	166.44
	Lodhran	1.92 ± 0.32	133.78 - 249.11	181.97
	Vehari	1.64 ± 0.30	224.85 - 481.88	316.75
Cypermethrin	Khanewal	1.94 ± 0.33	267.70 - 495.48	363.71
	BWP	1.74 ± 0.33	581.73 - 2403.34	1007.42
	Lodhran	1.37 ± 0.28	98.91 - 252.69	169.60
	Vehari	0.85 ± 0.24	340.89 - 1380.68	616.77

4.6.2 Mealybug *(Phenacoccus solenopsis)*

Phenacoccus solenopsis, mealybug collected from cotton fields at Multan, Lodhran, Melsi and Khanewal were exposed to eight insecticides viz. nitenpyram, methoxyfenozoide, pyriproxyfen, profenophos, imidacloprid, emamectin benzoate, acetamiprid, and clothianidin using leaf dip method. 2^{nd} instars of *P. solenopsis* were exposed and observations on mortality were taken 48 hours after treatment for conventional insecticides and 72 h after treatment for new chemistry insecticides.

LC^{50} value of nitenpyram, profenophos and imidacloprid were comparatively lower in all locations except Multan as compared to other insecticides. Lodhran population showed higher LC50 values for pyriproxyfen as compared to other locations. LC50 values of emamectin benzoate, acetamiprid and clothianidin were higher in the populations collected from Lodhran, Melsi and Multan, respectively. LC50 values of methoxyfenozide was generally higher in field population of Multan as compared to other insecticides, indicating a resistance to this insecticide in this location **(Table-4.10)**.

Table-4.10 Response of *Phaenococcus solenopsis* to different insecticides

Insecticide	Location	Slope ± SE	95% fiducial limits	LC50 (ppm)
Nitenpyram	Multan	0.59 ± 0.17	15.47 - 88.05	28.45
	Lodhran	1.35 ± 0.29	0.80 - 2.25	1.43
	Melsi	1.03 ± 0.26	0.11 - 0.60	0.34
	Khanewal	0.89 ± 0.11	2.13 - 4.33	3.06
Methoxyfenozide	Multan	0.51 ± 0.17	735.4 – 51537	2090.6
	Lodhran	1.04 ± 0.34	69.89 - 465.98	136.27
	Melsi	1.23 ± 0.27	2.63 - 9.53	5.88
	Khanewal	0.73 ± 0.09	31.39 - 70.50	46.75
Pyriproxyfen	Multan	1.05 ± 0.31	4.12 - 19.85	6.90
	Lodhran	1.62 ± 0.43	100.64 - 258.56	163.48
	Melsi	2.04 ± 0.35	58.42 - 108.05	80.43
Profenophos	Multan	0.69± 0.18	25.63 – 113.51	49.74
	Lodhran	1.74 ± 0.45	1.99 - 4.78	3.23
	Melsi	0.99 ± 0.20	0.09 - 0.34	0.20
	Khanewal	0.81 ± 0.11	4.28 - 9.37	6.43
Imidacloprid	Multan	0.56 ± 0.18	10.02 - 85.32	23.78

	Lodhran	2.08 ± 0.58	6.62 - 14.37	10.16
	Melsi	1.13 ± 0.21	1.24 - 3.31	2.11
	Khanewal	0.96 ± 0.12	1.89 - 3.72	2.68
Emamectin benzoate	Multan	0.49 ± 0.17	6.15 - 370.93	16.71
	Lodhran	0.53 ± 0.16	29.31 - 353.06	65.76
	Melsi	0.68 ± 0.24	8.59 - 812.26	24.98
	Khanewal	1.41 ± 0.27	1.07 - 2.67	1.81
Acetamiprid	Multan	0.58 ± 0.20	10.93 - 268.19	28.61
	Lodhran	1.15 ± 0.19	16.08 - 67.59	29.81
	Melsi	0.66 ± 0.41	70.53 - 360.19	133.47
	Khanewal	0.92 ± 0.14	1.27 - 7.27	2.89
Clothianidin	Multan	0.50 ± 0.17	85.54-3204.0	216.30
	Lodhran	0.72 ± 0.17	77.47 - 371.78	141.44
	Melsi	0.55 ± 0.09	43.63 - 174.71	81.08
	Khanewal	0.84 ± 0.15	2.79 - 12.57	6.70

4.6.3 Whitefly (***Bemisia tabaci***)

Bemisia tabaci, whitefly collected from cotton fields at Vehari, Khanewal,a Lodhran and Multan were exposed to bifenthrin, buprofezin, diafenthiuron, pyriproxyfen, imidacloprid, acetamiprid, dinotefuran and pyrifluquinazon using leaf dip method. Adults of *B. tabaci* were temporarily immobilized with carbon dioxide afterwards 20-30 adults were exposed to each treated leaf discs laid on layer of agar gel (5mm thick) in plastic petri dishes. Five to six concentrations for each insecticide were tested and each concentration was replicated eight times. Observations on mortality were taken 48 h after treatment.

LC^{50} values of diafenthiuron were comparatively lower in field population of Vehari, Khanewal and Lodhran locations as compared to other insecticides. While, pyriproxfen, imidacloprid and acetamiprid showed very high LC50 in field population of all the tested locations. These LC^{50} values indicate resistance development to all the tested insecticides in various locations **(Table-4.11)**. Hence, there is a dire need to develop and imply insecticide resistance management (IRM) strategies.

Table-4.11 Response of *Bemisia tabaci* to different insecticides

Insecticide	Location	Slope ± SE	95% fiducial limits	LC50 (ppm)
Bifenthrin	Vehari	0.72 ± 0.07	18.54 - 60.33	35.46
	Khanewal	0.73 ± 0.14	45.35 - 162.72	74.77
	Lodhran	0.48 ± 0.12	118.72 - 3245.4	334.69
	Multan	0.81 ± 0.12	1.10 - 4.22	2.54
Burpofezin	Vehari	1.45 ± 0.19	19.28 - 30.08	24.14
	Khanewal	0.68 ± 0.13	36.30 - 135.75	61.28
	Lodhran	0.53 ± 0.12	127.64 - 2461.8	335.35
	Multan	1.03 ± 0.11	35.65 - 63.18	48.18
Diafenthiuron	Vehari	0.60 ± 0.12	3.62 - 12.79	6.06
	Khanewal	0.83 ± 0.12	2.06 - 6.84	3.49
	Lodhran	0.56 ± 0.12	14.32 - 147.32	31.88
	Multan	0.92 ± 0.14	2.51 - 12.36	4.82
Pyriproxyfen	Vehari	0.57 ± 0.12	1858.1 – 11989	3629.3
	Khanewal	0.95 ± 0.14	1193.76 - 2597.95	1676.85
	Lodhran	0.51 ± 0.11	3343.8 – 46000	7951.4
	Multan	0.78 ± 0.16	1610.9 – 16060	3335.2
Imidacloprid	Vehari	1.01 ± 0.16	947.38 - 1922.20	1314.09
	Khanewal	1.28 ± 0.13	73.64 - 275.18	163.56
	Lodhran	0.57 ± 0.12	3145.6 – 27639	6704.8
	Multan	0.61 ± 0.11	81.42 - 230.43	150.05
Acetamiprid	Vehari	1.31 ± 0.18	317.20 - 1159.52	661.87
	Khanewal	0.77 ± 0.12	926.36 - 2238.64	1357.37
	Lodhran	0.64 ± 0.12	2452.2 – 12865	4523.6
	Multan	1.097 ± 0.131	316.35 - 1055.216	579.42
Dinotifuran	Vehari	1.60 ± 0.14	6.73 - 13.80	9.81
	Khanewal	1.03 ± 0.18	27.31 - 57.18	38.33

	Lodhran	0.56 ± 0.11	22.03 - 70.80	34.98
	Multan	1.14 ± 0.12	3.80 - 9.45	6.32
Pyrifluquinazon	Vehari	0.90 ± 0.13	31.60 - 71.33	44.81
	Khanewal	1.04 ± 0.15	15.75 - 29.35	21.38
	Lodhran	0.71 ± 0.11	25.41 - 63.81	37.26
	Multan	0.74 ± 0.13	45.99 - 157.37	74.65

4.6.4 Armyworm *(Spodoptera litura)*

Spodoptera litura adults were collected from light trap at CCRI, Multan and then kept in the laboratory on artificial diet in 8 lbs glass jars covered with muslin cloth. For oviposition, nappy liner strips were hanged in the jar. The eggs laid were collected daily and placed in glass jars (800 ml capacity). After hatching newly emerged larvae were fed on artificial diet. Second instar larvae were exposed to seven insecticides viz. triazophos emmamectin benzoate, cypermethrin, profenofos, chlorpyriphos, indoxacarb and flubendamide 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 while lower LC50 values for emamectin benzoate as compared to other insecticides **(Table-4.12).**

Table-4.12 Response of *Spodoptera litura* to different insecticides

Insecticide	Slope ± SE	95% fiducial limits	LC50 (ppm)
Triazophos	0.99 ± 0.13	134.85 - 306.79	207.48
Emamectin benzoate	1.11 ± 0.14	0.23 - 0.43	0.31
Cypermethrin	2.23 ± 0.53	832.36 - 1441.53	1118.78
Profenophos	1.46 ± 0.16	25.54 - 42.33	33.01
Chlorpyrifos	1.78 ± 0.28	4.08 - 7.67	5.86
Indoxacarb	0.96 ± 0.18	2.80 - 6.85	4.67
Flubendamide	1.43 ± 0.16	3.95 - 6.57	5.11

4.7 Screening of new and commercially available insecticides

4.7.1 Jassid (*Amrasca devastans*)

Fifteen insecticides of different groups were evaluated against jassid at CCRI, Multan field keeping untreated check for comparisons. Different insecticides gave move than 75% pest mortality expect Fipronil 80%WG imidacloprid, Nitenpyram, Flonicamid and Dinotefuron. Almost insecticides gave maximum morality after one week of spray application.

Table-4.13 Efficacy of different insecticides against Jassid during-2022

Common Name	Formulation (% age)	Dose (ml/g)	Mortality %	
			72 hour	1-Week
Spinosad 13% + Flonicamid 40%	53% WDG	75	83.3	91.7
Fipronil	80% WG	30	72.8	76.9
Chlorfenapyr 30% + Dinotefuron 13%	43%WDG	150	77.4	80.1
Flonicamid	50% WDG	60	78.5	79.8
Isocyloseram	100 DC	240	77.5	79.3
Abamectin 36 G + Thiamethixam 72g/l	108sc	300	76.7	80.1
Clothiandin	20% SC	150	75.3	77.6
Dinotefuron + Spirotetramat	50% WDG	300	75.1	77.9
Acetamiprid + Pyriporxfen + Chlorfenapyr	52% EC	80	76.6	78.5
Flonicamid	60% WDG	120	79.2	87.5
Chlorantraniliprolen + Thiamethaxium	24%SC	100	76.3	79.8
Imidaclorprid	20 SL	250	72.4	76.5
Nitenpyrm	24 SP	50	73.3	75.1
Flonicamid	50% DF	60	69.6	75.8
Dinotefuron	30 SC	100	67.5	73.8
CD5%	-	-	10.33	8.37

Pre-treatment data-2.63 per leaf

4.7.2 Whitefly *(Bemisia tabaci)*

Almost proudest gave maximum mortality after 72 hours and one week except pyriproxyfen 10.8EC, Aectamiprid 20 SL Spirotetramat 240 SC, Difenthiuron 50 SC and Flonicamid 50% WG.

Table-4.14 Effcacy of different insecticides against Whitefly during-2022

Common Name	Formulation (% age)	Dose (ml/g)	Mortality %	
			72 hour	1-Week
Matrin 0.5% + Acetamiprid 5%	5.5% AS	500	79.6	81.2
Matrine + Acetampirid + Thiamethoxam	21% ME	150	78.8	80.4
Spinosad 13% + Flonicamid 40%	53% WDG	125	81.6	84.7
Matrin 0.5% + Acetamipirid 5% + Pyriproxyfen 6%	11.5% ME	80	85.5	89.3
Flonicamid	60% WDG	500	79.0	82.9
Dinotefuron + Spirotetramat	50% WDG	150	79.4	80.5
Cyantraniloprol 80 G + Diafentiuron 400 G	480 SC	125	75.8	79.5
Chlorfenapyr 30% + Dinotefuron 13%	43%WDG	80	76.8	79.4
Pyriproxfen	40% WDG	500	76.6	78.2
Flonicamid	50% WDG	150	75.3	78.5
Flonicamid 20% + Acetamiprid	35% WDG	125	77.4	80.1
Pyriproxfen 21.6% + Acetamiprid	41.6% EC	80	75.9	79.7
Acetamiprid + Pyriporxfen + Chlorfenapyr	52% EC	500	77.0	80.4
Flonicamid + Pyriproxfen	10% WP	150	76.3	79.9
Abamectin 36 G + Thiamethixam 72g/l	108 SC	125	76.7	79.2
Afidopyropen	5% DC	80	77.8	80.6
Pyriproxfen	10.8 EC	500	55.8	69.2
Acetamiprid	20 SL	150	57.6	70.8
Spirotetramat	240 SC	125	50.6	57.1
Flonicamid	50% WG	80	51.9	69.2
Difenthiuron	50 SC	200	49.1	57.5
CD 5%	-	-	8.06	10.13

Pre-treatment data-7.62per leaf

4.7.3 Thrips *(Thrips tabaci)*

Efficacy of Seventeen (17) insecticides of different groups were tested against thrips at CCRI, Multan farm. For spray application hand operated knapsack sprayer was used. All insecticides gave better result after 72 hours and one week of sprays application except Fipronil 80% WG and Chlofenapyr 70 WDG.

Table-4.15 Efficacy of different insecticides against thrips during-2022

Common Name	Formulation (%age)	Dose (ml/g)	Mortality %	
			72 hour	1-Week
Chloprfenapyr + Abamectin	17% SC	300	80.4	84.8
Spinosad 13% + Flonicamid 40%	53% WDG	75	81.3	85.7
Spinosad + Abamectin	8.4% SE	100	79.6	81.5
Chlorantraniliprole + Abamectin	5.2% SC	250	78.4	80.9
Spinosad	10% SC	120	77.5	79.2
Flonicamid	50% WDG	80	75.9	78.6
Isocyloseram	100 DC	250	77.8	87.9
Chlorfenapyr 30% + Dinotefuron 13%	43%WDG	240	85.2	88.3
Spinosad 10% + Chlorfenapyr 27.5%	37.5% SC	150	80.8	92.3
Chlorfenapyr + Abamectin	17% SC	200	79.3	82.7
Abamectin 36 G + Thiamethixam 72g/l	108 SC	300	81.3	86.4
Acetamiprid + Pyriporxfen + Chlorfenapyr	52% EC	300	76.8	79.5
Fipronil	80% WG	250	74.9	77.8
Acephat	75 SP	350	80.7	83.2
Spinetoram	20 WDG	75	83.8	71.9
Chlorfenapyr	70WDG	125	64.4	69.3
Solvigo	108 SC	300	82.1	86.7
CD 5%			9.33	11.61

Pre-treatment data-13.8 per leaf

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5. PLANT PATHOLOGY SECTION

Main mandate of Plant Pathology of central cotton research, Multan is to conduct research on plant diseases caused by Fungi, Bacteria, and Viruses. Management of plant diseases is achieved by evaluation of crops germplasm to find out resistance source against diseases and development of integrated management strategies of cotton diseases.

Screening of Cotton varieties against CLCuD,and other diseases of cotton Similarly, Evaluation of new chemicals for management of cotton diseases for standardization purpose is also mandate of the Institute

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 forty 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 there was not a single family showed resistance against CLCuD in all breeding material

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	18.07~ 81.37	
VT-2	10	0	12.21 ~80.87	
VT-3	8	0	44.50~ 74.07	
VT-4	8	0	34.96~ 80.85	
MVT-1	9	0	4.68~68.94	
MVT-2	9	0	13.52~ 84.14	
MVT-3	9	0	1.95~ 78.01	
MVT-4	7	0	12.66~73.31	
MVT-5	8	0	52.88~78.73	
NCVT-A	22	0	50.53~80.85	
NCVT-B	23	0	48.15~79.54	
SVT-I	7	0	78.13~85.00	
SVT-II	10	0	74.14~80.46	
Total	140	0		

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 was planted in two sets. In Set-A twenty-two strains and Set-B twenty-three strains were tested against stunting, boll rot and Cotton Leaf Curl Disease under field conditions.

NCVT-Set-A

In set-B, all the NCVT strains were found highly susceptible to cotton leaf curl disease. Minimum disease incidence (67%), disease index (50.53) was recorded in FH-333 and minimum disease severity was observed in Tahafuz-2025. Boll rot incidence was observed only in two genotypes (VH-442 (0 28 % and ASPL-710 (0.63 %) While rest of strains was free from boll rot incidence Table 5.2).

NCVT-Set-B

In set-B, all the NCVT strains were observed to be highly susceptible to cotton leaf curl disease. Minimum disease incidence (67%), disease severity (2.86) and disease index (48.15) was recorded in FH-189 and Maximum disease severity (3.18) and disease index (79. 54) was recorded in IUB-23 All strains were free from boll rot incidence (Table-5.3).

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

NCVT Set A Strain	Cotton Leaf Curl Disease			Boll Rot (%)
	Disease % age	Disease Severity	Disease Index	
NAIB-585	100.00	3.06	76.38	0.00
FH-416	100.00	2.98	74.51	0.00
CS-303	100.00	3.10	77.42	0.00
CIM-600 Bt Standard	100.00	3.03	75.67	0.00
FH-938	100.00	2.99	74.68	0.00
ZAR-22	100.00	3.05	76.25	0.00
IUB-21	100.00	3.23	80.85	0.00
PC-2208	100.00	3.07	76.63	0.00
NAIB-787	100.00	3.11	77.87	0.00
Super Sultan -22	100.00	3.02	75.41	0.00
IR-NIBGE-19	100.00	3.06	76.55	0.00
VH-442	100.00	3.07	76.68	0.28
Inqalab-101	100.00	3.02	75.44	0.00
Tahafuz-2025	95.20	**2.96**	70.34	0.00
Sahara 500	100.00	3.16	78.98	0.00
IUB-222/111	100.00	3.11	77.74	0.00
Certus-10	100.00	3.12	77.99	0.00
FH-333	**67.00**	3.02	**50.53**	0.00
PC-2219	100.00	3.18	79.47	0.00
CS-424	100.00	3.01	75.32	0.00
MNH-Super-Gold-2022	100.00	3.08	76.99	0.00
ASPL-710	100.00	3.06	76.44	0.63

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-B

NCVT Set B Strain	Cotton Leaf Curl Disease			Boll Rot (%)
	Disease % age	Disease Severity	Disease Index	
CAMB-AAS-3	100.00	3.10	77.61	0.00
IR-NIBGE-17	100.00	3.01	75.31	0.00
IR-NIBGE-20	100.00	3.07	76.68	0.01
KZ-181	100.00	3.03	75.71	0.00
NIAB-868	100.00	3.11	77.81	0.00
Silver-Queen-44	100.00	3.07	76.77	0.00
CIM-600(Bt. Standard)	100.00	3.10	77.55	0.00
IUB-4	94.74	3.02	71.49	0.00
Bahar-GTG-155	100.00	3.02	75.56	0.00
IUB-23	**100.00**	**3.18**	**79.54**	0.00
Captain-300	100.00	3.08	77.07	0.00
PC-2234	100.00	3.09	77.20	0.00
VH-447	100.00	3.14	78.55	0.00
Tipu-10	100.00	3.07	76.69	0.00
PC-2237	100.00	3.05	76.34	0.00
FH-415	100.00	3.04	76.10	0.00
Diamond-2024	100.00	3.06	76.43	0.00
FH-189	**67.00**	**2.86**	**48.15**	0.00
Sahara Klean-10	100.00	3.08	76.94	0.00
RH-Bagh-o-Bahar	100.00	3.07	76.67	0.00
KZ-111	100.00	3.03	75.85	0.00
RH-Gold-1	100.00	3.04	75.98	0.00
Silver Queen-33	100.00	3.08	76.96	0.00

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

5.3 Impact of cotton sowing period on Cotton leaf curl virus and its vector white fly population tendency

The trial was conducted to assess the effect of different sowing periods of cotton on buildup of CLCuD and its vector whitefly population and to devise their management strategies. The Set-1 (Early-April) was planted on 1st April, Set-II (Early-May) on 2nd May and Set-III (Early-June) on 1st June. Two Bt varieties (Bt.CIM.663 & Bt.CIM-785) and two non Bt varieties (CIM-554 & CIM-620) were planted in split-plot design with three replicates. Main plots were sowing dates whereas varieties were in subplots. Data recording on CLCuD and whitefly population was started 20 days after sowings (DAS) at weekly interval. It is seen from the Fig-5.1 that the level of disease was low as compare to level of whitefly population on crop in April planting due to presence of viruliferous whiteflies. The disease incidence reached maximum level (100 %) at day 75 after planting in April. In May planting, the level of cotton leaf curl disease incidence was high as compare to level of whitefly population (fig.5.2). The disease incidence reached maximum level (100 %) at day 60 after planting. Average across the varieties CLCuD incidence was higher in June (Fig. 5.3). Varieties showed no profound impact on whitefly intensity and its maximum population was observed in April planting and June on all the tested varieties.as compared to May.

The current study conducted at on station in three different sowing dates, strengthen our understanding about the epidemiology of CLCuV for improved forecasting to manage the disease monitoring and detection of viruliferous whiteflies rather than total whitefly population. CLCuD primary disease incidence primarily depends on the presence of viruliferous whiteflies in the environment. Additionally, the study holds the importance in controlling the transmission of CLCuV through timely detection of viruliferous whitefly level in the field during the off-season as well as during the crop season from cotton and other alternate plant-hosts. Thus, timely detection of viruliferous whitefly level can serve as a useful tool which will help in timely application of the appropriate management strategies for management of viruliferous whitefly and ultimately reducing CLCuD

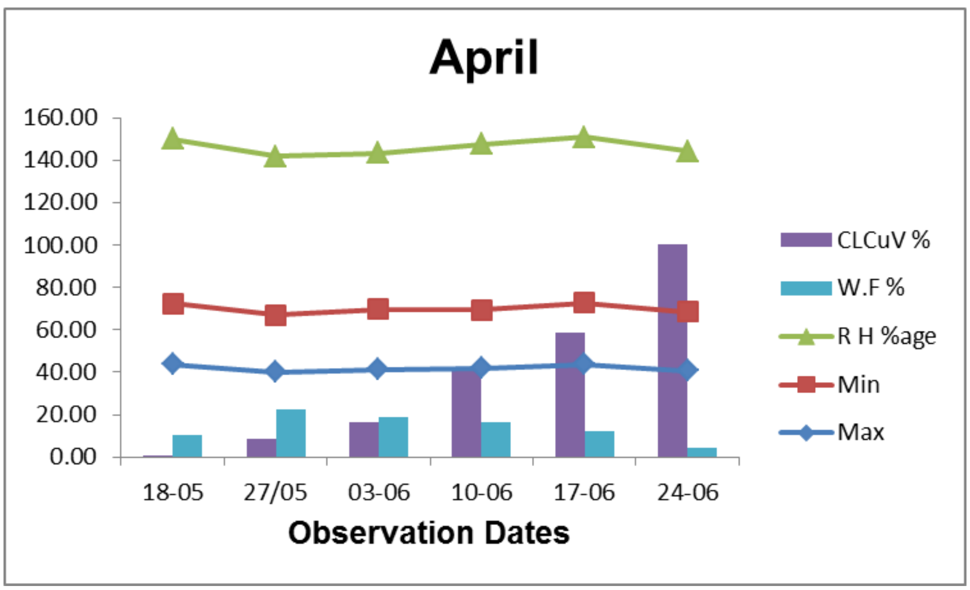

Fig 5.1

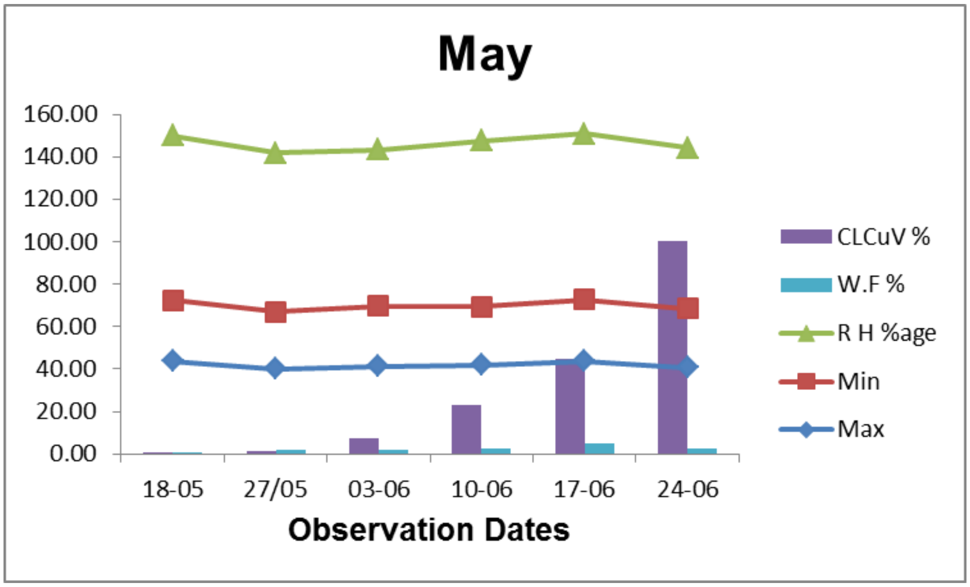

Fig.5.2

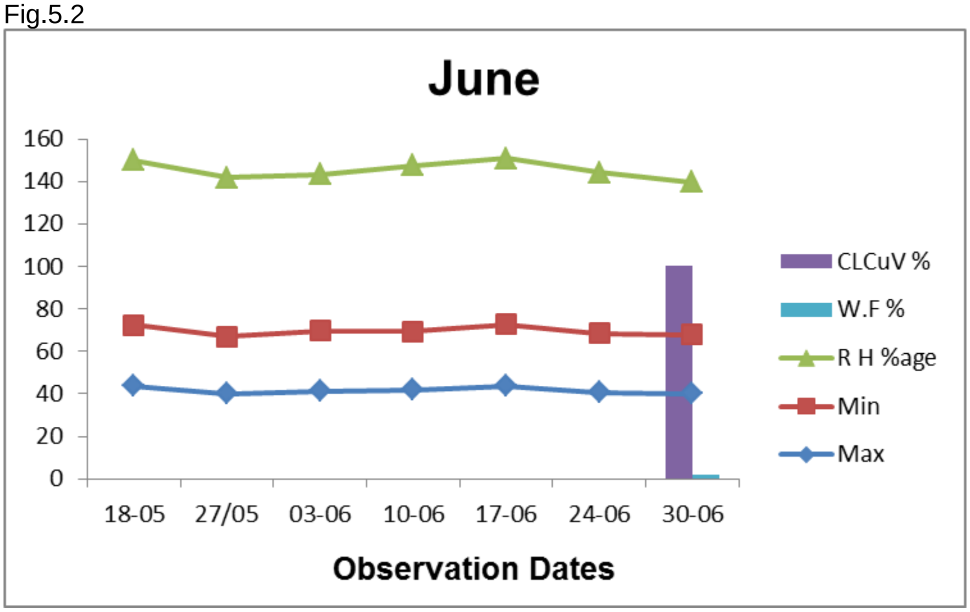

Fig.5.3

5.4 Boll Rot of Cotton

(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, 15tht March to 1st June with fortnightly interval. The results are given in Table 5.40

Averaged across the strains, the crop planted on 15th March was more affected by boll rot as compared to other planting times. Similarly averaged across sowing dates, CIM-663 was free from boll rot of cotton and other remaining strains showed less than 2 % boll rot incidence. The boll rot disease ranged from 0.00 to 0.46 % in all sowing dates on an average basis of varieties (Table 5.4).

(b) Effect on Non-Bt-Strains

Another experiment (non-Bt varieties) was conducted to quantify the boll rot disease in different strains planted from 15tht March to 1st June with fortnightly interval. The boll rot disease was recorded and results are given in Table 5.5.

Averaged across sowing dates, maximum boll rot was recorded in CIM-231 as compared to other strains. Averaged across the strains, the crop planted on 15th March was more affected by boll rot incidence as compared to other planting times. On an average basis, boll rot disease ranged from 0.00 to 0,66 % in different sowing dates (Table-5.5).

Table-5.4 Boll Rot Disease (%) on Bt cotton Cultivars planted at different times

Strains	15-Mar	1st April	15th April	1st May	15th May	1st June	Average
CIM-663	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CIM-975	0.00	0.00	0.00	0.55	0.47	0.00	0.17
CIM--990	0.44	0.00	0.04	0.00	0.00	0.00	0.08
Cyto-541	1.04	0.33	0.00	0.00	0.00	0.00	0.23
CIM-545	0.00	0.00	0.00	0.47	0.56	0.00	0.17
CIM-535	1.14	0.41	0.47	0.00	0.75	0.00	0.46
Average	0.44	0.12	0.09	0.17	0.30	0.00	

Table-5.5 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-231	0.95	0.54	0.25	0.71	0.00	0.49
CIM-232	0.00	0.29	0.67	0.68	0.00	0.00
CIM-610	0.87	0.33	0.39	0.00	0.00	0.00
Average	0.61	0.39	0.44	0.46	0.00	

5.5 Evaluation of bio pesticides (Plants Extracts) to delay application of first pesticide against whitefly of cotton

An experiment was conducted at CCRI Multan to evaluate different plants extracts and oils against whitefly to delay application of first pesticide against whitefly of cotton Planting of the crop was done on 29th May. To validate the results a control plot was established adjacent to trial plot in same locality.

he variety grown on these field was same that is CIM-537 which was selected being suitable according to climatic condition ten plant extracts @ 600gm/100lit of water /acre were used. Trial field and control were regularly monitored for whitefly scouting. Data recorded was against days after sowing for pest scouting and application of bio pesticide spray in trial and control Averages of pest scouting data of whitefly,bio pesticide spray used at different days after sowing was taken from all treated and control plots.

It was found that initially the whitefly population from trial plot and control plot was approximately similar but after first spray the population of whitefly remain below 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 all, extract treatment only at the early stage when whitefly did not flare-up to ETL.

The results are given in (Table-5.12) although bio pesticide application at early stage can reduce the use of chemical pesticide and will support in climate mitigation by least addition of chemicals to soil, water and environment

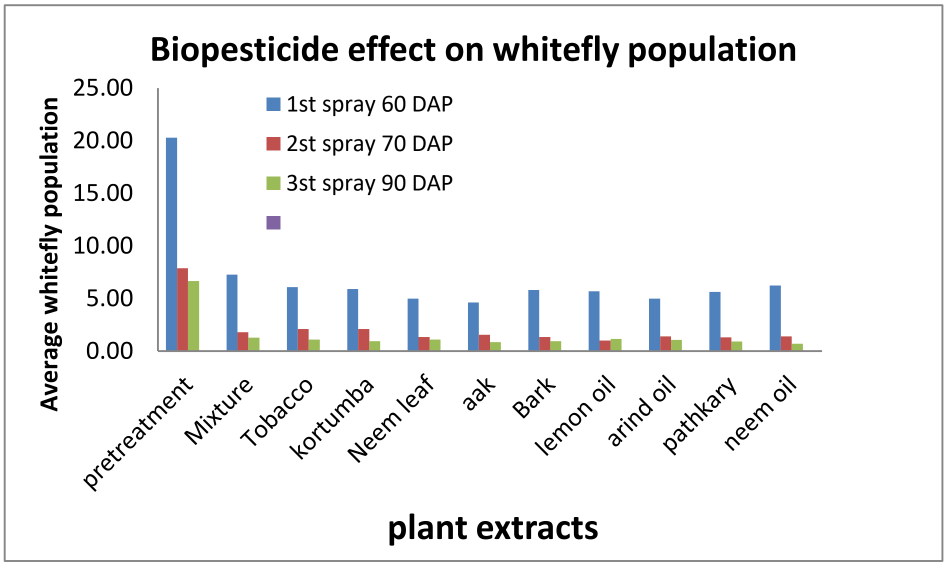

Fig 5.4.Effect of bio pesticides on whitefly population

5.6 Blackening of cotton leaves

In cotton growing areas sucking pests(specially whitefly) are responsible for development of sooty mould on cotton. The honeydew produced by sucking pests favoring the growth of fungi on the lower leaves and gradually spreads as the sucking pests move to the upper parts of the plants Fungi that cause sooty mold do not attack plants directly, but obtain their nutrients from the honeydew itself. Although the fungi do not feed on the plants, they can indirectly destroy the beauty of the plant and, if the concentration of the mold is heavy enough, shade out enough light to yellow and stunt the plant. In severe cases, the plant or plant parts may die, but this is probably due to damage caused by the insects.

. Field experiment with four fungicides against black mould was carried out in August .Sulfur, Chlorothalonil, Thiophanate methyl @300gm/100 lit water and Tebuconazole @ 65gm/100-lit water respectively to the acre. Complete mortality was not observed, however infestation of leaves decreased on an average more than 60 percent in sulfur treatment. The spray was applied from below .It was found that sulfur did not affect the quality of cotton fiber.

5.7 Cotton Wilt

A survey was conducted to observed stress in cotton crop It was found that cotton plants showing wilt symptoms but after physical and microscopic examination no, fungi, bacteria or similar was involved. It was observed that this wilting was developed in matter of hours and without a specific spatial pattern. The sporadic distribution and untimely occurrence are typical signs of Para wilt It is now known that the disorder is due to accumulation of water around root (excess irrigation or heavy rainfall) followed by hot temperature and blazing sunshine, Rapid plant growth and imbalance nutrients are also involved. Soil with heavy clay contents or soil with poor drainage increase the possibility of plants developing this disorder.

For management of Para wilt we applied 2% urea through foliar spray, and 250gm/100-lit copper oxychloride through irrigation Cobalt chloride application @ 1gm/100 lit immediately after the appearance of symptoms

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6. PLANT PHYSIOLOGY/CHEMISTRY SECTION

6.1 Genotype-Environment Relationship

6.1.1 Adaptability of genotypes to high temperature stress

Heat stress is the primary restraining factor affecting cotton growth and production. Cotton is mainly cultivated across tropical and sub-tropical regions with temperatures ranging from 40 to 45°C. Heat stress resulting from elevated temperature is considered a severe agricultural issue across many areas worldwide. The occurrence of elevated temperature causes an array of biological changes within plants, ultimately affecting plant growth and development, thereby leading to a severe decline in productivity. It is assumed that plant development and biomass accumulation are highly temperature-dependent across the growing season. Plant response to heat stress mainly considers the peak temperature duration and degree. Different studies suggested that higher than optimal temperatures negatively impacted cotton morphology, physiology, metabolism and yield. The heat stress at reproductive phases is a major constraint to attain yield potential in Pakistan. From May–June, the temperature elevates up to 47°C that couples with high humidity in July–August and thus negatively affects cotton reproductive stages. Due to elevated temperatures (day & night), 65 to 70% of the fruiting points shed down, lowering the cotton yield. In Pakistan, the high temperature at reproductive phase is a primary reason for lower seed cotton yields. High temperature also disrupts the stomatal movement that leads to poor gaseous exchange. This situation compelled the cotton breeders to develop cotton genotypes through breeding and selection that would retain more bolls under heat stress. The optimum temperature for germination of cottonseed and root development is 12°C and 30°C, respectively. For seedling development and stomatal conductance, the optimum temperature is 28–30°C, and the adequate boll development requires a temperature range of 25.5 to 29.5°C.

To combat with the temperature stress during cropping season of cotton, the current study has been designed to identify available cotton germplasm that have higher temperature tolerance and could generate the adequate yields in the region's hotter climates.

In the current study, twenty four cotton genotypes were planted for screening against high temperature stress in the month of April so as the fruiting phase faces the hottest period of crop season. The experiment was conducted under field conditions in the research area of CCRI, Multan.

The results revealed that the genotypes showed wide variation in various physiological parameters conferring heat tolerance in cotton. Genotypes CIM-990, CIM-975, GH-Sanabal and NIAB-585 excelled in heat tolerance considering different traits compared with the other genotypes (Table 6.1).

Physiological traits having relevance to heat tolerance were recorded in the genotypes. Results showed that there were positive correlations of pollen viability (r=0.92), percent boll set on first (r=0.99) and second (r=0.95) positions along sympodia with seed cotton yield. There were negative correlations of cell injury (r = –0.91) and electrical conductivity (r = –0.52) with the seed cotton yield. These traits can be taken into account while selecting future genotypes to overcome heat stress problems (Table 6.2).

The dehiscence of anthers was maximum during the 3rd week of June, dipping sharply to the lowest level in 2nd week of July and then gradually increasing upto the 4th week of August. Anther dehiscence showed a fluctuating trend in different genotypes and reached to its maximum by 2nd week of September. Among the genotypes studied, CIM-990 showed the highest while Khoonj showed 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.1.

Genotypes differed greatly in their overall yield performance. The genotype CIM-990 produced the highest seed cotton yield than the other genotypes tested. Seed cotton yield of different genotypes ranged from 717 to 1883 kg ha^{-1} (Table 3.3).

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)
CIM-990	89	83	7	9	18	10	39	280	9.7
CIM-975	75	81	8	10	17	9	42	289	9.4
GH-Sanabal	73	79	7	10	16	9	45	388	9.1
NIAB-585	72	76	9	11	16	8	49	378	8.9
Cyto -541	67	77	8	12	15	8	52	389	8.3
CYTO-537	65	75	9	10	14	7	57	422	7.9
NIAB-989	63	70	8	11	14	7	53	423	7.6
TH-88/14	62	71	9	11	13	6	51	430	7.5
CRIS-700	62	70	10	14	13	6	55	489	7.3
NIAB-868	53	69	9	13	13	6	57	435	7.4
NIAB-992	51	68	10	16	12	4	58	411	7.2
GH-238	49	65	12	18	12	5	61	429	7.2
SLH-68	48	63	11	16	12	6	63	430	6.9
SLH-98	45	63	13	16	10	5	66	437	6.1
CIM-775	42	67	12	19	9	5	69	463	5.9
NIAB-787	40	58	10	15	8	4	69	468	5.8
SLH-94	40	49	13	18	7	4	73	504	5.4
SLH-103	39	48	12	15	6	3	73	527	5.3
CRIS-682	35	45	11	15	4	6	75	530	5.1
Shahbaz	34	44	11	14	2	3	77	530	4.8
TH-108/12	33	40	14	21	2	2	78	542	4.5
Sindh-1	30	39	13	18	3	3	82	564	4.2
Cyo-545	30	35	12	18	3	2	88	577	3.8
Koonj	22	33	13	22	2	1	90	649	3.6
LSD(0.1%)	7.2**	11.0**	3.39^{ns}	4.8**	5.9**	3.2**	9.8**	33.2**	0.8^{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

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

Parameters	AD	PV	EC	RCI	BSFP	BSSP	NBPP	BW
PV	0.97**							
EC	-0.56**	-0.67**						
RCI	-0.91**	-0.86**	0.46**					
BSFP	0.97**	0.93**	-0.51**	-0.94**				
BSSP	0.97**	0.94**	-0.48**	-0.92**	0.98**			
NBPP	0.28**	0.30**	-0.40**	-0.18**	0.23**	0.28**		
BW	0.41**	0.34**	-0.32**	-0.36**	0.39**	0.35**	0.08**	
SCY	0.92**	0.90**	-0.52**	-0.91**	0.99**	0.95**	0.28**	0.41**

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

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

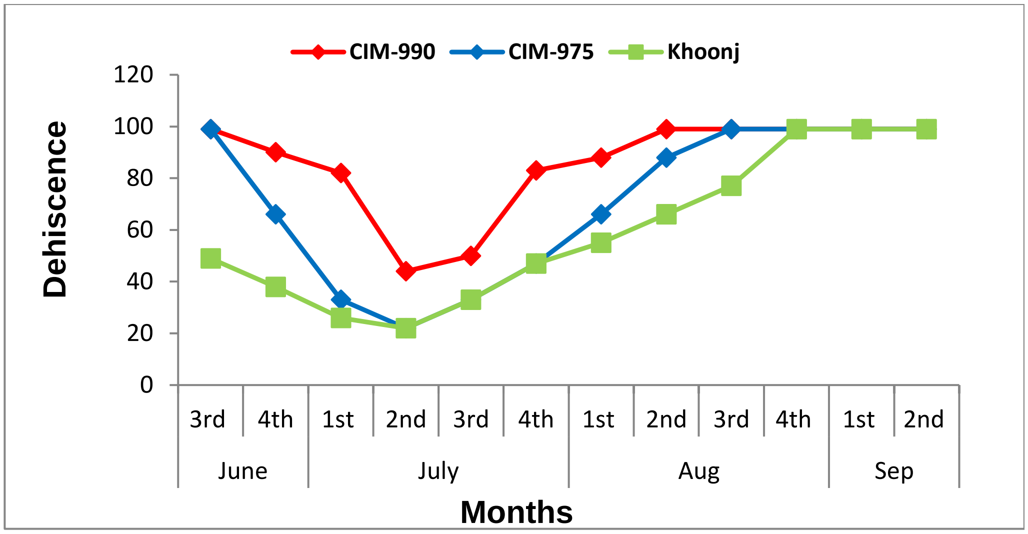

Fig. 6.1 Dehiscence of anthers during the season for three genotypes

Table 6.3 Seed cotton yield in different genotypes planted in April

Genotypes	**Number of bolls per plant**	**Boll weight** (g)	**Seed cotton yield** (kg ha^{-1})
CIM-990	31	3.17	1883
CIM-975	29	2.54	1704
GH-Sanabal	27	2.86	1614
N-585	25	2.81	1614
Cyto -541	26	3.34	1435
CYTO-537	24	2.60	1255
N-989	23	2.06	1255
TH-88/14	22	2.64	1255
CRIS-700	22	2.66	1255
N-868	21	2.30	1255
N-992	21	2.32	1166
GH-238	20	2.52	1166
SLH-68	20	2.86	1166
SLH-98	19	2.36	1076
CIM-775	19	3.10	1076
N-787	18	2.90	1076
SLH-94	17	2.26	1076
SLH-103	17	2.48	986
CRIS-682	16	2.02	986
Shahbaz	15	2.42	986
TH-108/12	13	2.58	897
Sindh-1	14	2.62	897
Cyo-545	12	2.28	717
Koonj	10	2.18	717
LSD	1.99**	0.30^{ns}	111.2**

**significant at $p<0.01$

The assessment of fibre characteristics like staple length, uniformity index, fibre strength and fibre fineness varied marginally among different genotypes. Staple length varied from 22.9 to 27.4 mm, uniformity index from 80.8 to 83.5%, micronaire varied from 4.3 to 6.0 and fibre strength from 20.1 to 28.7 G/Tex among different genotypes (Table 6.4).The genotype CIM-990 showed the maximum staple length, uniformity index and fibre strength 27.4mm, 83.5 % and 28.7 G/Tex, respectively.

Table 6.4 Effect of heat stress on fiber characteristics in different genotypes

Genotypes	Staple length (mm)	UI (%)	Micronaire	Strength (G/Tex)
CIM-990	27.4	83.5	4.8	28.7
CIM-975	25.3	82.1	4.5	26.1
GH-Sanabal	26.2	81.6	4.6	26.6
N-585	25.3	82.8	5.1	25.5
Cyto -541	26.7	83.0	4.6	23.1
CYTO-537	25.5	83.5	5.4	22.7
N-989	26.4	82.8	4.8	26.3
TH-88/14	25.9	81.3	5.4	25.2
CRIS-700	25.6	83.0	5.0	24.4
N-868	25.9	81.9	4.8	25.4
N-992	25.2	81.1	5.0	25.2
GH-238	24.3	81.3	4.8	23.8
SLH-68	25.5	82.6	5.3	26.0
SLH-98	25.2	81.5	5.1	24.2
CIM-775	26.2	82.0	4.8	26.3
N-787	26.5	81.9	4.6	24.7
SLH-94	24.8	81.0	4.8	25.8
SLH-103	24.1	82.7	4.8	25.1
CRIS-682	23.7	82.2	5.1	21.5
Shahbaz	24.8	80.8	4.5	24.9
TH-108/12	25.0	83.4	4.9	25.5
Sindh-1	25.7	83.4	4.4	27.0
Cyo-545	22.9	81.4	6.0	20.1
Koonj	25.5	81.3	4.3	26.1

6.1.2 Physiological and biochemical analysis to examine the effect of seed priming on heat stress tolerance mechanisms in *Gossypium hirsutum* L.

Seed priming is an economical hydration technique to stimulate rapid germination and homogenous seedling emergence. Numerous factors such as reduction in imbibition time, activation of pre-germinative enzymes, enhancement of metabolite production and osmotic adjustment contribute to increased and uniform germination of primed seeds. Priming also induces numerous molecular changes such as de novo synthesis of DNA and proteins, DNA repair, ATP production, and accumulation of osmolytes and antioxidant metabolites. Rising temperatures stand to threaten cotton plant productivity. Although cotton is regarded as a crop of hot, semi-arid regions, its growth and yield are negatively correlated with higher temperatures particularly during flowering and early boll development. Another stage very sensitive to temperature is seedling growth three weeks post-emergence. Physiological processes like germination, growth, development, reproduction, and production are compromised in heat stress in cotton. It has been reported that seed osmopriming enhanced the defense system against heat stress. Several studies suggest a positive correlation between proline accumulation and plant stress. It has been suggested that under stress conditions proline acts as an osmoprotectant, and also as an antioxidant defense and signaling molecule, stabilizing cellular structures and protecting membranes, proteins, DNA and eliminating free radicals of oxygen. Moreover, proline is also an important source of nitrogen, carbon and energy. A significant amount of this amino acid is found in the reproductive organs of different species of plants. Therefore, overall outcome is the plant growth, yield and superior seed germination. Seed priming with lower concentration of Salicylic acid plays an essential role in the plant's resistance against environmental tension such as heat stress. It can influence germination, ion exchange and transfer, penetrability of the membrane, photosynthesis and growth of plants. Salicylic acid increased dry weight, germination percentage, chlorophyll (a+b) content, while reduced lipid peroxidation rates with increasing antioxidant activity. Priming is one of the most feasible and economic technology 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-541 (heat tolerant) and CIM-789, Cyto-535 (heat susceptible). The crop was sown on 1st April 2022 and 22nd April 2022 in a randomized complete block design (RCBD) with split plot arrangement (genotypes; main plot and seed treatment; sub plots. 1st April sown plots were designated as Set-A and 22nd April sown plots as 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	0.01%
T4	Disprin	0.01% (S.A)

Plant reproductive parameters like seed cotton yield, number of bolls per plant and boll weight differed significantly ($p<0.05$) among various treatments and among genotypes ($p<0.01$). Picking of seed cotton was done at maturity and yield calculated on hectare basis. Data showed that seed primed with proline, salicyclic acid and disprin prior to sowing, performed differently in seed cotton production. In **Set A,** in heat tolerant genotypes (GH-Hamaliya & CIM-541), the seed cotton yield, number of bolls per plant and boll weight varied from 826 to 1201 kg ha^{-1}, 15 to 22 and 2.71g to 3.62g, respectively. While in heat susceptible genotypes (Set B; CIM-789 & Cyto-535) the seed cotton yield, number of bolls per plant and boll weight varied from 895 to 1239 kg ha^{-1}, 14 to 23 and 2.46g to 3.67g, respectively, in different treatments. In Set B, in heat tolerant genotypes (GH-Hamaliya & CIM-541), the seed cotton yield, number of bolls per plant and boll weight varied from 826 to 1790 kg ha^{-1}, 16 to 26 and 2.70g to 3.54g, respectively. While in heat susceptible genotypes (CIM-789 & Cyto-535) the seed cotton yield, number of bolls per plant and boll weight varied from 1101 to 1514 kg ha^{-1}, 18 to 23 and 2.38g to 3.33g, respectively, in different treatments. In both sowing dates, Disprin and salicyclic acid seed treatment showed the substantial effect on seed cotton production, number of bolls per plant and boll weight in all genotypes over other treatments. The crop sown on 1st April showed the higher seed cotton yield, number of bolls per plant and boll weight as compared to 22nd April sown crop because in late sown crop, the fruiting period faced the temperature stress (Table 6.5, 6.6, 6.7).

Table 6.5 Effect of seed priming on seed cotton yield

Seed Treatments	**Heat tolerant**		**Heat susceptible**		**Mean**
	GH-Hamaliya	CIM-541	CIM-789	CYTO-535	
1st April					
Control (Untreated)	826	895	895	1001	**904**
Proline	835	964	964	1101	**966**
Salicylic Acid	926	1101	1014	1170	**1053**
Disprin	1033	1201	1089	1239	**1141**
Mean	**905**	**1040**	**991**	**1128**	
Genotypes	**				
Seed priming	**				
Genotypes × Seed priming	NS				
22nd April					
Control Untreated)	826	1239	1101	1308	**1119**
Proline	895	1308	1308	1446	**1239**
Salicylic Acid	964	1478	1322	1488	**1313**
Disprin	1308	1790	1377	1514	**1497**
Mean	**998**	**1454**	**1277**	**1439**	
Genotypes	**				
Seed priming	NS				
Genotypes × Seed priming	NS				

Table 6.6 Effect of seed priming on number of bolls per plant

Seed Treatments	Heat tolerant		Heat susceptible		Mean
	GH-Hamaliya	CIM-541	CIM-789	CYTO-535	
1st April					
Control (Untreated)	15	18	17	14	**16**
Proline	17	19	18	17	**18**
Salicylic Acid	19	20	20	19	**20**
Disprin	21	22	23	20	**22**
Mean	**18**	**20**	**20**	**18**	
Genotypes	NS				
Seed priming	**				
Genotypes × Seed priming	NS				
22nd APRIL					
Control Untreated)	19	16	18	19	**18**
Proline	20	22	20	20	**20**
Salicylic Acid	23	23	20	21	**22**
Disprin	25	26	23	22	**24**
Mean	**22**	**22**	**20**	**21**	
Genotypes	NS				
Seed priming	**				
Genotypes × Seed priming	NS				

Table 6.7 Effect of Seed priming on Number of Boll weight (g)

Seed Treatments	Heat tolerant		Heat susceptible		Mean
	GH-Hamaliya	CIM-541	CIM-789	CYTO-535	
1st April					
Control (Untreated)	2.71	3.18	2.46	3.09	**2.86**
Proline	2.80	3.28	2.48	3.18	**2.94**
Salicylic Acid	3.11	3.46	2.69	3.26	**3.13**
Disprin	3.26	3.62	3.01	3.67	**3.39**
Mean	**2.97**	**3.39**	**2.66**	**3.30**	
Genotypes	NS				
Seed priming	**				
Genotypes × Seed priming	**				
22nd April					
Control Untreated)	2.70	3.00	2.38	2.82	**2.73**
Proline	2.77	3.16	2.42	3.08	**2.86**
Salicylic Acid	3.00	3.22	2.65	3.18	**3.01**
Disprin	3.16	3.54	2.98	3.33	**3.25**
Mean	**2.91**	**3.23**	**2.61**	**3.10**	
Genotypes	NS				
Seed priming	**				
Genotypes × Seed priming	**				

Biochemical parameters such as, total chlorophyll contents, proline contents and cell injury (%) were determined from the leaves collected from 90 days old crop. The assessment of these biochemical parameters indicated that, in **Set A,** seed primed with proline, salicyclic acid and disprin prior to sowing, performed contrarily as compared to control (Tables 6.8, 6.9, 6.10). In heat tolerant genotypes (GH-Hamaliya & CIM-541), the total chlorophyll contents, proline and cell injury (%) varied from 5.36 to 8.16 (mg/g FW), 4.80 to 7.10 (µg/g FW) and 44 to 70 (%) respectively. While in heat susceptible genotypes (CIM-789 & Cyto-535) the total chlorophyll contents, proline and cell injury (%) varied from 4.82 to 7.99 (mg/g FW), 3.90 to 5.10 (µg/g FW) and 50 to 74 (%), respectively in different treatments. In **Set-B**, in heat tolerant genotypes (GH-Hamaliya & CIM-541), the total chlorophyll content, proline and cell injury (%) varied from 5.67 to 7.82 (mg/g FW), 4.00 to 6.30 (µg/g FW) and 45 to 75 (%), respectively. While in heat susceptible genotypes (CIM-789 & Cyto-535) the total chlorophyll contents, proline and cell injury (%) varied from 5.34 to 6.98 (mg/g FW), 3.00 to 4.70 (µg/g FW) and 62 to 85(%) respectively in different treatments.

Table 6.8 Total Chlorophyll content (mg/g FW) in different genotypes

Seed Treatments	Heat tolerant		Heat susceptible		Mean
	GH-Hamaliya	CIM-541	CIM-789	CYTO-535	
1st April					
Control (Untreated)	6.10	5.36	5.92	4.82	**5.55**
Proline	6.60	6.11	6.45	5.45	**6.15**
Salicylic Acid	7.16	6.72	6.75	6.89	**6.88**
Disprin	8.16	7.82	7.99	7.52	**7.87**
Mean	**7.01**	**6.50**	**6.78**	**6.17**	
Genotypes	**				
Seed priming	**				
Genotypes × Seed priming	NS				
22nd April					
Control Untreated)	5.67	5.89	5.34	5.80	**5.68**
Proline	6.34	6.26	5.88	6.01	**6.12**
Salicylic Acid	6.45	6.57	6.72	6.42	**6.54**
Disprin	7.82	6.99	6.83	6.98	**7.16**
Mean	**6.57**	**6.43**	**6.19**	**6.30**	
Genotypes	**				
Seed priming	**				
Genotypes × Seed priming	NS				

Table 6.9 Proline contents (µg/g FW) data in different genotypes

Seed Treatments	Heat tolerant		Heat susceptible		Mean
	GH-Hamaliya	CIM-541	CIM-789	CYTO-535	
1st April					
Control (Untreated)	4.80	5.00	3.90	4.00	**4.43**
Proline	5.10	6.30	4.20	4.10	**4.93**
Salicylic Acid	6.00	6.50	4.90	4.30	**5.43**
Disprin	6.20	7.10	5.10	4.90	**5.83**
Mean	**5.53**	**6.23**	**4.53**	**4.33**	
Genotypes	**				
Seed priming	**				
Genotypes × Seed priming	**				
22nd April					
Control Untreated)	4.00	4.70	3.00	3.20	**3.73**
Proline	4.80	5.50	3.30	3.50	**4.28**
Salicylic Acid	5.10	6.00	3.90	4.10	**4.78**
Disprin	5.80	6.30	4.70	4.50	**5.33**
Mean	**4.93**	**5.63**	**3.73**	**3.83**	
Genotypes	**				
Seed priming	**				
Genotypes × Seed priming	**				

On the basis of above results, it is observed that in both sowing dates, the seed priming has substantial effect, on both heat tolerant and heat susceptible genotypes, in improving their biochemical parameters. Seed priming with disprin and salicyclic acid increased remarkably the total chlorophyll and proline contents and decreased the cell injury of leaves; a positive modification in plants to cope with high temperature stress conditions.

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 aims 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.

Table 6.10 Cell Injury (%) data in different genotypes

Seed Treatments	Heat tolerant		Heat susceptible		Mean
	GH-Hamaliya	CIM-541	CIM-789	CYTO-535	
1st April					
Control (Untreated)	70	69	72	70	**70**
Proline	62	64	64	71	**65**
Salicylic Acid	53	60	61	62	**59**
Disprin	44	49	60	50	**51**
Mean	**57**	**61**	**64**	**63**	
Genotypes			**		
Seed priming			**		
Genotypes × Seed priming			NS		
22nd April					
Control Untreated)	75	82	85	83	**81**
Proline	66	70	76	72	**71**
Salicylic Acid	56	65	69	63	**63**
Disprin	45	50	62	57	**54**
Mean	**61**	**67**	**73**	**69**	
Genotypes			**		
Seed priming			**		
Genotypes × Seed priming			NS		

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 48 accessions of the cotton genepool entries were collected from the field to determine relative cell injury (RCI%), an indicator of heat tolerance. Results revealed that the RCI ranged from 17 to 90% in different accessions of gene pool material. Minimum RCI was found in accession number 1015 and 1036 (17) and maximum was found in accession number 1065 (90) (Table 6.11).

Based on RCI the accessions were grouped into 3 categories. Out of total,20 accessions had RCI in the range of 17-40% and categorized as heat tolerant, 17 with RCI in the range of 41-60% and categorized as medium tolerant, and 11 accessions with RCI > 60% were categorized as heat susceptible (Figure 6.2).

Table 6.11 Relative cell injury in different accession of gene pool material

Acc. No	RCI	Acc. No	RCI	Acc. No	RCI	Acc. No	RCI
1001	78	1015	17	1031	36	1055	62
1002	76	1017	18	1032	46	1056	33
1003	37	1018	26	1033	51	1057	53
1004	61	1019	47	1034	52	1058	27
1005	77	1020	57	1036	17	1059	18
1006	80	1021	56	1037	37	1061	40
1007	78	1023	58	1038	31	1062	24
1009	48	1025	30	1039	58	1063	24
1011	67	1026	67	1048	30	1064	25
1012	56	1027	29	1051	60	1065	90
1013	43	1028	41	1052	42	1066	24
1014	39	1029	63	1054	45	1067	45

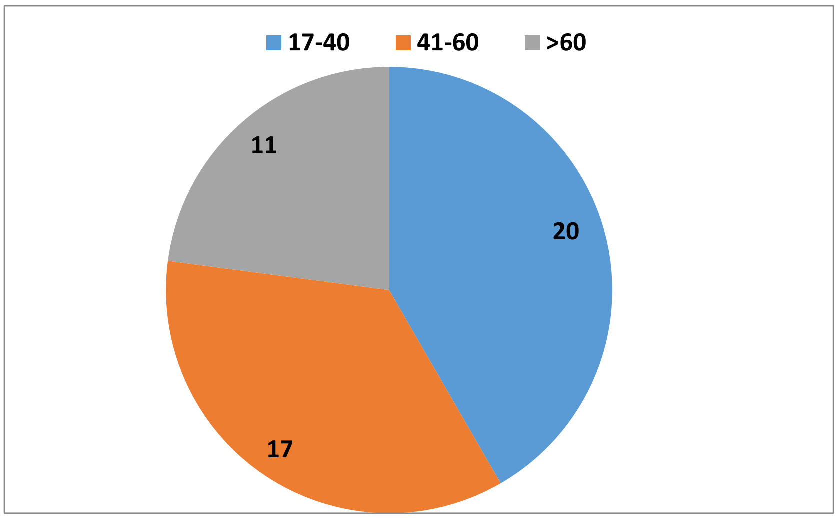

Figure 6.2 Categorization of genepool accessions based on relative cell injury

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, 2022.

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 8.30 while in reduced tillage plot it was 8.23. Electrical conductivity remained at 2.73 mS cm^{-1} in normal tillage and 2.78 mS cm^{-1} in reduced tillage plots, organic matter content remained at 0.74% in normal tillage plot and 0.80% in reduced tillage plot, extractable phosphorus at 23.8 mg kg^{-1} soil in normal tillage while 29.4 mg kg^{-1} soil in reduced tillage plots, extractable potassium at141 mg kg^{-1} and 147 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 58 cm and 76 cm, number of nodes 30 and 36, inter nodal length 3.06 and 3.13 cm, number of bolls per plant 19 and 22, boll weight 3.12 and 3.12 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 6.12).

Table 6.12 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
	58	76	30	36	1.93	2.11	19	22	3.12	3.12	113 8	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	8.30	8.23	2.73	2.78	0.74	0.80	23.8	29.4	141	147

NT=Normal Tillage RT= Reduced Tillage

6.2.2 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 (plant space 1.25') +Rice in furrows
T4	Cotton row skip+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 2.55mS 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 479mg kg^{-1} soil across the field (Table 6.13).

Table 6.13 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 regarding plant structure development at maturity were recorded. Plant height varied from 92 to 97 cm, number of nodes from 43 to 45 and intermodal length varied from 2.12 to 2.21 in Cyto-536 while, in NIAB-989 height varied from 94 to 97 cm, number of nodes from 42 to 44 and intermodal length varied from 216 to 22.29 in different treatments. In the treatment with row skip in cotton + rice in furrows maximum height, number of nodes on main stem and intermodal length were observed in both genotypes (Table 6.14).

Table 6.14 Effect of different treatments on plant structure development

Treatment	**Height (cm)**		**Node**		**Inter node**	
	Cyto-536	**NIAB-989**	**Cyto-536**	**NIAB-989**	**Cyto-536**	**NIAB-989**
Cotton-sole	92	95	43	44	2.12	2.17
Cotton (1' PxP) + Rice	96	96	44	43	2.19	2.23
Cotton (1.25' PxP) +Rice	96	94	45	43	2.16	2.16
RS (1' PxP) + Rice	97	97	44	42	2.21	2.29
Treatment	ns		Ns		*	
Genotype	ns		*		*	
Interaction	ns		Ns		ns	

Seed cotton yield, yield attributing factor and rice yield varied significantly among various treatments. Seed cotton yield, boll weight and number of bolls per plant varied from 554 to 923 kg ha^{-1}, 2.26 to 2.69 (g) and 21 to 26, respectively in Cyto-536 while, in NIAB-989 seed cotton yield boll weight and number of bolls per plant varied from 633 to 949 kg ha^{-1} , 2.27 to 2.75 (g) and 20 to 24, respectively in different treatments. Maximum seed cotton yield was obtained in control treatment followed by cotton (1.25' PxP)+ rice, cotton (1' PxP)+ rice and row skip in cotton +

rice(Table 6.20). Paddy yield varied from 2425 to 2584 kg ha^{-1} in Super variety, while in KS-33 paddy yield varied from 2980 3006 kg ha^{-1} in different treatments (Table 6.20). Maximum paddy yield was observed in row skip in cotton + rice in furrows treatment as compared to other treatments (Table 6.15)

Table 6.15: Effect of different treatments on seed cotton yield, yield attributing factors and paddy yield

Treatment	Yield (kg ha^{-1})		Boll weight (g)		Bolls per plant		R.yield (kg ha^{-1})	
	Cyto-536	NIAB-989	Cyto-536	N-989	Cyto-536	NIAB-989	Sup.	KS-33
Cotton-sole	923	949	2.69	2.75	26	24	-	-
Cotton (1' PxP) + Rice	804	870	2.26	2.27	21	23	2425	2980
Cotton (1.25' PxP) +Rice	870	936	2.29	2.31	23	20	2478	3000
Row skip (1' PxP) + Rice	554	633	2.44	2.43	25	20	2584	3006
Treatments	*		*		*		*	
Genotypes	*		*		*		*	
Interaction	ns		Ns		*		ns	

Land equivalent ratio (LER) and area time equivalent ratio (ATER) were calculated for different treatments. LER indicate the efficient utilization of land and higher value of LER indicates 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, when Super variety of rice intercropped the LER varied from 1.18 to 1.50 and ATER varied from 0.59 to 0.75 in Cyto-536, while in NIAB-989 LER varied from 1.25 to 1.54 and ATER varied from 0.62 to 0.77 in different treatments. Similarly, when KS-33 variety of rice intercropped, LER varied from 1.21 to 1.55 and ATER varied from 0.60 to 0.77 in Cyto-536, while in NIAB-989 the LER varied from 1.28 to 1.59 and ATER varied from 0.64 to 0.80 in different treatments (Table 6.23). Maximum value of LER and ATER were observed in the treatment where Cotton planted at 1.25' PxP +Rice in furrows in both genotypes of rice and cotton (Table 6.16).

Table 6.16: Land equivalent ratio and area time equivalent ratio in different treatments

Treatment	LER= Yp/Ym				ATER= (LERxDc/Dt)			
	SUP		SUP		SUP		KS-33	
	Cyto-536	Cyto -536	Cyto-536	Cyto-536	Cyto-536	NIAB-989	Cyto-536	NIAB-989
Cotton-sole	--	--	--	--	--	--	--	--
Cotton (1' PxP) + Rice	1.42	0.71	0.71	0.71	0.71	0.73	0.74	0.76
Cotton (1.25' PxP) +Rice	1.50	0.75	0.75	0.75	0.75	0.77	0.77	0.80
Row skip in cotton (1' PxP) + Rice	1.18	0.59	0.59	0.59	0.59	0.62	0.60	0.64

Yp=crop yield in inter-cropping, Ym= crop yield in mono-cropping
Dc= Time taken by inter crop , Dt=total time of crop

Cotton yield equivalent ratio (CYER) was calculated for different treatments, CYER give the additional yield from intercrop in cotton, when Super variety of rice intercropped the CYER values varied from 923 to 1465 in Cyto-536, while in NIAB-989 CYER varied from 949 to 1531. similarly, when KS-33 variety of rice intercropped, CYER varied from 923 to 1470 in Cyto-536, while in NIAB-989 the CYER varied from 949 to 1536 in different treatments (Table 6.24). Maximum value of CYER was observed in the treatment where Cotton planted at 1.25' PxP +Rice in furrows in both genotypes of rice and cotton (Table 6.17).

Net profit was calculated for different treatments, net profit varied significantly among various treatments, when Super variety of rice intercropped the net profits values varied from 33150 to 119250 in Cyto-536, while in NIAB-989 net profit varied from 39650 to 135650. Similarly, when KS-33 variety of rice intercropped, net profit varied from 33150 to 120500 in Cyto-536, while in NIAB-989 the net profit varied from 39650 to 137000 in different treatments (Table 6.18). Maximum net profit was observed in the treatment where Cotton planted at 1.25' PxP +Rice in furrows in both genotypes of rice and cotton (Table 6.23).

Table 6.17: Cotton yield equivalent ratio in different treatments

Treatment	CYER=SCY+(IYxIYP/PSC)			
	SUP		KS-33	
	Cyto-536	NIAB-989	Cyto-536	NIAB-989
Cotton-sole	923+000=923	949+000=949	923+000=923	949+000=949
Cotton (1' PxP) + Rice	804+582=1386	870+582=1452	804+596=1400	870+596=1466
Cotton (1.25' PxP) +Rice	870+595=1465	936+595=1531	870+600=1470	936+600=1536
Rrow skip in cotton (1' PxP) + Rice	554+620=1174	633+620=1253	554+601=1155	633+601=1234

IY= Intercrop yield, IYP= Intercrop yield Price, PSC=Price of one kg seed cotton

Table 6.18: Net profit from different treatments

Treatment	Net profit=Gross income-Cost of production			
	SUP		KS-33	
	C-536	N-989	C-536	N-989
Cotton-sole	230750-197600 =33150	237250-197600 =39650	230750-197600 =33150	237250-197600 =39650
Cotton (1' PxP) + Rice	346500-247000 =99500	363000-247000 =116000	350000-247000 =103000	366500-2470000 =119500
Cotton (1.25' PxP) +Rice	366250-147000 =119250	382750-247000 =135750	367500-247000 =120500	384000-247000 =137000
Row skip in cotton (1' PxP) + Rice	288500-147000 =41500	313250-47000 =66250	288750+247000=41 750	308500-247000 =61500

6.2.3 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.

An 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-541 and CIM-775 were used for execution of the experiment. Detail of experiment is given below:

Tr.	Nutrients
T1	Control
T2	Recommended dose of NPK nutrients (RD)
T3	50% of RD by fertigation
T4	40% of RD by fertigation + 10% foliar
T5	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 8.17 to 8.35, electrical conductivity from 2.23 to 2.59 mS cm^{-1}, organic matter content from 0.51 to 0.78%, extractable potassium (K) from 121 to 136 mg kg^{-1} soil and extractable sodium from 3373 to mg441 kg^{-1} soil across the field (Table 6.19).

Table 6.19 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	8.35	2.39	0.71	136	441
2	8.17	2.23	0.78	124	373
3	8.32	2.25	0.61	121	391
4	8.21	2.59	0.51	108	431
Mean	**8.26**	**2.34**	**0.65**	**122**	**410**

Data regarding plant growth development were measured at maturity. Results revealed that plant height ranged from 101 to 122 cm, number of nodes ranged from 48 to 52 and intermodal length ranged from 2.07 to 2.34 cm in Cyto-541 while, in CIM-775 plant height ranged from 125 to 137 cm, number of nodes from 45 to 49 and inter nodal length ranged from 2.61 to 3.03 cm in different treatments. Averaged across genotypes, in treatment T5 that received 35% of recommended dose by fertigation+15% by foliar spray of fertilizers, the main stem height and number of nodes on main stem remained higher over control as well as over other treatments in both genotypes (Table 6.20).

Table 6.20 Plant structure at maturity in two genotypes under different fertilizer application methods

Tr.	Height (cm)			Nodes			Inter Node		
	Cyto-541	CIM-775	Av.	Cyto-541	CIM-775	Av.	Cyto-541	CIM-775	Av.
T1	101	125	113	49	48	49	2.07	2.61	2.34
T2	112	137	125	50	46	48	2.22	2.97	2.60
T3	109	135	122	48	45	47	2.27	2.98	2.63
T4	118	136	127	51	45	48	2.31	3.03	2.67
T5	122	134	128	52	49	51	2.34	2.72	2.53
Treatment	*			*			*		
Genotype	*			*			*		
Interaction	*			*			*		

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 in both genotypes 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 22% and 13% in Cyto-541, and 15% and 11% in CIM-775,respectively, as compared to those where 50% of recommended fertilizer was applied by fertigation (Table 6.21).

Table 6.21 Fresh weights of leaves and stalk at maturity in two genotypes under different fertilizers application methods

Treatments	Leaves weight (g)		Stalk weight (g)	
	Cyto-541	CIM-775	Cyto-541	CIM-775
T1	63.6	74.2	123.4	137.6
T2	98.9	109.0	168.6	211.4
T3	78.5	89.7	143.3	172.2
T4	93.4	100.5	155.5	187.6
T5	95.7	103.4	162.4	191.4
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 T5 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 T2 (Table 6.22).

Table 6.22 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-541	CIM-775	Cyto-541	CIM-775	Cyto-541	CIM-775
T1	25	27	3.32	2.74	1037	1177
T2	29	31	3.66	3.25	1513	1849
T3	27	26	3.37	2.81	1205	1261
T4	28	28	3.46	3.03	1205	1345
T5	28	28	3.58	3.15	1457	1513
Genotype	*		*		*	
Application method	ns		ns		*	
Interaction	ns		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 T5 treatment where 35% of recommended fertilizer dose was applied by fertigation+15% by foliar as compared to other treatments in both cotton genotypes. Furthermore, T5 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 (Table6.23).

Table 6.23 Economic analyses in two genotypes under different fertilizer application method

Tr.	Seed index (g)		Agronomic efficiency of fertilizers		Benefit/cost ratio	
	Cyto-541	CIM-775	Cyto-541	CIM-775	Cyto-541	CIM-775
T1	8.12	7.13	3.18	4.15	2.10	2.38
T2	8.60	7.78	4.73	5.78	2.36	2.88
T3	8.50	7.52	7.09	7.42	2.22	2.32
T4	8.60	7.63	7.09	7.91	2.14	2.39
T5	9.00	7.68	8.57	8.90	2.59	2.69
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 T5 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 6.24).

Table 6.24 Fiber traits in two genotypes under different P treatments

Tr.	Staple length (mm)		Uni. index (%)		Micronaire		Strength (G/Tex)	
	Cyto-541	CIM-775	Cyto-541	CIM-775	Cyto-541	CIM-775	Cyto-541	CIM-775
T1	26.1	26.0	81.7	80.8	4.6	5.0	27.5	25.0
T2	27.7	26.9	80.4	82.1	4.4	4.9	27.4	26.1
T3	26.4	26.1	81.7	80.8	4.6	5.0	27.5	25.0
T4	27.2	26.4	82.0	80.7	4.3	4.3	27.8	26.7
T5	28.1	27.5	83.4	82.9	4.5	4.9	28.7	28.5
Genotype	*		ns		*		*	
Application methods	*		*		*		*	
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 undernourishment, 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 2022-23. A total of twelve cotton genotypes viz.

CIM-875, CIM-975, CIM-990, Cyto-536, Cyto-545, Cyto-541, NIAB-868, CRIS-700, NIAB-585,NIAB-787, NIAB-992 and NIAB-989 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, 2022. 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.

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 100 to 157 cm, nodes on main stem from 45 to 54 and inter-nodal length from 2.21 to 3.07 cm in different genotypes under normal irrigation. In water stress conditions, the main stem height ranged from 96 to 140 cm, nodes on main stem from 44 to 52 and inter-nodal length from 1.97 to 2.88 cm in different genotypes. Averaged across water regimes, main stem height varied from 98 to 146 cm, nodes on main stem from 45 to 52 and inter-nodal length from 2.09 to 2.97 cm. Imposition of water stress caused a decrease of 9.84% in main stem height and 5.35% in inter-nodal length, irrespective of genotypes (Table 6.25).

Table 6.25 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	151.33	140.00	145.67	49.33	48.67	49.00	3.07	2.88	2.97
CIM-975	121.33	102.33	111.83	51.00	48.33	49.67	2.38	2.12	2.25
CRIS-700	118.00	114.33	116.17	51.33	49.33	50.33	2.29	2.31	2.30
Cyto-541	121.67	115.33	118.50	53.33	51.67	52.50	2.28	2.23	2.26
CIM-990	132.33	124.00	128.17	54.33	49.67	52.00	2.43	2.50	2.47
NIAB-868	115.33	106.00	110.67	49.33	49.67	49.50	2.34	2.13	2.24
NIAB-585	112.33	105.67	109.00	49.33	47.00	48.17	2.27	2.25	2.26
NIAB-787	119.33	102.67	111.00	53.67	50.67	52.17	2.24	2.03	2.13
NIAB-992	114.33	96.67	105.50	50.67	47.00	48.83	2.25	2.06	2.16
Cyto-536	105.67	96.33	101.00	46.67	44.33	45.50	2.26	2.17	2.22
NIAB-989	119.67	113.33	116.50	52.00	51.00	51.50	2.30	2.22	2.26
Cyto-545	100.33	97.00	98.67	45.33	49.33	47.33	2.21	1.97	2.09
Mean	119.31	109.47	114.39	50.53	48.89	49.71	2.36	2.24	2.30
WR		*	*	*	*	*	*	*	*
G		*	*	*	*	*	*	*	*
WRxG		*	*	*	*	*	*	*	*

WR= Water Regime G= Genotype

Proline content, relative water content (RWC) and chlorophyll SPAD values varied significantly among genotypes and between water regimes. The proline ranged from 8.5 – 14.45 (µg g^{-1} FW), RWC from 82.3 – 94.1%, and chlorophyll content (SPAD) from 48.7 to 58.6 in different genotypes, irrespective of water regimes. The imposition of water stress increased proline content from 9.6 to 13.0 (µg g^{-1} FW), decreased RWC from 93.1 to 84.5%, and also lowered chlorophyll content from 55.4 to 51.5, on overall basis (Table 6.26).

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 19 to 44, boll weight from 2.40 to 3.85 g, and seed cotton yield from 1281 to 2306 kg ha^{-1}, in different genotypes, irrespective of water regimes. With the imposition of water stress, seed cotton yield decreased from 1915 to 1623 kg ha^{-1}, bolls per plant from 28 to 23 and boll weight from 2.91 to 2.70 g irrespective of the genotypes. Water stress decreased the seed cotton yield, number of boll per plant and boll weight by 15.24%, 19.9% and 7.21%, respectively. The genotype CIM-990 produced the maximum seed cotton yield of 2306 kg ha^{-1} with 44 bolls per plant and boll weight of 3.42 g in normally irrigated plots and also performed well among water stressed conditions. 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 6.27).

Table 6.26 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	94.1	82.5	10.65	12.35	56.75	52.25
CIM-975	92	85.15	10.1	13.35	53.6	49.9
CRIS-700	93.9	84.25	9.2	11.25	56.55	48.75
Cyto-541	92.5	85.25	8.8	13.3	56.8	52.5
CIM-990	95	86.25	9.95	13.1	57.1	55.3
NIAB-868	91.7	85.75	9.5	14.25	56.35	51.75
NIAB-585	94.4	85.2	10.35	14.3	58.6	53.4
NIAB-787	94.15	83.7	8.5	12.15	53.75	51.25
NIAB-992	92.45	82.3	9.9	12.55	50.7	47.5
Cyto-536	91.45	82.85	9	11.8	55.95	53.4
NIAB-989	93.4	84.1	10.45	14.45	57.7	52.05
Cyto-545	92.75	87.65	8.85	13.5	52.05	50
Mean	**93.15**	**84.57917**	**9.604167**	**13.02917**	**55.49167**	**51.50417**
G	**		*	*	*	*
WR	*		*	*	*	*
GxWR	*		*	*	*	*

WR= Water Regime G= Genotype

Table 6.27 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
CIM-875	28.3	22.0	25.2	3.85	3.30	3.6	1965	1794	1879
CIM-975	26.7	19.0	22.8	2.60	2.40	2.5	1452	1367	1409
CRIS-700	24.3	26.3	25.3	2.78	2.66	2.7	1965	1794	1879
Cyto-541	23.3	20.0	21.7	3.43	3.34	3.4	2135	1794	1965
CIM-990	44.3	28.0	36.2	3.42	3.15	3.3	2306	1794	2050
NIAB-868	28.3	19.0	23.7	2.71	2.61	2.7	1965	1794	1879
NIAB-585	18.3	23.7	21.0	2.65	2.42	2.5	2306	1794	2050
NIAB-787	25.3	18.7	22.0	2.63	2.62	2.6	2135	1794	1965
NIAB-992	27.3	19.3	23.3	2.48	2.26	2.4	1538	1281	1409
Cyto-536	30.0	24.3	27.2	2.64	2.59	2.6	1708	1367	1538
NIAB-989	28.0	23.3	25.7	2.56	2.51	2.5	1538	1452	1495
Cyto-545	33.0	26.3	29.7	3.19	2.54	2.9	1965	1452	1708
Mean	28.1	22.5	25.3	2.91	2.70	2.8	1915	1623	1769
Treatment (Tr)	*	*	*	*	*	*	*	*	*
Genotype (G)	*	*	*	*	*	*	**	*	*
TrxG	*	*	*	*	*	*	**	*	*

6.3.2 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, Arbuscularmycorrhizal fungi enhanced salinity-tolerance of *Panicumturgidum* 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:

<table>
<tr><th>Water level</th><th colspan="2">PGPR treatment</th></tr>
<tr><td>Normal Irrigation</td><td rowspan="2">Seed-coated</td><td rowspan="2">Seed-uncoated</td></tr>
<tr><td>Water stress</td></tr>
</table>

Data regarding plant structure development were taken at maturity. Results revealed that in PGPR-coated treatment the plant height remained at 112 cm and 93 cm, number of nodes on main stem 39 and 36, intermodal length 2.87 and 2.56 cm in Cyto-541 and Cyto-537, respectively, under NS, while plant height remained at 97 cm and 87 cm, number of nodes on main stem 36 and 35, inter nodal length 2.68 and 2.49 cm in Cyto-541 and Cyto-537, respectively, under WS condition. Similarly, in PGPR-uncoated treatment, plant height remained at 109 cm and 88 cm, number of nodes on main stem remained at 38 and 36, inter-nodal length 2.89 and 2.46 cm in Cyto-541 & Cyto-537, respectively, under NS condition, while plant height remained at 91 cm and 80 cm, nodes on main stem remained at 35 and 35, inter-nodal length 2.58 and 2.29 cm in Cyto-541 and Cyto-537, respectively, under WS condition **(Table 6.28).**

Table 6.28 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	112	93	39	36	2.87	2.56
	WS	97	87	36	35	2.68	2.49
Seed-uncoated	NS	109	88	38	36	2.89	2.46
	WS	91	80	35	35	2.58	2.29
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 8.65 and 8.54 g, benefit/cost ratio at 3.13 and 3.02 in Cyto-541 and Cyto-537, respectively, under no stress, while seed index remained at 8.23 and 7.62 g, benefit/cost ratio at 2.62 and 2.42 in Cyto-541 and Cyto-537, respectively, under water stress condition. Similarly, in PGPR-uncoated treatment seed cotton index remained at 8.47 and 8.41, benefit/cost ration at 2.97 and 2.87 in Cyto-541 and Cyto-537, respectively, under no stress, while seed cotton index remained at 7.91and 7.03, benefit/cost ration at 2.52 and 2.27 in Cyto-541 and Cyto-537, respectively, under water stress condition (Table 6.29).

Table 6.29 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-541	Cyto-537	Cyto-541	Cyto-537
Seed-coated	NS	8.54	8.65	3.13	3.02
	WS	7.62	8.23	2.62	2.42
Seed-uncoated	NS	8.41	8.47	2.97	2.87
	WS	7.03	7.91	2.52	2.27
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 16 and 18, boll weight at

3.50 and 3.32, seed cotton yield at 1853 and 1793 kg ha^{-1}, in Cyto-541 and Cyto-537, respectively, under no stress, while the bolls per plant remained at 11 and 12, boll weight at 3.42 and 2.98 g, seed cotton yield at 1554 and 1435 kg ha^{-1} in Cyto-541 and Cyto-537, respectively, under water stress condition. Similarly, in PGPR-uncoated treatment the bolls per plant remained at 15 and 16, boll weight at 3.47 and 3.11 g, seed cotton yield seed at 1763 and 1704 kg ha^{-1}, in Cyto-541 and Cyto-537, respectively, under no stress, while the bolls per plant remained at 9 and 10, boll weight at 3.16 and 2.79 g, seed cotton yield at 1494 and 1345 kg ha^{-1} in Cyto-541 and Cyto-537, respectively, under water stress condition (Table 6.30).

Table 6.30 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 (kg ha^{-1})	
		Cyto-541	Cyto-537	Cyto-541	Cyto-537	Cyto-541	Cyto-537
Seed-coated	NS	16	18	3.50	3.32	1853	1793
	WS	11	12	3.42	2.98	1554	1435
Seed-uncoated	NS	15	16	3.47	3.11	1763	1704
	WS	9	10	3.16	2.79	1494	1345
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 heat susceptible genotypes at different sowing time in improving the cottonseed health and quality

Cottonseeds with high oil content can easily be deteriorated. The deterioration in cottonseed can adversely affect germination, seedling emergence & vigor, and subsequent performance of plants. Reactive oxygen species (ROS) are continuously produced by the metabolically active cells of seeds, and apparently play important roles in biological processes such as germination and dormancy. ROS production negatively affects cellular integrity and metabolism, such as damage to membranes and to cellular components like proteins, lipids, and DNA. Losses of ROS-scavenging enzyme activities, the occurrence of oxidative reactions lead to membrane damage and lipid peroxidation and production of free fatty acids and free radicals. Free fatty acids and free radicals in seed are associated with seed deterioration. Deteriorated seeds loose their normal morphology and physiology. Cotton plant has several mechanisms to combat with different abiotic environmental stresses such as inadequate and inconsistent rainfall, salinity, water shortage, extreme temperature, and some other factors. Such stresses limit crop yields by square drying, premature floral abscission and either failure to set the bolls or development of seeds with poor germination. In this way boll productivity and cottonseed health is affected. Priming of cottonseed with proline and salicylic acid work as antioxidant defense by reducing lipid peroxidation and eliminating free radicals of oxygen. Therefore, seed priming improves production of healthy seed with greater germinaton. The seed priming biochemicals play crucial role in de novo synthesis of DNA and proteins, and antioxidant metabolites. Seed priming cause numerous metabolic changes to overcome germination problems when plant is in stress.

The main objective of this study was to evaluate the effect of seed priming and high temperature stress on cotton growth, cottonseed health and productivity. A field experiment was conducted to evaluate the efficacy of seed priming on four cotton genotypes viz. GH-Hamaliya, CIM-541 (heat tolerant) and CIM-789, Cyto-535 (heat susceptible). The experiment was divided into two sets prior to sowing i.e. Set-A and Set-B. Set-A was sown on 1st of April 2022 and Set-B on 22nd April 2022 in a randomized complete block design (RCBD) with split plot arrangement (genotypes; main plot and seed treatment; sub plots). 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.

Treatments	Bio-chemicals seed priming	Dose
T1	Control	No priming
T2	Proline	0.1%
T3	Salicylic Acid	0.01%
T4	Disprin	0.01% (S.A)

Assessment of seed quality parameters was done from the mature cotton seeds. Results indicated that the seed priming of four cotton genotypes viz. GH-Hamaliya, CIM-541 (heat tolerant) and CIM-789, Cyto-535 (heat susceptible) improved seed health parameters such as seed germination, seed index, oil and crude protein content. Average across the genotypes, in both sets, pH and electrical conductivity of the seed exudates increased in April 22 sowing and seed priming with disprin @ 0.01% SA showed the maximum change. Biochemical analysis of the oil revealed that the free fatty acids in seeds of all genotypes (both sets) were within safe limits i.e. less than1.0%. In **Set-A**, in heat tolerant genotypes, seed germination varied from 40-82%, seed index from 6.0-8.2g, oil content from 16 to 20% and crude protein from 15 to 27% and in heat susceptible genotypes, seed germination varied from 38 -73%, seed index from 6.1-7.9g, oil content from 14 to 18% and crude protein from 14 to 24% in different treatments. while in **Set-B**, in heat tolerant genotypes, seed germination varied from 35-74%, seed index from 6.1- 7.9g, oil content from 15 to 20% and crude protein from 14 to 25% and in heat susceptible genotypes, seed germination varied from 37- 69%, seed index from 5.8 – 7.3g, oil content from 13 to 17% and crude protein from 14 to 22%. in different treatments.

Table 6.31 Effect of seed priming on seed quality parameters

Seed Priming Treatments	Heat tolerant		Heat susceptible		Mean
	GH-Hamaliya	CIM-541	CIM-789	CYTO-535	
		pH			
		1st April			
T1 : Control	6.4	6.1	5.9	6.7	**6.3**
T2 : Proline @ 0.1%	6.7	6.2	6.2	6.8	**6.5**
T3 : SA @ 0.01%	7.1	6.4	6.4	7.2	**6.8**
T4 : Disprin @ 0.01% SA	7.2	6.6	6.6	7.4	**7.0**
Mean	**6.9**	**6.3**	**6.3**	**7.0**	
		22nd April			
T1 : Control	7.1	6.5	7.3	7.1	**7.0**
T2 : Proline @ 0.1%	7.2	6.7	7.2	7.3	**7.1**
T3 : SA @ 0.01%	7.5	6.9	7.4	7.6	**7.4**
T4 : Disprin @ 0.01% SA	7.7	7.3	7.7	7.9	**7.7**
Mean	**7.4**	**6.9**	**7.4**	**7.5**	
		EC (µS cm^{-1})			
		1st April			
T1 : Control	267	256	312	344	**295**
T2 : Proline @ 0.1%	287	277	333	354	**313**
T3 : SA @ 0.01%	309	311	345	367	**333**
T4 : Disprin @ 0.01% SA	312	323	378	388	**350**
Mean	**294**	**292**	**342**	**363**	
		22nd April			
T1 : Control	306	316	332	333	**322**
T2 : Proline @ 0.1%	312	322	345	364	**336**
T3 : SA @ 0.01%	336	345	367	377	**356**
T4 : Disprin @ 0.01% SA	377	389	379	398	**386**
Mean	**333**	**343**	**356**	**368**	
		Germination (%)			
		1st April			
T1 : Control	40	44	38	42	**41**
T2 : Proline @ 0.1%	55	68	58	59	**60**

T3 : SA @ 0.01%	77	79	66	67	**72**
T4 : Disprin @ 0.01% SA	80	82	70	73	**76**
Mean	**63**	**68**	**58**	**60**	
		22nd April			
T1 : Control	35	41	37	39	**38**
T2 : Proline @ 0.1%	50	59	55	51	**54**
T3 : SA @ 0.01%	72	61	61	58	**63**
T4 : Disprin @ 0.01% SA	74	69	69	61	**68**
Mean	**58**	**58**	**56**	**52**	
		Seed index (g)			
		1st April			
T1 : Control	6.9	6.0	6.1	6.8	**6.5**
T2 : Proline @ 0.1%	7.4	6.6	6.4	7.3	**6.9**
T3 : SA @ 0.01%	7.6	6.9	6.8	7.5	**7.2**
T4 : Disprin @ 0.01% SA	8.2	7.2	6.9	7.9	**7.6**
Mean	**7.5**	**6.7**	**6.6**	**7.4**	
		22nd April			
T1 : Control	6.2	5.5	5.8	6.1	**5.9**
T2 : Proline @ 0.1%	7.1	6.1	6.1	6.7	**6.5**
T3 : SA @ 0.01%	7.2	6.5	6.3	7.1	**6.8**
T4 : Disprin @ 0.01% SA	7.9	6.9	6.5	7.3	**7.2**
Mean	**7.1**	**6.3**	**6.2**	**6.8**	
		Oil Contents(%)			
		1st April			
T1 : Control	17	16	14	16	**16**
T2 : Proline @ 0.1%	19	18	16	17	**18**
T3 : SA @ 0.01%	22	21	18	21	**21**
T4 : Disprin @ 0.01% SA	27	24	21	22	**24**
Mean	**21**	**20**	**17**	**19**	
		22nd April			
T1 : Control	15	16	13	14	**15**
T2 : Proline @ 0.1%	17	17	15	17	**17**
T3 : SA @ 0.01%	19	20	20	20	**20**
T4 : Disprin @ 0.01% SA	22	22	21	22	**22**
Mean	**18**	**19**	**17**	**18**	
		Free fatty acid (%)			
		1st April			
T1 : Control	0.99	0.87	0.97	0.79	**0.91**
T2 : Proline @ 0.1%	0.85	0.77	0.85	0.67	**0.79**
T3 : SA @ 0.01%	0.78	0.69	0.72	0.60	**0.70**
T4 : Disprin @ 0.01% SA	0.76	0.66	0.69	0.61	**0.68**
Mean	**0.85**	**0.75**	**0.81**	**0.67**	
		22nd April			
T1 : Control	0.98	0.99	0.99	0.96	**0.98**
T2 : Proline @ 0.1%	0.96	0.91	1.04	0.92	**0.96**
T3 : SA @ 0.01%	0.87	0.84	0.79	0.87	**0.84**
T4 : Disprin @ 0.01% SA	0.81	0.77	0.92	0.71	**0.80**
Mean	**0.91**	**0.88**	**0.94**	**0.87**	
		Crude protein (%)			
		1st April			
T1 : Control	18.0	15.0	14.0	17.0	**16.0**
T2 : Proline @ 0.1%	22.0	18.0	16.0	21.0	**19.3**
T3 : SA @ 0.01%	25.0	22.0	21.0	23.0	**22.8**
T4 : Disprin @ 0.01% SA	27.0	25.0	22.0	24.0	**24.5**
Mean	**23.0**	**20.0**	**18.3**	**21.3**	
		22nd April			
T1 : Control	17.0	14.0	14.0	16.0	**15.3**
T2 : Proline @ 0.1%	21.0	15.0	15.0	19.0	**17.5**
T3 : SA @ 0.01%	24.0	19.0	19.0	21.0	**20.8**
T4 : Disprin @ 0.01% SA	25.0	21.0	21.0	22.0	**22.3**
Mean	**21.8**	**17.3**	**17.3**	**19.5**	

SA= Salicylic acid

7. TRANSFER OF TECHNOLOGY SECTION

Transfer of Technology Section is playing a pivotal role to disseminate the all types of research findings/ practices of cotton researchers for the development of both new cotton production & seed technology to cotton growers & the stakeholders through information & communication technologies (ICT) / mass media.

7.1 Human Resource Development

7.1.1 Training Programs

The following training programs were arranged during the season:

i) Cotton production technology
ii) Advance agronomic practices for better cotton yield
iii) Land preparation for cotton crop
iv) Soil health & its analysis
v) Soil sampling & testing
vi) Method of cotton seed germination
vii) Cultivation of approved cotton varieties
viii) Fertilizer applications for cotton crop
ix) Current cotton crop situation
x) Insect Pest Management(IPM)especially to Whitefly
xi) Wilting in cotton crop
xii) Clean cotton picking
xiii) Fiber traits
xiv) Post-harvest management and techniques of cotton
xv) Off-season management of the cotton crop through PB-Ropes
xvi) Use of PBW Manager for control of PBW
xvii) Management of seasonal and non-seasonal Pink Bollworm (PBW)
xviii) Insect Pest Management (IPM) especially related to Pink Bollworm

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

Date	Organized/ Coordinated by	Venue	Resource Person	Participants
22.03.2022	CCRI Multan (BCI-Project)	CCRI Multan	i.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed	**Total=65** (BCI field staff)
23.03.2022	CCRI Multan (BCI-Project)	-do-	.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed	**Total=71** (BCI field staff)
29.03.2022	CCRI Multan (BCI-Project)	CCRI Multan	i.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed ii.Dr.Rabia Saeed	**Total=203** Master Trainees= 26 Farmers = 177
01.04.2022	CCRI,Multan,CCRI Sakrand & Agri .Ext.Sindh (BCI-Project)	Sakrand & Agri Extension ,sindh	i.Dr.Zahid Mahmood ii. Allah Dino Kalhoro iii.Others	**Total=97** Master Trainees = 07 Farmers =90
27.04.2022	CCRI Multan (BCI-Project)	CCRI Multan	i.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed	**Total=57** (BCI field staff)
11.05.2022	CCRI Multan (BCI-Project)	-do-	i.Dr.Zahid Mahmood ii.Dr.Fiaz Ahmed	**Total=33** (BCI field staff
14.05.2022	CCRI Multan (BCI-Project)	Chak Faiz-4, Multan	i.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed	**Total=103** Farmers=96

			iv.Mr.Sajid Mahmood	BCI Staff=07
16.05.2022	CCRI Multan & PW&QC, Punjab (Agri.Officers)	CCRI Multan	i.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv.Ms.Sabhat Hussain v.Dr.Rabia Saeed	**Total=12** (Agri.Officers)
17.05.2022	CCRI Multan & Agri.Extension Deptt.Punjab	-do-	Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv.Ms.Sabhat Hussain v.Dr.Rabia Saeed	**Total=24** (Agri.Officers)
18.05.2022	CCRI, FFC & Agri.Ext,Punjab	Dunya Pur	Dr.Zahid Mahmood	**Total=465** Agri.Ext.DDA=01 Field Staff=04 Farmers= 448 FFC Staff=12
19.05.2022	CCRI Multan & Crop Reporting Deptt.Agri.Punjab	CCRI Multan	Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv.Ms.Sabhat Hussain v.Dr.Rabia Saeed	**Total=53** (Agri.Officers)
21.05.2022	CCRI Multan (BCI-Project)	Moza Chatta,Makhdu m Rashid	.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv.Mr.Sajid Mahmood	**Total=205** Farmers= 198 BCI Staff=07
04.05.2022	CCRI Multan (BCI-Project)	19-Kassi Moza Mirzaan Pur,Basti Sahoo	i.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv.Mr.Sajid Mahmood	**Total=213** Farmers=205 BCI Staff=08
06.05.2022	CCRI Multan (BCI-Project)	CCRI Multan (Auditorium)	i Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv. Dr.Rabia Saeed v.Mr.Sajid Mahmood	**Total=227** Farmers=215 BCI Staff=12
09.06.2022	CCRI Multan (BCI-Project)	DG Khan U/C Sameena Bubber Wala	i.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv.Mr.Sajid Mahmood v.Junaid A Daha	**Total=219** Farmers=205 BCI Staff=14
11.06.2022	CCRI Multan & Agri.Ext.Punjab (BCI-Project)	CCRI Multan	i.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv.Dr.Rabia Saeed	**Total=277** Farmers =252 BCI Staff =16 Agri.Ext.DD = 01 F.A =08
14.06.2022	CCRI Sakrand & CCRI Multan	Sakrand	.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv.Mr.Sajid Mahmood v.Junaid Ahmed Daha vi.Scientific staff of CCRI Sakrand	**Total=341** Farmers =307 Scientific staff of both CCRI Sakrand & Multan =34
23.06.2022	CCRI Multan (BCI-Project)	CCRI Multan (Auditorium)	i.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv.Dr.Rabia Saeed iv.Mr.Sajid Mahmood	**Total=229** Farmers=211 BCI Staff=18

27.06.2022	CCRI Multan (BCI-Project)	DG Khan Shadan Lund	i Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv.Mr.Sajid Mahmood v.Junaid Khan Daha	**Total=317** Farmers=302 BCI Staff=15
02.07.2022	CCRI Multan	Mian Channu	i Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iv.Mr.Sajid Mahmood v.Junaid Khan Daha	**Total=42** Farmers
19.09.2022	CCRI Multan (BCI-Project)	CCRI Multan	i.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed	**Total=55** BCI Staff=55
16.09.2022	SAS PVT Ltd. & CCRI	Bahawalnagar (Faqeerwali)	Dr.Zahid Mahmood	**Total=73** Farmers= 68 SAS Staff=07
22.09.2022	CCRI Multan (BCI-Project)	CCRI Multan	i.Dr.Zahid Mahmood ii.Dr.M.Naveed Afzal iii.Dr.Fiaz Ahmed iv.Dr.Rabia Saeed	**Total=217** Lead Farmers=209 BCI Staff=08
17.10.2022	NPO,ILO,PWF & PCCC	CCRI Multan	i.Senator Rana Mahmood Ul Hasan ii.Mr.Mujtaba Gillani iii.Rana Iqbal Saraj iv.Dr.Zahid Mahmood v.others	**Total=293** Farmers=263 PCCC Staff=09 NPO=05 ILO=11 PWF=05
21.12.2022	CCRI,Multan & Agr.Ext (PP),Baluchistan	CCRI,Multan	i.Dr.Zahid Mahmood ii.Dr.Rabia Saeed	**Total=15** (Agri.Officers)

7.1.2 TV Programs/ SOT's

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

7.1.3 Radio Programs

Six (06) Radio Programs, one (01) group discussion and one (01) documentary conducted during the season.

7.1.4 Press Coverage/Media Talk

The section arranged Ten (10) press coverage and two (02) media talks during the season.

7.1.5 Preparation of Video Clips

Eleven (11) video clips were prepared and uploaded on social media for farmer's advice /information during the season.

7.1.6 Urdu Articles

Six (06) Urdu articles on "Cotton Production Technology" were sent & published in newspapers during the season.

7.1.7 Press Releases

Sixty Nine (69) press releases throughout the season 2022-23 were sent to the press time to time for the guidance of cotton farming community.

7.1.8 Press Report

A press report on "Review of cotton crop 2022-23" was sent to Daily-92, Lahore, and published.

7.1.9 Interview for Associated Press of Pakistan

A special interview of vice president, PCCC, Dr. Muhammad Ali Talpur regarding cotton production and Government policies was arranged for Associated Press of Pakistan (APP) on March 24, 2022.

7.1.10 Distribution of Printed Material

a. The following leaflets were distributed among cotton 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 Bt.CIM-785
- Recommendations of Cotton Variety Bt.CIM-678
- Recommendations of Cotton Variety Bt.CIM-632
- Recommendations of Cotton Variety Bt.CIM-663
- Recommendations of Cotton Variety Bt.Cyto-535
- Recommendations of Cotton Variety Cyto-226
- 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*
- *LEEF Technology*
- *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 during the season:

Sr#	Leaflet	No. of Copies
1.	سفارشات برائے کپاس کی قسم بی ٹی سی آئی ایم 785	**3000**
2.	سفارشات برائے کپاس کی قسم بی ٹی سی آئی ایم 678	**3000**
3.	سفارشات برائے کپاس کی قسم بی ٹی سی آئی ایم 663	**3000**
4.	سفارشات برائے کپاس کی قسم بی ٹی سائیٹو535	**3000**
5.	سفارشات برائے کپاس کی قسم سائیٹو 226	**3000**
6.	کپاس کے لئے لیف ٹیکنالوجی کے فوائد	**3000**

7.1.11 Agriculture Exhibitions

The institute planted stalls in agricultural exhibition during the season 2022-23:

Date	Organized by	Venue	Event	Resource Persons
17th October,2022	NPO,ILO,PWF & PCCC	CCRI Multan (Auditorium)	"Agricultural Production Convention"	i.Rana Mahmood UL Hassan,senator ii.Ahmed Mujtaba Gillani iii.Dr.Zahid Mahmood iv.others
7th October,2022	CCRI Multan	CCRI Multan	World Cotton Day	-do-

7.2 Meetings

7.2.1 Agriculture Research Sub-Committee (ARSC)

Two days consecutive meeting of Agriculture Research Sub-Committee (ARSC) of Pakistan Central Cotton Committee (PCCC) was held at Central Cotton Research Institute (CCRI), Multan on March 25-26, 2022 under the chairmanship of Dr. Muhammad Ali Talpur, Vice President (PCCC). The agenda of the meeting was the consideration of Annual Summary Progress Report for the year 2021-22 and the approval of Annual Program of Research Work for the year 2022-23. The meeting was attended by all members of the subcommittee PCCC offices, other public stakeholders, private seed sector and progressive farmers.

7.2.2 Annual Research Program of Adaptive Research Punjab

Annual Research Program for Kharif 2022 meeting of Adaptive Research Punjab was held in Auditorium at Agriculture House 21-Davis Road Lahore on March 28, 2022 under the supervision of Ch. Mushtaq Ali, DAC (FT&AR) Punjab Lahore. Dr. Muhammad Anjum Ali, Worthy DG, (Ext. & AR) Lahore, Punjab chaired the meeting. All SSMS/ DD Adaptive Research Punjab presented farmer’s problems oriented Research Trials studies. Professors of different Universities and scientists from Basic Research Institutes attended the meeting and they gave suggestions to improve the presented studies. The director Central Cotton Research Institute Multan also attended the meeting.

7.2.3 83rd Expert subcommittee meeting of Punjab Seed Council

83rd Expert subcommittee meeting of Punjab Seed Council was held on 22nd August 2022 at AARI Faisalabad under the chairmanship of Mr.Muhammad Nawaz Khan, Chief scientist AARI Faisalabad. In this meeting two (02) new BT varieties i.e BT CIM 343 and BT Cyto 537 of CCRI Multan were recommended for Punjab Seed Council. Dr.Zahid Mahmood, Director CCRI Multan and Dr. Muhammad Idrees Khan Head, PBG attended the meeting along with other participants.

7.2.4 Cotton Production Plan 2023-24

A significant meeting regarding cotton production plan 2023-24 was held at Ayub Agricultural Research Institute (AARI), Faisalabad on 9th December, 2022. Dr.Zahid Mahmood, Director, CCRI,Multan attended the meeting along with other stakeholders. Dr.Zahid Mahmood presented the valuable suggestions on cotton production plan in respect of climatic change scenario.

7.2.5 Meeting on "Pink Bollworm Management"

Experience Sharing Meeting on "Pink Bollworm Management" under the chairmanship of Dr. Zahid Mahmood, Director,CCRI Multan was held at the institute on March 22, 2022. Dr. Rabia Saeed,Head Entomology Section, briefed about PBW Management studies. Entomologists from different Research stations/departments also shared their studies.

7.2.6 Current cotton crop situation

A meeting regarding current cotton crop situation and others issues like integrated pest management for cotton, PB Ropes, PBW Manager, contamination free cotton, federal committee on agriculture, extension and media campaigns were discussed between Director CCRI Multan, and Director-General Agriculture Extension Punjab at the Institute on 7th May ,2022.

7.2.7 National Steering Committee Meeting

National steering committee meeting regarding “Adaption to Landscape Approach (ATLA)" hosted by BCI Pakistan was held in Lahore on 8th June 2022.Dr. Zahid Mahmood, Director, CCRI Multan attended the meeting with other participants.

7.2.8 Advisory Committee Meetings

Sixteen (16) meetings of farmers’ advisory committee were held at the Institute under Director CCRI Multan during the season 2022-23. Fortnightly recommendations were presented in the meeting for the guidance of all cotton growers’ community.

7.2.9 Quarterly BKN Meetings

Three quarterly Better Knowledge Network (BKN) meetings were held during the season 2022-23. Dr. Zahid Mahmood, Director CCRI Multan & his team participated in the meetings along with other representatives of various organizations working on cotton i.e Reeds, KB, BCI & WWF etc.

7.2.10 Knowledge partner with Better Cotton (BC)

A significant meeting regarding Knowledge Partner among Better Cotton (BC) & CCRI Multan was conducted at the institute under the chairmanship of Dr.Zahid Mahmood, Director of the institute on 16th November, 2022. The main objective of the meeting was to promote better cotton, enhancement of farmer’s capacity building and to protect the basic rights of workers associated with cotton value chain.

7.3 Punjab Agriculture Convention

Punjab Agricultural Productivity Convention organized by the Employers' Federation of Pakistan in Collaboration with the International Labor Organization, National Productivity Organization Pakistan & Central Cotton Research Institute Multan was held at the institute on October 17, 2022. Senator Rana Mahmood Ul Hasan was the chief guest of the convention. Mr. Ahmed Mujtaba Gillani, Rana Iqbal Saraj,Dr.Zahid Mahmood & others expressed their views. More than 250 participants attended the convention.

7.4 a. World Cotton Day

CCRI Multan celebrated the World Cotton Day today the 7th October 2022. Dr. Zahid Mahmood, Director of the institute was the chief guest of the program. While, the Vice President of PCCC Dr Muhammad Ali Talpur addressed the participants online. Dr. Zahid Mahmood, Director CCRI Multan; Mr. Sohail Mahmood Haral, Chairman PCGA, and Mr.Bilal Israiel, Chairman Punjab Agriculture Research Board (PARB) 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 300 participants from various stakeholders, NGOs and farmers attended the program.

b. Cotton Walk

On the eve of World Cotton Day at the institute, a cotton walk was arranged in commemorating the importance of cotton for the economy of Pakistan. Dr. Zahid Mahmood, Director of the institute along with other number of participated in the walk.

7.5 14th August 2022 Ceremony

Hoisting of National Flag ceremony & Tree Plantation was held on 14th August, 2022. 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 of the institute stated that we must all work with complete dedication and devotion for the country.

7.6 Participation in Conference/Workshop

Date	Workshop/Conference	Venue	Organized by	Participants
August 31, 2021	"5th Inspiring Change Conference (ICC) "	Lahore	Cotton USA & Other organizations	Dr.Zahid Mahmood
October4-7,2022	Workshop on "Sustainable Solutions for Revival of Cotton in Pakistan"	Cairo Egypt	World Cotton Research Conference (WCRC),Egypt	Dr.Fiaz Ahmed
November 8-10,2022	Workshop on "Better Cotton PP 2022"	Lahore	Better Cotton(BC)	Dr.ZAhid Mahmood
15th November,2022	Workshop on "Non-GM seed breeding, production & multiplication"	CCRI Multan	CABI & OCA	i.Dr.Yousaf Zafar ii.Dr.Zahid Mahmood iii.Dr.Taswar Hussain Malik iv.others
December 13-14, 2022	Workshop on "Elimination of Child Labour in Agriculture/Cotton, Textile and Garment Value Chains in Pakistan"	Islamabad	Food and Agriculture Organization of the United Nations (FAO) and International Labour Organization (ILO)	i.Dr.Zahid Mahmood

7.7 Visits

a. Dignitaries

Dignitaries/Delegation	Dated
Dr. Anjum Ali Butter, Director-General Agriculture Extension Punjab	07.05.2022
Four-member delegation from Sustainable Agriculture, Water & Intelligent Ecosystem (SAWiE), UK visited CCRI Multan.	23.05.2022
Delegation of Arysta Lifesciences Pakistan comprising Mr. Askif, from Indonesia; Mr. Irfan Jameel, Manager R&D and Mr. Naveed Ahmad, Assistant Manager R&D visited CCRI Multan.	29.06.2022
Mr. Muhammad Bashir Khetran, Joint Secretary, Ministry of National Food Security & Research	24.07.2022
A Delegation from Elevate Limited, REEDS Pakistan, and PCSI Multan visited CCRI Multan. Director CCRI Multan briefed about the activities of CCRI Multan.	12.08.2022
SANIFA Delegation (Ali Sufia, GM Commercial)	09.09.2022
Ch. Asad ur Rehman Ex-MNA, Cotton Grower, Mian Basit Hafeez and Ch. Javed Riaz Progressive Grower	21.09.2022
Mr. Muhammad Bashir Khetran, Joint Secretary, Ministry of National Food Security & Research	24.07.2022
A Delegation from Elevate Limited, REEDS Pakistan, and PCSI Multan visited CCRI Multan. Director CCRI Multan briefed about the activities of CCRI Multan.	12.08.2022
Ch. Waheed Arshad, Chairman, Pakistan Cotton Ginners Association visiting cotton fields at CCRI Multan.	20.10.2022
Secretary Agriculture South Punjab Dr. Faisal Zahoor along with, Additional Secretary Agriculture, Imtiaz Ahmed Waraich	01.11.2022
Mr. Javed Yousaf, Technical Manager, Insecticides, Bayer Pakistan	11.11.2022
Mr. Aashiq Hussain, Director Farms Training and Adaptive Research, Vehari	27.10.2022
Mr.Graham Bruford cotton expert from the UK visited CCRI Multan along with BCI team	16.11.2022
Mr. Bilal Israel, Chairman, Cotton Research & Development Board, Punjab	30.11.2022
Delegation of farmers from Sindh	30.11.2022
Malik Talat Sohail, Coordinator Federation of Pakistan Chamber of Commerce and Industry	01.12.2022

(FPCCI)	
Visit of progressive cotton farmers from Basti Malook (Mehr Zafar Hussain, Malik Muhammad Saleem, and Malik Sajjad	07.12.2022
35th Mid-Career Management Course, NIM, Lahore	14.12.2022
Ch. Muhammad Asif, Secretary, Housing Urban Development & Public Health Engineering Department (HUD & PHED) and Asif Raouf Khan, Additional Secratary, (HUD & PHED)	15.12.2022
Mr. Malik Imtiaz Hussain Chawra, and Ch. Tariq Mahmood Arain (Progressive farmers) from Mian Channu	21.12.2022

b. 31st Mid-Career Management Course, NIM, Islamabad

A group of 13 member trainees from 31 Mid-Career Management Course (In-land Study Tour) from National Institute of Management, Islamabad visited CCRI Multan on 26th August, 2022. Dr. Zahid Mahmood, Director, CCRI Multan briefed them about the cotton research & development activities carried out at the Institute. They appreciated the research work conducted by the scientists.

c. 35th Mid-Career Management Course, NIM, Lahore

A group of 15 member trainees from 35th Mid-Career Management Course (In-land Study Tour) from National Institute of Management (NIM), Lahore visited CCRI Multan on December 14, 2022. Dr. M.Naveed Afzal, Head, Agronomy Section, CCRI Multan briefed them about the cotton research & development activities carried out at the Institute. Participants also visited experimental fields of the Institute and appreciated the research work conducted by the scientists.

d. Student Study Tour

Students visited CCRI Multan during the season:

Name of University/Institution	Participants
University of Agriculture, Faisalabad	366
B.Z.U. Multan	50
University of MNSUA, Multan	58
Agricultural Training Institute Karor, Layyah	92

7.8 Social Media Activities

a. Face book Page CCRI, Multan

A page on Face book www.facebook.com/CCRI.MTN is being regularly updated by the Section to disseminate regular cotton R&D activities of the Institution social media.

b. Twitter/YouTube

An account on Twitter https://twitter.com/CCRI_Multan & YouTube Channel https://youtube.com/@CCRICottonNews9200 are updated on regular basis by the Section to disseminate regular cotton R&D activities of the Institution for the guidance of cotton growers.

c. Multimedia Presentations

During the month, the scientists of the Institute prepared almost 4221 multimedia slides for various activities.

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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 Mirpur Khas, Ghotki, Sibbi, Sahiwal, Lasbella, D.I.Khan, and to other relevant public and private parties. Research activities were focused to study the enhancing nutrient use efficiency by synchronizing application rate & methods and their impact on fibre properties, and the effect of different intercrops in cotton on fibre characteristics.

The section was conducted "Quality Survey" for the crop year 2022 in the core cotton producing districts. The lint samples collected from ginning factories carried out for determining the quality of cotton fibre available in market. 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	6804	6804	6804	-	**20412**
Cyto-genetics Section, CCRI, Multan	4023	4023	4023	-	**12069**
Agronomy Section, CCRI, Multan	285	285	285	-	**855**
Fibre Technology Section, CCRI, Multan	38	38	38	38	**152**
Plant Physiology/Chemistry Section, CCRI, Multan	144	144	144	-	**432**
Research Material Director CCRI, Multan	10607	10607	10607	-	**31821**
Central Cotton Research Institute, Sakrand	1900	1900	1900	-	**5700**
Cotton Research Station, Mirpur Khas	75	75	75	-	**225**
Cotton Research Station, Ghotki	195	195	195	-	**585**
Cotton Research Station, Sibbi	40	40	40	-	**120**
Federal Seed Certification, Khanewal	78	78	78	-	**234**
Cotton Research Station, Sahiwal	94	94	94	-	**282**
Cotton Research Station, Lasbella	94	94	94	-	**282**
Cotton Research Station, DI Khan	551	551	551	-	**1653**
Quality Survey (Punjab)	458	458	458	458	**1832**
Total	**25386**	**25386**	**25386**	**496**	**76654**

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)	Micro-naire	Fibre Strength (g tex^{-1})	Color grade	Trash (%)	Total
Private Sector	546	546	546	71	05	**1714**

8.3 Enhancing Nutrient Use Efficiency (NUE) by Synchronizing Application Rate and Methods

The objective of this study was to evaluate the efficiency of nutrients on cotton fibre properties. 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 Cyto-541 and CIM-775 as altered by nutrients

8.3.1 Genotypic Variation in Fibre Characteristics

Genotype	Fibre length (mm)	Uni. Index	MIC	Strength (g/tex)	Lint (%)	Rd	+b
Cyto-541	26.3	82.3	4.7	27.1	41.5	73.9	9.1
CIM-775	25.6	82.4	4.6	26.4	40.0	75.1	8.1

8.3.2 Nutrients effect on Fiber Characteristics

Nutrients		Fibre length (mm)	Uni. Index	MIC	Strength (g/tex)	Lint (%)	Rd	+b
Recommended dose (RD) of NPK nutrients	T1	26.1	82.6	4.6	26.1	39.0	74.7	8.9
50% of RD by fertigation	T2	25.4	82.6	4.7	26.6	40.1	74.0	8.7
40% of RD by fertigation + 10% foliar	T3	26.9	82.7	4.7	28.0	41.2	76.2	8.6
35% fertigation+15% foliar	T4	25.9	81.7	4.6	27.2	41.3	74.4	8.9
Control (without nutrients)	T5	25.3	82.4	4.7	26.0	42.0	73.2	8.3

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 Cyto-541 had better fibre characteristics. Table 8.3.2 represent the nutrients effect on fibre characteristics which showed that 40% of RD by fertigation + 10% foliar improved fibre characteristics than other treatments' and control (Figures, 8.3.1, 8.3.2, 8.3.3 & 8.3.4)

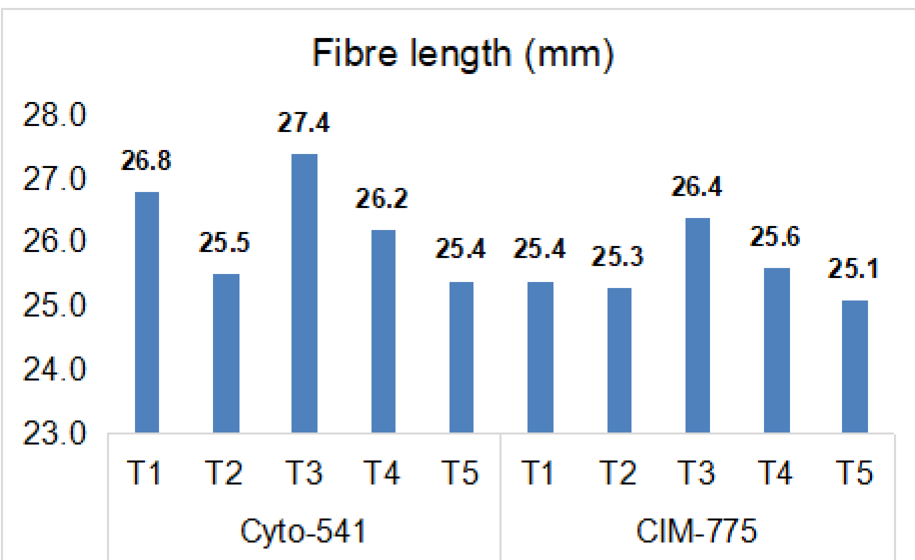


Fig. 8.3.1 Effect of nutrients use efficiency on fibre length

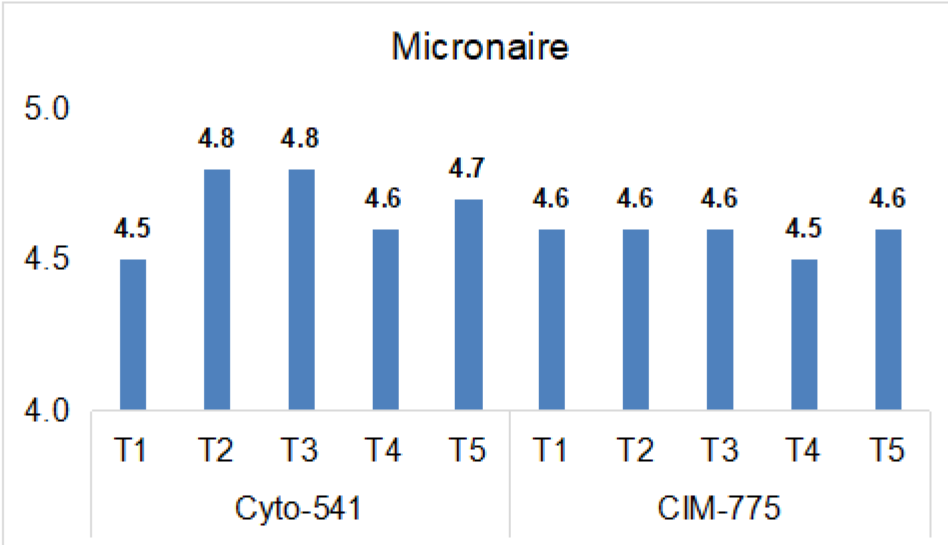


Fig. 8.3.2 **Effect of nutrients use efficiency on MIC**

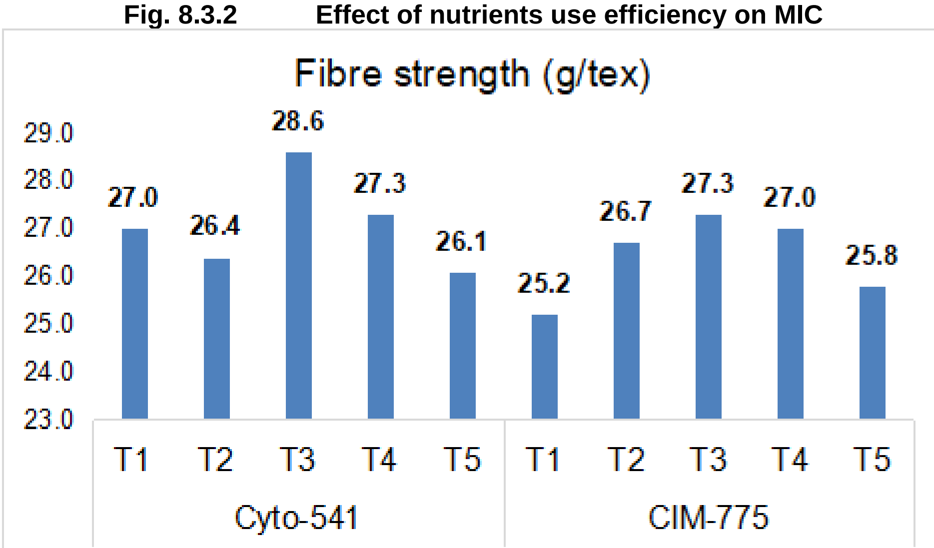


Fig. 8.3.3 **Effect of nutrients use efficiency on fibre strength**

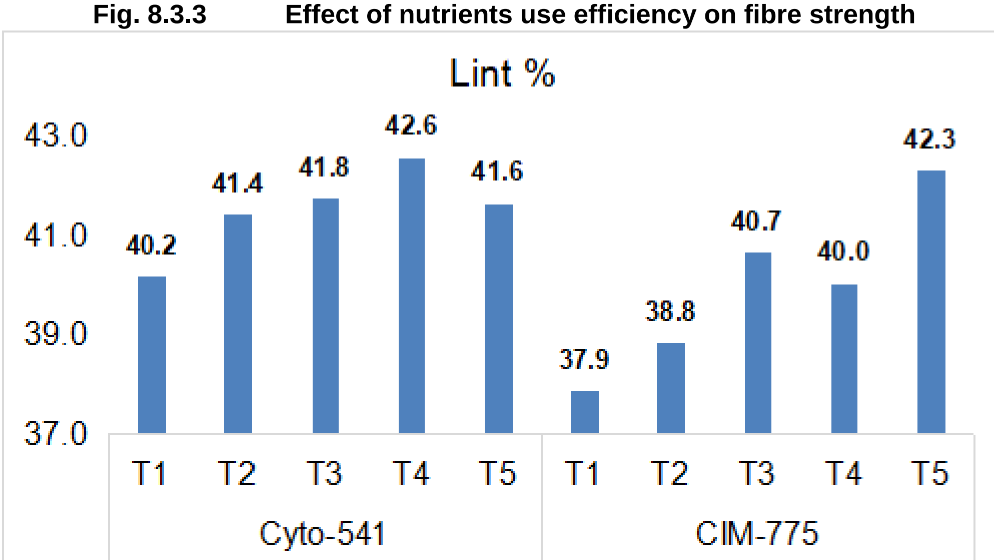


Fig. 8.3.4 **Effect of nutrients use efficiency on lint percentage**

8.4 Effect of Different Intercrops in Cotton on Fibre Characteristics

The objective of the experiment was to evaluate the impact of different intercrops in cotton on fibre quality characteristics. This study was conducted with the collaboration of Agronomy section of the institute. Sowing was done at 14th March 2022 and *Bt.*Cyto-535 was selected and sown with four different crops i.e., mung bean, sesame, peanut and fodder maiza. Plants tagging were done on 6th July, 2022 and cotton bolls were picked in two pickings viz., 22nd August, 2022 and 28th November 2022. 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	Fibre length (mm)	Uni. Index	MIC	Strength (g/tex)	Lint (%)	Rd	+b
Picking 1	25.8b	80.6a	3.7b	26.7b	39.1a	67.7b	10.7a
Picking 2	27.2a	82.3a	3.9a	28.2a	37.6b	71.7a	9.5b

8.4.2 Effect of Intercrops on Fibre Characteristics

Intercrops	Fibre length (mm)	Uni. Index	MIC	Strength (g/tex)	Lint (%)	Rd	+b
Cotton	26.4a	81.1a	3.9a	27.4a	38.3bc	69.8a	10.1a
Cotton + Mung Bean	26.7a	82.1a	3.6b	27.7a	39.7ab	68.8a	10.2a
Cotton + Sesame	26.7a	81.1a	4.0a	27.5a	39.8a	69.8a	10.2a
Cotton + Peanut	26.6a	81.5a	3.8a	27.5a	37.3c	70.0a	10.0a
Cotton + Fodder Maize	26.2a	81.5a	3.9a	27.3a	36.9c	69.8a	9.9a

The results revealed that the 2nd pick had better fibre characteristics. There is no effect seen of different intercrops on fibre length, uniformity index, micronaire, fibre strength, degree of whiteness and degree of yellowness. Only cotton+sesame had better lint percentage as compared to other intercrops and cotton alone.

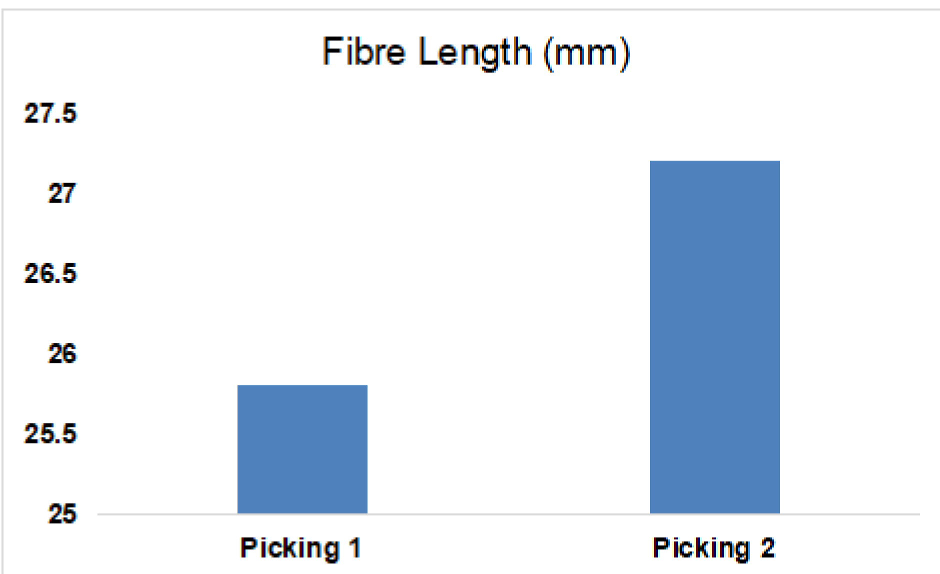


Fig. 8.4.1 Effect of pickings on fibre length

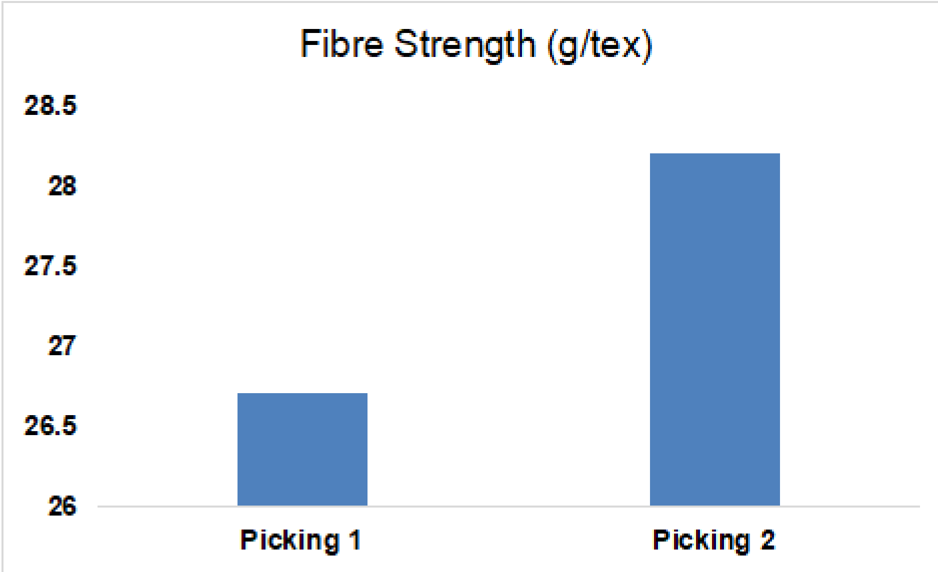


Fig. 8.4.2 Effect of pickings on fibre strength

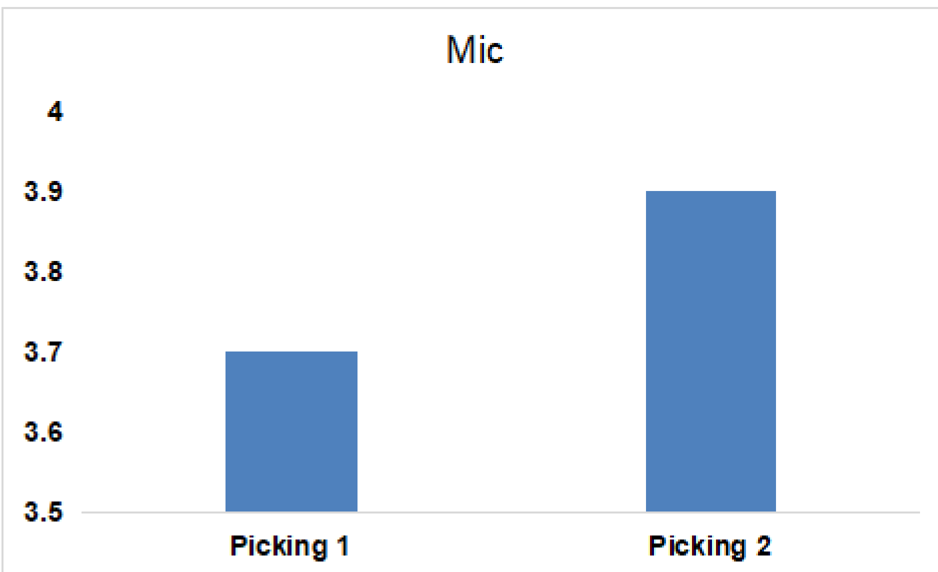


Fig. 8.4.3 Effect of pickings on MIC

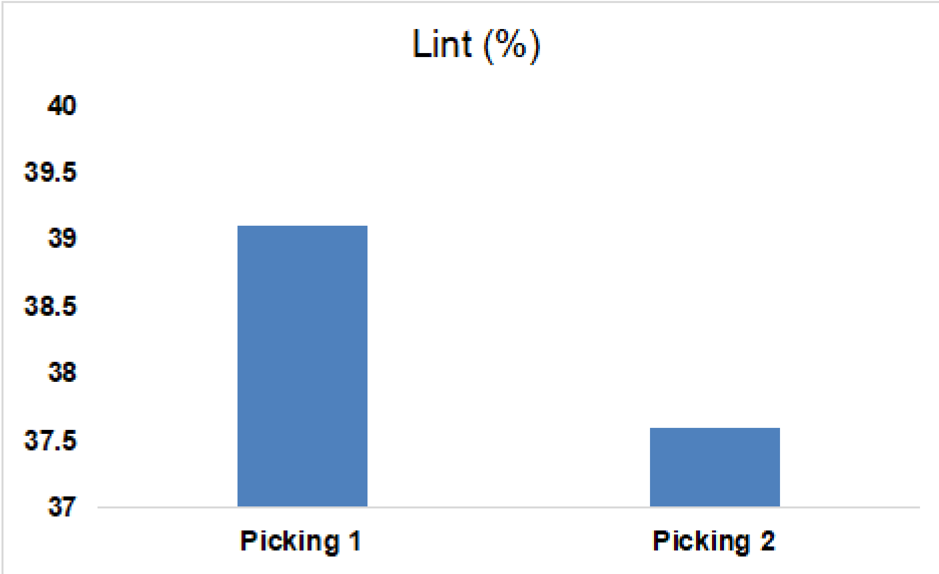


Fig. 8.4.4 Effect of pickings on Lint (%)

8.5 Quality survey of lint collected from ginning factories

The Quality Survey of Ginning industry for the crop year 2022 conducted. The cotton fibre properties, i.e., fibre length, fibre strength, micronaire, and colour grade, may display variation due to area and environmental factors. Keeping this in mind, the Fibre Technology Section conducted a research study of the core cotton areas of the Punjab region and the Ghotki region of Sind. This comprehensive report entitled "Quality Survey of Punjab Cotton" will be useful for all actors in the cotton supply chain, i.e., farmers, ginners, spinners, traders, and researchers. This report depicts the fibre traits of commercially grown cotton varieties under different climatic conditions in Punjab.

The team included technical personnel from Fibre Technology Section, visited the ginning industry in the core cotton-growing area of the Punjab province. The lint samples were collected from randomly selected ginning factories. The samples were taken to the Fibre Technology Section laboratory for their fibre analysis. The samples were conditioned at standard atmospheric conditions (Temp. 20+ 2o & R.H% 65+2) before being tested at High Volume Instrument (HVI-900A) to determine the fibre characteristics;

Table 8.3 The details of surveyed area and industry are as under,

Name of District	No. of Ginning Factories Visited
Bahawalnagar	18
Bahawalpur	18
Dera Ghazi Khan	10
Faisalabad	01
Jhang	01
Khanewal	13
Multan	04
Muzaffargarh	03
Vehari	09
Sahiwal	06
Toba Tek Singh	05
Rajanpur	05
Rahim Yar Khan	82 (Farmers)
Ghotki	57 (Farmers)
Total	**93 Factories & 139 Farmers**

The fibre results given in tables below show the maximum, minimum and average value of each fibre character for the reported district. The name of cities visited in that districts are also enlisted in table. The district wise fibre results are presented as follows;

BAHAWALNAGAR

City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Fortabbas Faqirwali Haroonabad Chishtian	Max	27.0	82.9	4.9	28.4	16.4	72.2	11.5
	Min.	24.1	78.8	4.0	25.0	10.5	64.4	8.6
	Avg.	**25.4**	**80.8**	**4.3**	**26.6**	**13.7**	**69.0**	**9.8**

BAHAWALPUR

City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Bahawalpur Lodhran Yazman Ahmedpur East Uch Sharif Hasilpur	Max.	27.9	84.1	5.0	28.9	16.0	76.1	11.9
	Min.	25.0	79.0	3.9	25.6	8.6	59.5	7.4
	Avg.	**26.2**	**81.3**	**4.4**	**27.1**	**12.7**	**68.4**	**9.8**

DERA GHAZI KHAN

City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
DG Khan	Max.	28.6	84.4	4.9	30.3	14.0	75.4	10.3
	Min.	26.1	79.9	3.7	26.3	8.2	64.6	8.8
	Avg.	**27.4**	**82.0**	**4.3**	**28.2**	**11.4**	**72.1**	**9.4**

FAISALABAD

City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Samundri	Max.	25.5	82.1	4.2	26.5	14.1	69.4	11.6
	Min.	24.8	80.7	4.2	25.3	12.0	66.7	10.2
	Avg.	**25.2**	**81.4**	**4.2**	**26.1**	**13.0**	**68.3**	**11.1**

JHANG

City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Jhang	Max.	27.4	83.2	4.6	27.9	12.8	74.7	10.6
	Min.	26.3	81.1	4.1	26.4	10.3	71.5	8.7
	Avg.	**26.8**	**82.3**	**4.4**	**27.1**	**11.3**	**72.5**	**9.7**

KHANEWAL

City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Khanewal	Max.	27.3	83.7	4.9	27.9	15.9	71.1	12.3
Kabirwala	Min.	24.5	79.3	4.0	23.1	9.4	58.9	8.4
Mianchannu	**Avg.**	**25.8**	**81.5**	**4.5**	**26.5**	**12.7**	**67.6**	**10.5**

MULTAN

City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Shujabad Jalalpur	Max	27.1	84.0	5.1	28.2	16.1	70.2	10.9
	Min.	24.9	79.0	4.1	25.6	9.0	61.0	8.6
	Avg.	**25.7**	**81.1**	**4.6**	**26.6**	**13.2**	**65.4**	**9.9**

MUZAFFARGARH

City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Muzaffargarh	Max	28.3	82.8	4.5	28.8	12.9	75.6	9.5
	Min.	26.5	80.9	3.9	27.0	10.3	70.9	8.9
	Avg.	**27.4**	**81.9**	**4.3**	**28.0**	**11.5**	**72.9**	**9.2**

VEHARI

City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Vehari Booraywala Mailsi	Max	27.0	83.2	5.1	28.2	18.6	76.8	13.6
	Min.	23.8	77.2	3.7	24.2	10.5	56.0	8.3
	Avg.	**25.5**	**81.1**	**4.4**	**26.3**	**13.2**	**68.2**	**10.0**

SAHIWAL

City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Chichawatni	Max	26.7	82.3	4.8	27.9	16.2	71.9	11.1
	Min.	24.5	78.9	4.4	25.3	11.5	61.8	9.1
	Avg.	**25.5**	**81.4**	**4.6**	**26.4**	**12.9**	**69.9**	**10.0**

TOBA TEK SINGH

City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Toba Tek Singh Gojra Peer Mehal	Max	26.3	82.3	4.8	27.7	16.1	72.6	11.9
	Min.	24.4	78.9	4.2	25.0	11.6	60.3	9.3
	Avg.	**25.5**	**81.0**	**4.4**	**26.3**	**13.3**	**69.5**	**10.5**

RAHIM YAR KHAN

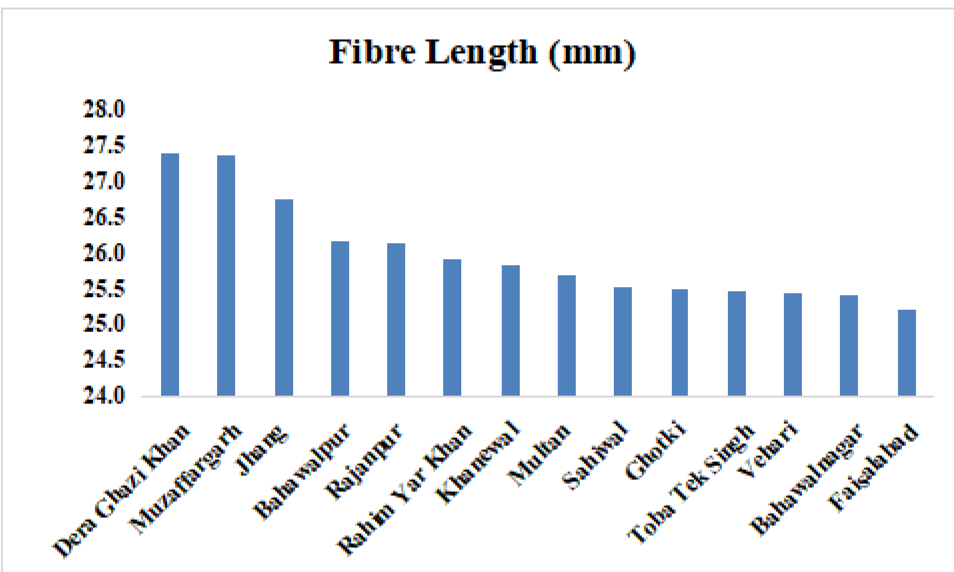
City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Rahim Yar Khan Sadiqabad Liaqatpur Khanpur	Max	28.2	85.1	6.0	28.5	15.7	76.7	11.1
	Min.	23.6	79.1	3.5	22.6	7.3	58.6	7.7
	Avg.	**25.9**	**81.8**	**4.9**	**25.7**	**12.2**	**71.8**	**9.2**

RAJANPUR

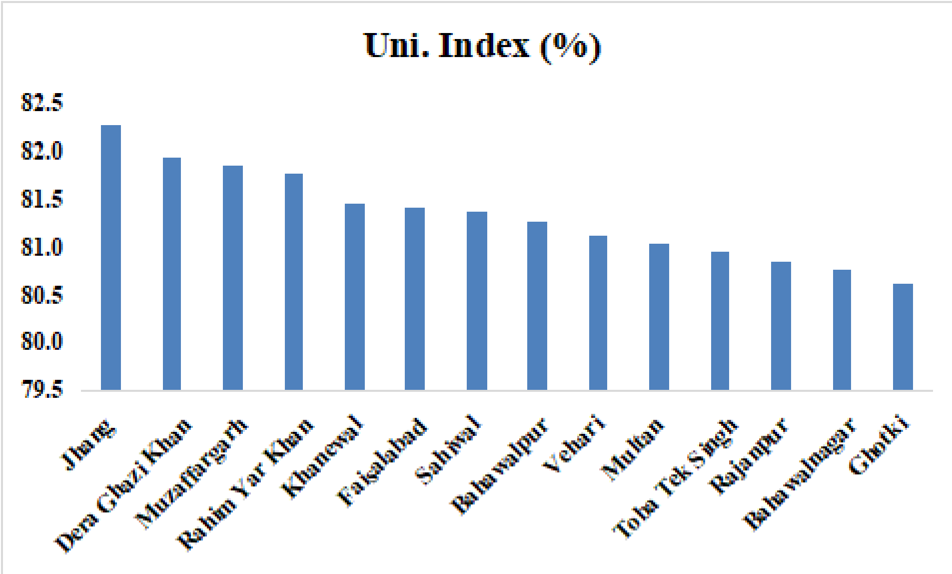
City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Fortabbas Faqirwali Haroonabad Chishtian	Max	27.5	82.1	4.8	28.3	15.1	74.1	10.4
	Min.	24.8	79.8	4.1	26.2	11.2	65.2	9.6
	Avg.	**26.2**	**80.9**	**4.5**	**27.0**	**13.3**	**68.9**	**10.0**

GHOTKI

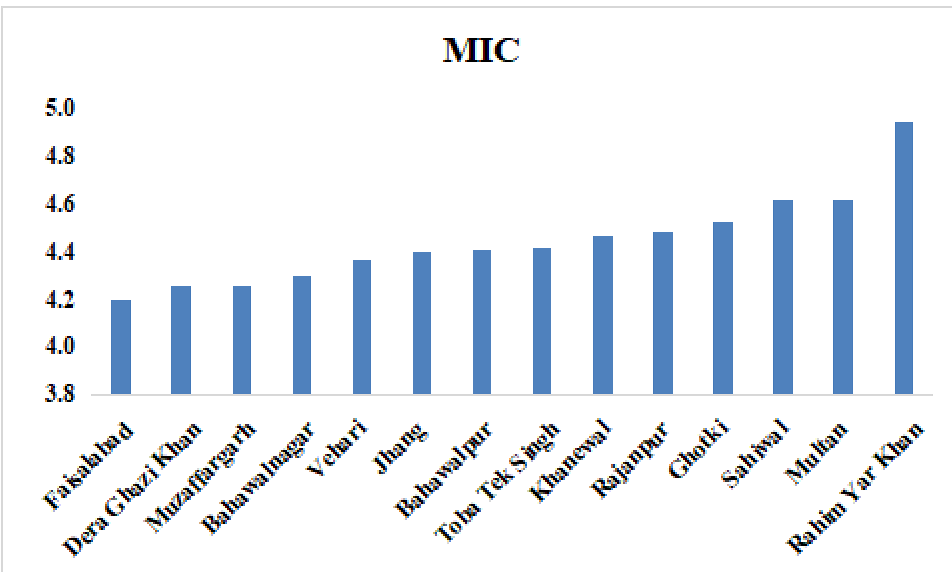
City Visited		Fibre Length (mm)	Uni. Index (%)	MIC	Strength (g/tex)	SFI (%)	Rd	+b
Ghotki	Max	27.9	84.6	5.3	29.8	17.6	75.4	10.9
	Min.	24.4	77.8	3.6	23.0	8.0	56.0	8.1
	Avg.	**25.5**	**80.6**	**4.5**	**25.9**	**13.8**	**67.8**	**9.4**



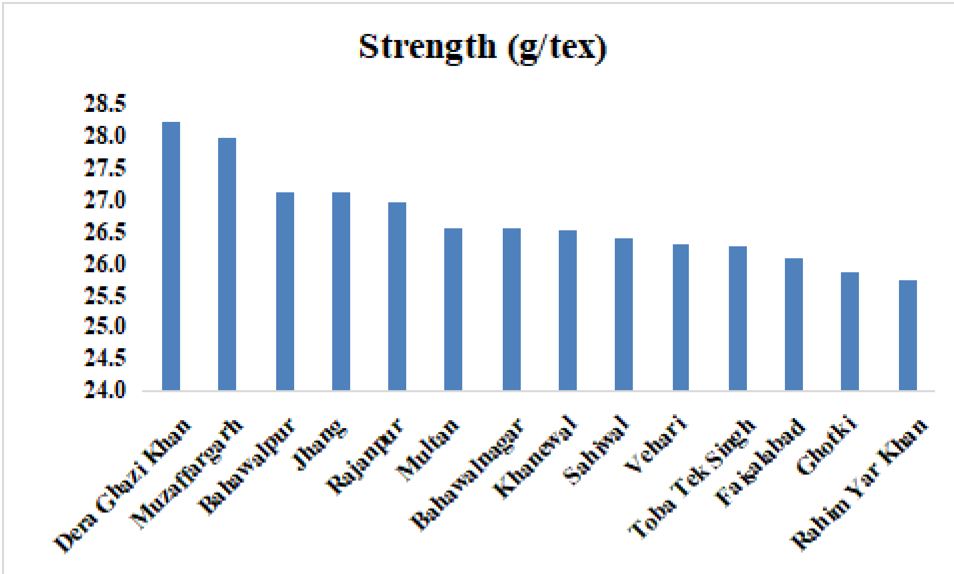
Fibre length among various Districts



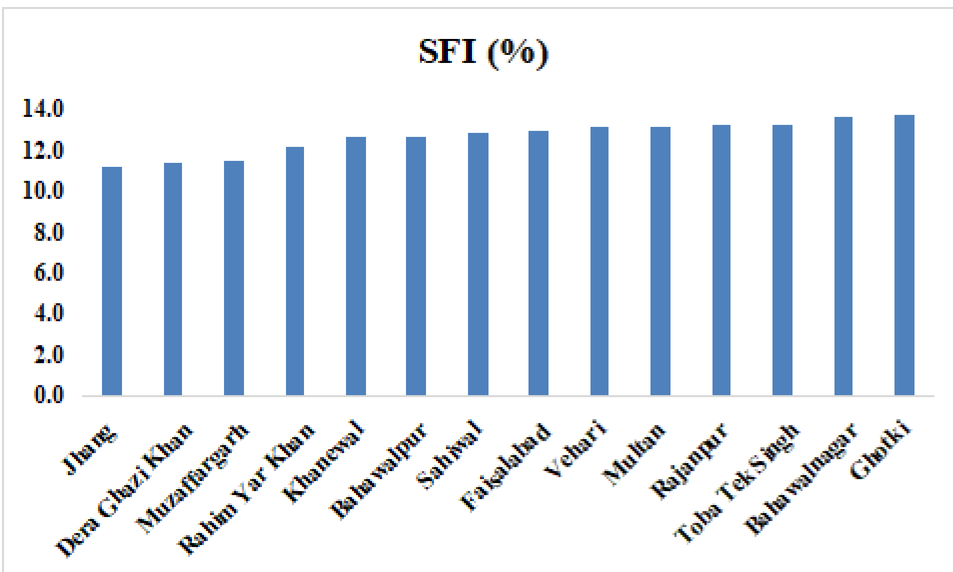
Uniformity Index % among various Districts



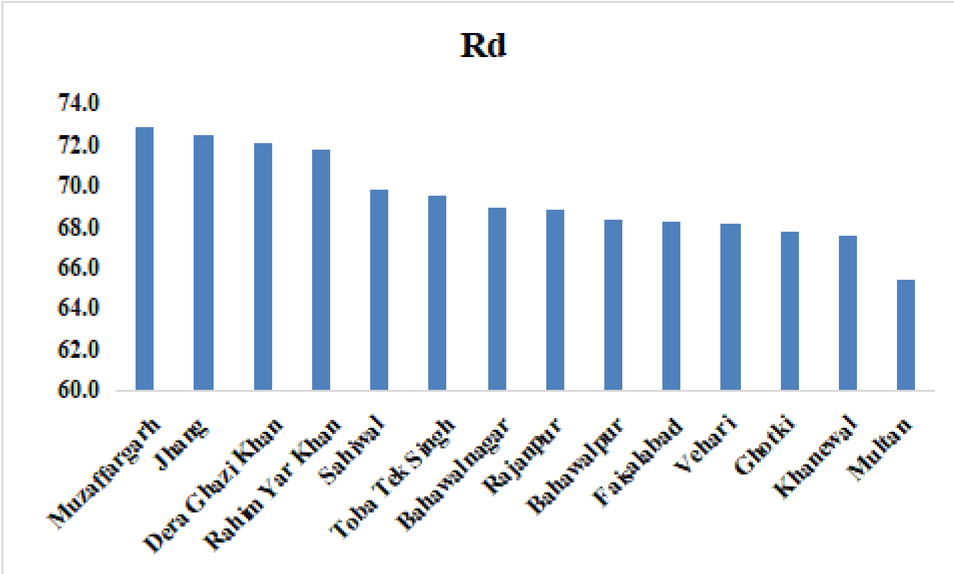
Micronaire among various Districts



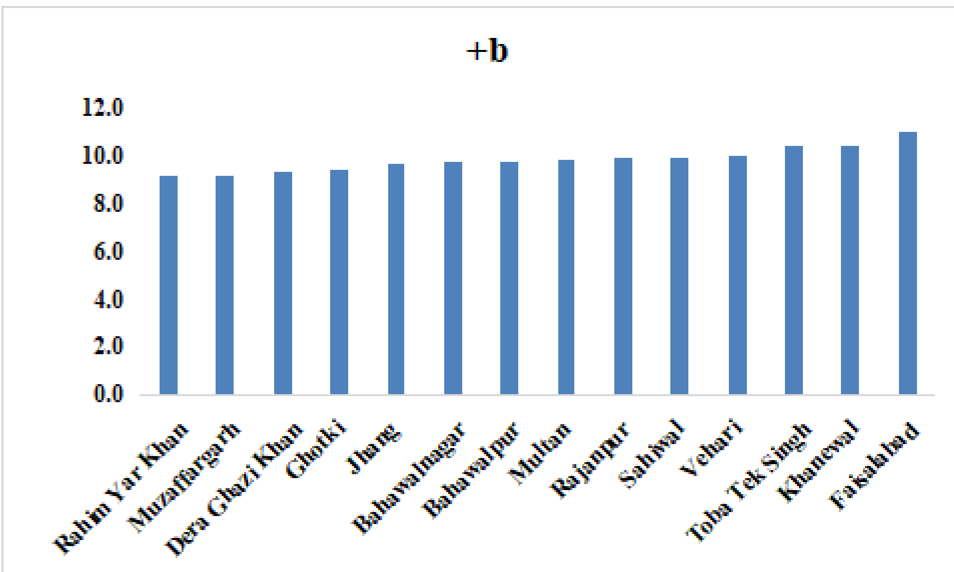
Fibre Strength among various Districts



Short Fibre Index (SFI) among various Districts



Degree of Reflectance (Rd) % among various Districts



Yellowness (+b) among various Districts

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. Two lint samples were received during the year 2022. 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)
23.04.2022	**2022/1**	**Conventional Instruments**			
		Micronaire	4.26	4.27	-0.01
		Pressley Index (0")	7.44	6.89	0.55
		G / tex (1/8")	19.9	20.05	-0.15
		Elongation (%)	5.5	5.95	-0.45
		Trash Content (%)	4.64	4.56	0.08
		Lint Content (%)	94.68	95.3	-0.62
		HVI-900A			
		U.H.M.L. (mm)	27.9	27.7	0.30
		Uniformity Index (%)	82.1	80.81	1.50
		Micronaire	4.2	4.29	0.90
		G/tex (1/8")	27.2	27.2	0.00
		Elongation (%)	5.4	6.06	-0.70
		Rd (Reflectance)	67.1	68.24	-1.30
		+b (Yellowness)	11.0	10.85	0.40
07.11.2022	**2022/3**	**Conventional Instruments**			
		Micronaire	4.42	4.43	-0.01
		Pressley Index (0")	6.93	6.45	0.48
		G / tex (1/8")	23.5	--	--
		Elongation (%)	5.8	--	--
		Trash Content (%)	1.53	1.82	-0.30
		Lint Content (%)	98.47	97.82	0.65
		HVI-900A			
		U.H.M.L. (mm)	29.3	29.06	0.20
		Uniformity Index (%)	81.4	82.37	-0.90
		Micronaire	4.34	4.46	-0.10
		G/tex (1/8")	28.2	29.32	-1.10
		Elongation (%)	6.30	6.07	0.20
		Rd (Reflectance)	69.5	72.30	-2.80
		+b (Yellowness)	13.5	13.7	-0.20

8.7 Survey of spinning industry of Pakistan

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.

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9. STATISTICS

This Section is imparting extensively (considerably) in the Statistical domain and stretching to extending assistance to scientists of the institute in planning experimental design and therein analysis of data. The record of cotton statistics and daily market rates of cotton commodities were maintained.

9.1 Experimental Design Layout:

This section designed layout of field experiments conducted by different sections of Central Cotton Research Institute Multan. Randomized complete block design was used in ninety experiments while split plot and split-split plot was used in six and eleven experiments respectively. Furthermore F-pool design was used in 8 experiments sown at CCRI, Multan and PSC Farms, Khanewal.

9.2 Statistical Analysis

115 set of experimental data were analyzed by Statistics Section during 2022-23 in which thirty two data sets of Breeding & Genetics, seven Cytogenetics, thirty one Entomology, forty five 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	24	---	---	8	---	**32**
Cytogenetics	7	---	---	---	---	**7**
Pathology	---	---	---	---	---	**---**
Entomology	31	---	---	---	---	**31**
Fiber	28	6 ---	11	---	---	**45**
Total	**90**	**6**	**11**	**8**	**---**	**115**

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. 2020-21, 2021-22 and 2022-23 exclusive of upcountry charges are shown in Fig 9.1.

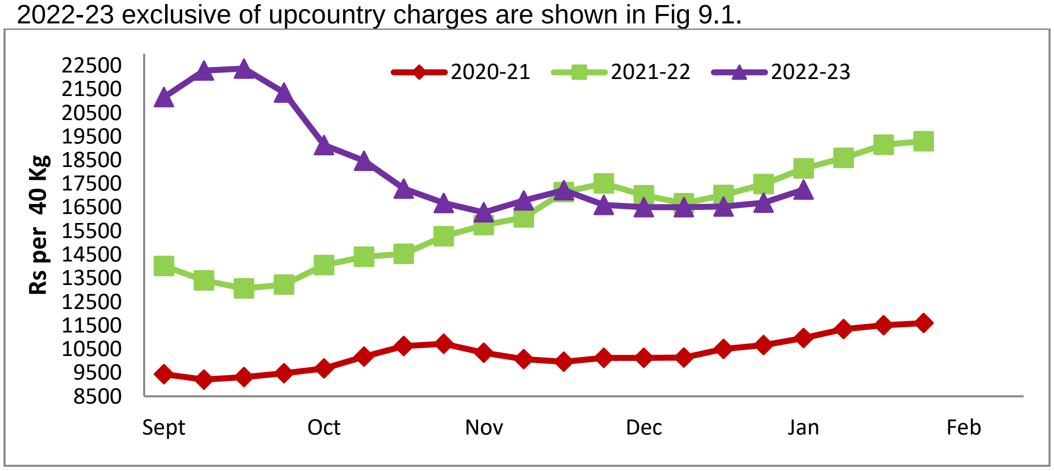


Figure 9.1: Weekly Average Spot Rates of Lint announced by Karachi Cotton Association during Cotton Seasons 2020-21, 2021-22 and 2022-23.

The data presented in Figure 9.1 showed the fluctuation of rate during the seasons of last three years. In year 2022-23 rates were comparatively higher than previous years. In year 2021-22 the average price was at Rs.16089 per 40 kg with the minimum value of Rs.13064 per 40 kg in the month of September 2020 and maximum of 19300 per 40 kg in January 2022 while in 2022-23 the average price was at Rs.22371 per 40 kg with the minimum value of Rs.13064 per 40 kg in September 2022 and maximum value of Rs.16283 per 40 kg in November 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.

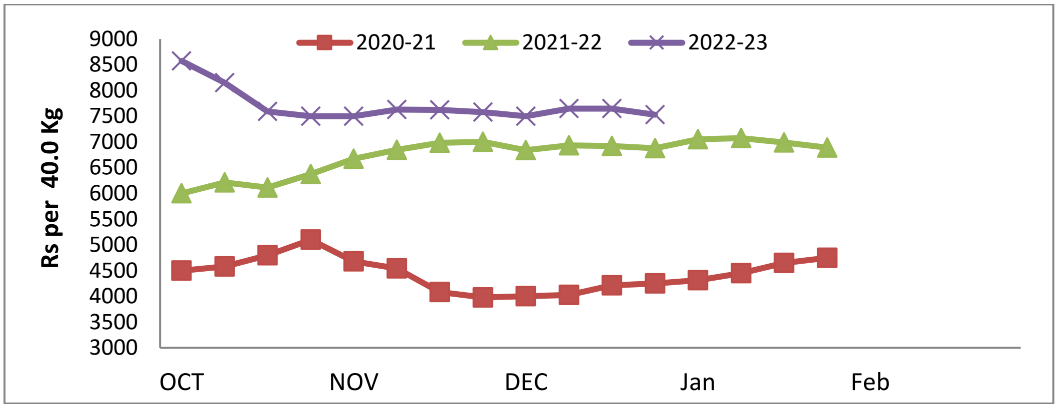


Figure 9.2: Weekly Average Rates (Rs /40Kg.) of Seed-cotton of Bahawalpur Market during 2020-2021, 2021-22 and 2022-23

The seed-cotton rates are presented in figure 9.2 showed that the rates of 2022-23 are much higher than that of previous years. In 2021-22 the average seed-cotton rates of Bahawalpur market were at 6737 per 40 kg with minimum of 6000 per 40 kg and maximum Rs.7075 per 40 kg while in 2022-23 the average rate was Rs.7707 per 40 kg with maximum rate was 8575 per 40 kg and minimum rate was Rs.7500 per 40 kg. The percent increase of prices in 2022-23 average price over 2021-22 is 14.39%, and from 2020-21 is 73.85%.

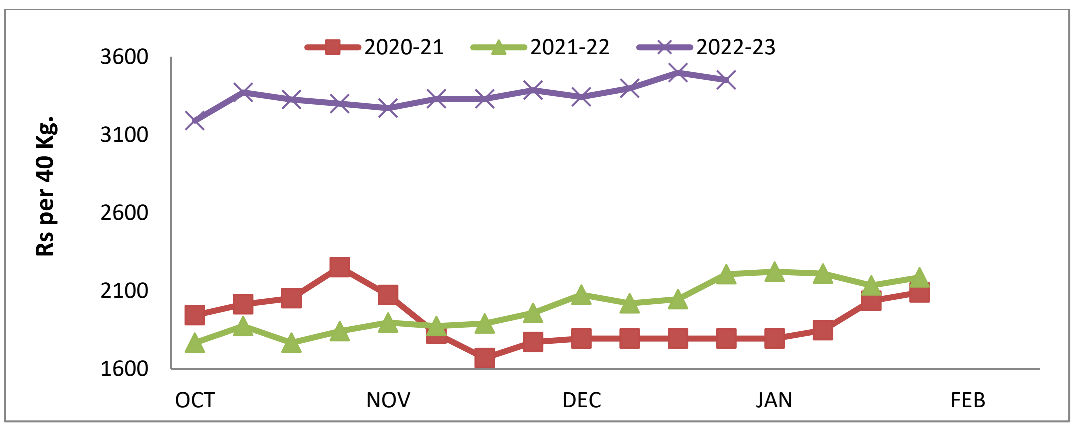


Figure 9.3: Weekly Average Rates (Rs /40Kg.) of Cottonseed cake of Bahawalpur Market during 2019-20, 2020-21 and 2021-22.

The cottonseed cake rates remained higher than the previous years. The maximum value of Rs.3497 was in December 2022 while minimum price of Rs.3190 was in October 2022. The average price for 2022-23 was 3349 per 40 kg. Price comparison from last year revealed that average price Rs.1919 per 40 kg was attained in 2021-22 with minimum price of Rs.1768 per 40 kg and maximum price of Rs.2223 per 40 kg in October 2021 & January 2022 respectively while the average price Rs.1910 per 40 kg was obtained in 2020-21 with maximum price was Rs.2251 per 40 kg and minimum price was 1670 per 40 kg.

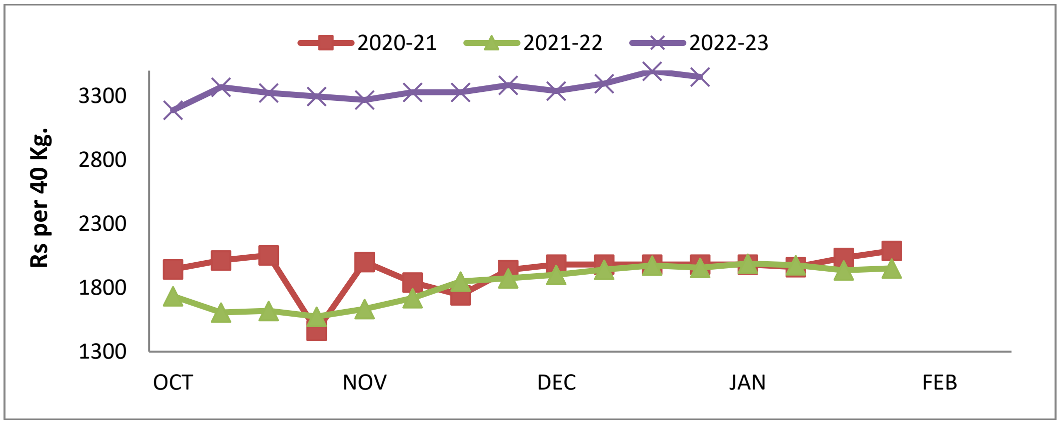


Figure 9.4: **Weekly Average Rates (Rs/40Kg.) of Cottonseed of Bahawalpur Market during 2020-22, 2021-22 and 2022-23.**

Cottonseed rates of year 2022-23 were higher than year 2021-222. Average rate of 2022-23 was Rs.3349 per 40 kg with maximum at Rs.3497 per 40 kg and minimum Rs.3190 per 40 kg while in 2021-22 the average rate was Rs.1828 per 40 kg with maximum Rs.1990 per 40 kg and minimum at Rs.1575 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.

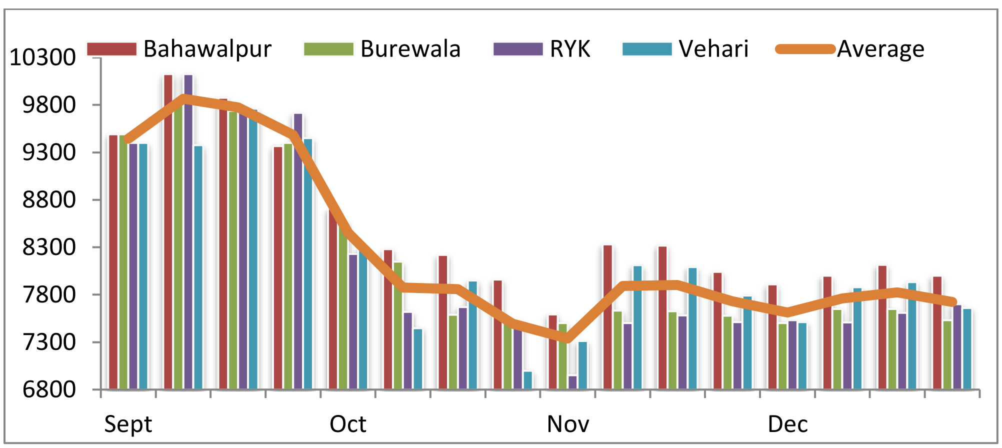


Fig 9.5: Rates of seed-cotton 2022-23 in Punjab

The highest average rate was Rs.8521 per 40 Kg in Bahawalpur, and the lowest average rate was Rs.8118 in Rahimyar Khan. The maximum rate of Rs.10125 per 40 Kg was in Rahimyar Khan and Bahawalpur in the second week of September and the lowest rate was Rs.7500 in Burewala in fourth week of October.

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..

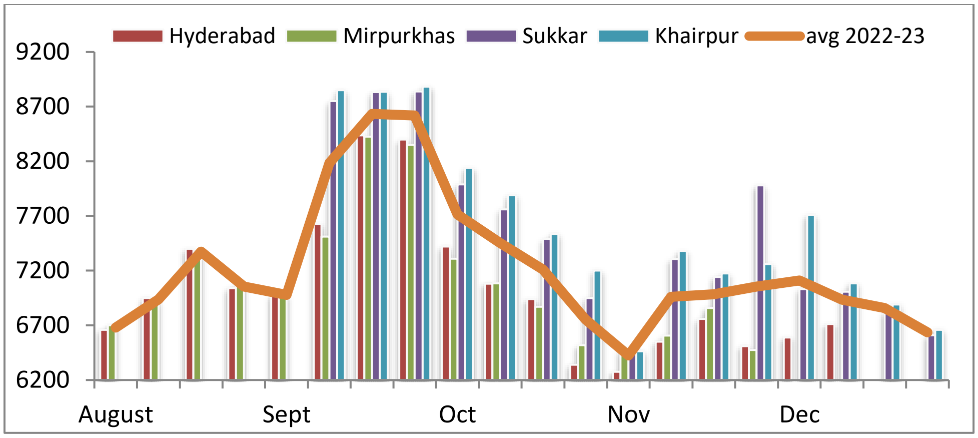
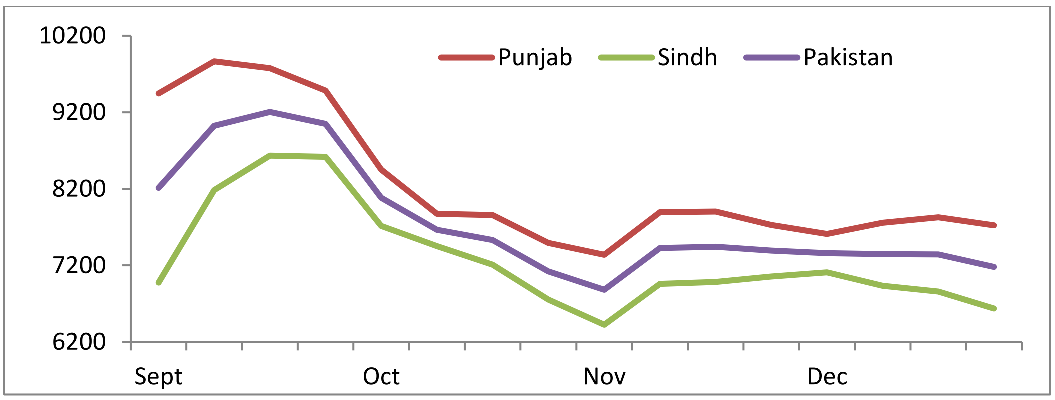


Fig 9.6: Rates of seed-cotton 2021-22 in Sind

The highest average rate was Rs.7630 per 40 Kg in Khairpur, and the lowest average rate was Rs.7001 in Hyderabad. The maximum rate of Rs.8840 per 40 Kg was in Sukkur in the fourth week of September and lowest rate was Rs.6275 in Hyderabad in first week of November.

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.

2022 had been a unique year for cotton market both globally and locally. In Pakistan the year started with positive trend dominating the market. The higher international price of cotton kept the local industry at their toes in competing with each other for purchase of local cotton. This trend of price hike continued till March 2022. In March 2022 the textile export increased by 36% in volume and doubled in value when calculated in rupees from last year. For four weeks of March the rates remained stable and after that it again started increasing in April and continued till June. From June onward due to discontinuation of "Discounted Tariff Package" for APTMA the market became bearish and it continued till August. With the revival of power tariff discounts the market became bullish till September.

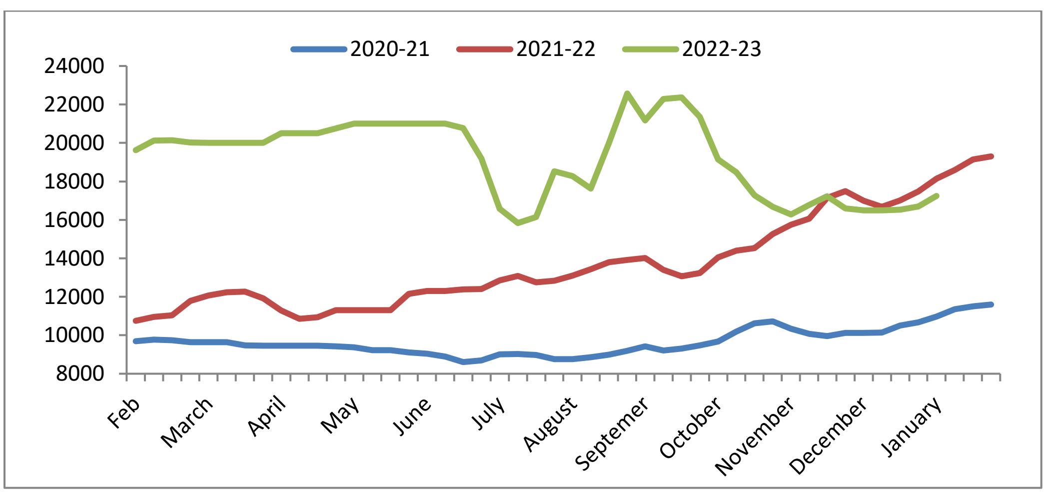
The recession in international market resulted in fewer export orders for local industry. This decrease in international demand made life difficult for industry. The export oriented industry had no option but to decrease production by reducing the working shifts. At the moment most of the textile mills are working at less than 50 percent of their capacity. Due to this a significant number of labors have become jobless which has further aggravated the life of working class in the country. The rise in power tariff rates made it difficult for our textile products to compete in international market.

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
07.02.22	19616	23.08.22	20000
15.02.22	20114	31.08.22	22571
23.02.22	20142	07.09.22	21167
28.02.22	20025	15.09.22	22285
07.03.22	20000	23.09.22	22371
15.03.22	20000	31.09.22	21357
23.03.22	20000	07.10.22	19133
31.03.22	20000	15.10.22	18471
07.04.22	20500	23.10.22	17285
15.04.22	20500	30.10.22	16683
23.04.22	20500	07.11.22	16283
30.04.22	20750	15.11.22	16785
07.05.22	21000	23.11.22	17228
15.05.22	21000	31.11.22	16600
23.05.22	21000	07.12.22	16500
31.05.22	21000	15.12.22	16500
07.06.22	21000	23.12.22	16528
15.06.22	21000	30.12.22	16700
23.06.22	20771	07.01.23	17250
30.06.22	19183	15.01.23	19285
07.07.22	16580	23.01.23	20000
15.07.22	15833	31.01.23	20214
23.07.22	16142	07.02.23	21833
31.07.22	18528	15.02.23	21915
07.08.22	18280	23.02.23	20072
15.08.22	17625	28.02.23	19800

The average rate from February 2022 till February 2023 was Rs.19344 per 40 kg while the lowest rate was Rs.15833 in second week of July 2022 and the highest rate was Rs.22571 in fourth week of August 2022.

The following graph shows the rates of lint in KCA for 2021, 2022 and 2023. It is evident that the rates in 2022-23 were significantly higher than previous year. The average rate of lint per maund increased by 40 percent.



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VIII. 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.

SOIL HEALTH IMPROVEMENT AND ITS PREPARATION

- 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 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, the tradition of burning wheat straw is not beneficial. It must be incorporated into the soil which improves the physical properties and organic matter content of soil. First slasher after that 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 the recommended quantity of gypsum into the soil followed by 2-3 heavy irrigations. This should be followed by green manuring to restore soil fertility.
- Where plant growth is restricted and downward penetration of water in the soil is slow, chiseling/ripping or deep ploughing should be done. It breaks down the hard and plough pan to improve root growth and soil health.
- Level the fields properly with laser leveler for uniform and economized application of irrigation water.

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 30% irrigation water over conventional planting (flat cultivation). It also saves the crop from the damages of untimely and heavy rains. Apply second irrigation 3-4 days 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 / field capacity level) and never cultivate in dry condition.
- Apply ½ bag of urea at the time of land preparation for efficient and accelerated decomposition of previous crop residues because of white-ant problem. It may increase and damage plant population if plant residues are not properly decomposed.

- 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-343, Bt.Cyto 537, 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 low germination.
- Always sow 10% area with Non-*Bt* along with *Bt* varieties, as a 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 17,000-23,000 plants per acre for obtaining profitable yield.

THINNING

- Thinning should be completed after dry hoeing and before first irrigation in flat planting (conventional) by keeping 9"-12" plant to plant distance with in the rows 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.

WEED CONTROL

- 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.
- Pendimathelin 330 EC can be used as pre-emergence herbicide before sowing 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.

- 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.
- Glyphosate 490 G/L @ 4.7 lit ha^{-1} can be used as post-emergence weedicide provided that the cotton plants are protected with 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 as 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 showing available phosphorus less than 10 ppm, use upto 100 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 at planting, to soils showing available potassium less than 125 mg kg^{-1} soil. 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, 150-200 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 and crop turn towards vegetative growth also 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 3% urea solution (3 kg urea per 100 litre water) but it should not be mixed with the insecticides.
- Fertigation (fertilizer solution dripping into irrigation water) of nitrogenous fertilizer is also a useful method to apply nitrogen during the cropping season but its efficacy is more in leveled fields.
- 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}.
- Three-four foliar sprays of boron and zinc @ 0.05% solution [(250g zinc sulphate with 21% Zn, 300g boric acid)/ per 100 litre water] should be done to improve fruiting in stress condition after rain.
- 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% KNO_3 or K_2SO_4 (soluble potash) solution improves yield over non-sprayed crop and minimizes the adverse effects of biotic and abiotic stresses.
- Half 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 conjunction with poultry broiler litter.
- For early germination and seedling vigor, cotton seed may be primed with Disprin + Salicylic acid (195 mg/L and 100 g) 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 Disprin + Salicylic acid @ 0.01 increases cotton health and production. The efficiency of Disprin + Salicylic acid 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 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 the 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 2021 and 2022

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	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
January	5.8	7.2	20.6	19.6	67	49	93	81	3.2	5.9	0.0	56.6	0.12	0.51	9.3	10.6
February	12.7	10.7	26.1	23.9	57	48	86	82	3.7	4.9	0.0	0.0	0.53	0.78	15.3	12.8
March	17.4	17.5	30.5	33.6	56	49	79	72	5.8	4.5	16.9	0.5	0.65	0.87	21.7	24.1
April	21.4	25.1	35.9	39.9	53	47	75	72	6.3	5.5	0.0	0.0	0.78	0.92	25.7	28.7
May	26.5	28.2	39.2	42.0	46	47	76	76	6.8	6.2	3.0	0.0	0.89	0.91	29.0	33.3
June	29.0	27.3	38.9	39.5	55	50	83	79	6.9	6.5	23.4	110.80	0.93	0.78	34.0	33.4
July	30.9	27.3	38.8	36.7	57	51	87	78	6.5	6.3	0.0	69.80	0.98	0.75	36.1	30.9
August	29.1	27.2	36.8	35.0	54	49	76	77	5.9	5.1	6.5	68.40	0.80	0.56	34.6	30.8
September	27.8	25.4	35.7	37.0	53	48	78	77	4.6	4.2	36.0	0.0	0.76	0.73	31.6	31.4
October	20.4	19.5	33.8	33.6	58	58	78	78	3.7	2.8	0.0	0.0	0.68	0.63	26.8	27.1
November	13.2	13.8	28.1	28.5	48	57	78	79	2.3	2.5	0.0	0.0	0.55	0.63	18.4	18.1
December	7.1	8.7	21.7	23.0	49	59	79	81	1.6	2.2	0.0	1.0	0.44	0.41	12.8	12.5