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The ICAC Recorder

International Cotton Advisory Committee

Editorial

Egypt hosted the seventh edition of the World Cotton Research Conference (WCRC-7) in Cairo from 4-7 October 2022. The conference was a huge success, despite the difficult COVID inflicted challenges that the organizing teams and researchers had to go through, which delayed the conference by two years. Notwithstanding the last-minute cancellations due to COVID and political disturbances in West Africa, 232 researchers from 28 countries participated in the conference. There was tremendous enthusiasm laced with festive fervor at the conference. There were ten plenary lectures delivered by globally renowned eminent cotton scientists, 98 presentations in concurrent sessions and 10 poster presentations. The conference culminated in the World Cotton Day on 7 October 2023. There was unanimity amongst experts that the conference was a great success.

The previous six editions of the World Cotton Research Conference were held in Australia (1994), Greece (1998), South Africa (2003), United States of America (2007), India (2011) and Brazil (2016). As a researcher, I have been fortunate to attend all the seven conferences and can vouch that each of them was technically brilliant in content and exuded a festive ambience. The conferences laid foundations for newer ideas, friendships, and research collaborations. The WCRC is held once every four years, but the WCRC-7 was delayed by two years. Therefore, the next conference WCRC-8 will be held in Uzbekistan in 2024, just two years after the WCRC-7.

The research papers presented at the WCRC-7 are now available as full publications in a pdf form as 'book of papers' and as power point presentations on the website of the International Cotton Research Association (ICRA). Readers can refer to them for full papers. This edition of the ICAC RECORDER captures the essence of the conference by presenting summaries of the Plenary lectures in Chapter-1 and the take-away messages from the concurrent session presentations in Chapter-2. Dr. MV Venugopalan and Dr Khalid Abdullah, deserve appreciation for not only editing several chapters of the 'book of papers' but also for authoring the Chapter-2 in this RECORDER.

The Plenary lectures were top notch. Chapter-1 summarizes the plenary lectures. The ten lectures were on different subjects. Experts described landmark achievements that were acquired through partnerships; the importance of different methods of fibre quality testing and the scientific importance of plant architecture and lint quality; the practical methods adopted by the United States of America in implementing regenerative agriculture; massive campaigns through social media on Pink Bollworm Management; the benefits of High Density Planting in India even with the cultivation of hybrids; new initiatives for insect pest management through native and introduced natural enemies to control pink bollworm, whitefly and mealy bugs; the use of ultra-narrow row and HDPS cotton and the role of decreased radiation interception, square shedding and the importance of chemicals in canopy management; the importance of varieties developed through RNAi based gene silencing of phytochrome gene that had improved fibre traits, high yields and showed resistance to abiotic stress factors and the importance of developing indigenous transgenic varieties for biotic stress management and CRISPR-Cas in generating gossypol-free cotton seeds and imaprting agronomically useful traits.

As you will see from the chapters in this edition of the RECORDER and the book of papers, the scientific standard of the conference was very high. And this wouldn't have been possible without the hard work of the organizing committees. The ICAC gratefully acknowledges the excellent leadership of Dr Mohamed Negm, Chair ICRA, Dr Eric Hequet, Vice-Chair and treasurer ICRA and Dr Khalid Abdullah, Chair of the ICRA Secretariat, in not only conducting the WCRC-7 successfully, but in taking it to greater heights. The team is now gearing up for the ensuing WCRC-8 to be held in Uzbekistan in 2024. The ICAC, ICRA and the Uzbek organizing committee of the WCRC-8 cordially invite you to the WCRC-8 and earnestly hope that your participation will enrich the proceedings to set new standards for the World Cotton Research Conferences.

– Keshav Kranthi

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Summary Notes of Plenary Lectures Presented at the WCRC-7

4-7 October 2022. Cairo Egypt

Dr. Jodi Scheffler

Dr. Eric Hequet

Dr. Kater Hake

Dr. C. D. Mayee

Dr. B. M. Khadi

Dr. I. Abdurakhmonov

Dr. Khalid Abdullah

Dr. Marcelo Paytas

Dr. Marc Giband

Dr. Shahid Mansoor

There were ten plenary lectures. Summary notes of the talks are presented in the subsequent pages of this chapter.

1. Dr. Jodi Scheffler presented the plenary talk on her scientific journey with several landmark achievements most of which were acquired through partnerships.
2. Dr. Eric Hequet drew the attention of the audience to the importance of different methods of fibre quality testing and the scientific importance of plant architecture and lint quality as well as lint quality of the early picked bolls as compared to the pick from late maturing bolls.
3. Dr. Kater Hake presented practical methods adopted by the US in implementing regenerative agriculture while emphasizing that the progress had its own share of challenges and drew the attention of the world on how to maximize the impact of regenerative agriculture using the US experience as an example.
4. Dr. Charudatta Mayee, presented the 'Changing Paradigms in Technology Transfer for Bridging Gaps in Smallholder Cotton Farms'. He spoke extensively on the adoption of High-density cotton farming in India and the lessons learnt. Dr Mayee highlighted the massive campaign on Pink Bollworm Management with focus on the importance of using social media for transfer of technology vis a vis conventional method. Dr.
5. B.M. Khadi spoke on High Density Planting in India and drew the attention of the house to its significant benefits even with the cultivation of hybrids.
6. Dr. Ibrokhim Abdurakhmonov presented the status of cotton production in Uzbekistan highlighting the importance of varieties developed in collaboration with the USDA using RNA interference. Varieties developed through RNAi based gene silencing of phytochrome gene had improved fibre traits, high yields and showed resistance to abiotic stress factors.
7. Dr. Khalid Abdullah spoke on the new initiatives for insect pest management targeting the pink bollworm, whitefly and mealy bugs. He highlighted the importance of native and introduced natural enemies in pest management. In his talk on 'Management Practices for High Density Planting Systems: Physiological Basis',
8. Dr. Marcelo Paytas, spoke of his experiences in the use of ultra-narrow row and HDPS cotton. He highlighted the role of decreased radiation interception, square shedding and the importance of chemicals in canopy management. In his talk on 'Molecular Genetics of Cotton Tolerance to Water Stress: Lessons Learned from a Genome-Wide Association Study',
9. Dr. Marc Giband described the use of molecular breeding techniques that are being adopted by CIRAD to combat abiotic stresses.
10. Dr. Shahid Mansoor explained the 'Use of genetic engineering, genomics and Genome editing for cotton crop improvement'. Dr. Mansoor highlighted the importance of developing indigenous transgenic varieties for biotic stress management and on the use of CRISPR-Cas in generating gossypol-free cotton seeds. He presented the progress of molecular work in NIBGE and its practical benefits through the generation of herbicide tolerant and insect resistant cotton.

International Partnerships and Solving Threats to Cotton Production

Jodi Scheffler
USDA-ARS Stoneville, Mississippi, USA.

Dr. Jodi Scheffler is Lead Scientist and a Cotton Geneticist at the USDA-ARS Research Center in Stoneville, Mississippi USA. Dr. Scheffler received a B.S. and M.S. degree from Iowa State University and Ph.D. from the University of Wisconsin. She worked 12 years in the United Kingdom and Germany, before joining USDA in 2000. At USDA, she has been instrumental in developing and making available molecular markers for the cotton community. Her research focuses on increasing cottonseed use and incorporating traits to improve host plant resistance. Internationally, she has worked with research partners developing ultra-early cotton with verticillium wilt resistance and producing cotton leaf curl disease resistant cotton along with diagnostic tests and best management practices to mitigate effects of the disease. Throughout her career she has mentored the next generation of scientists, starting early with STEM outreach activities in the schools. Dr. Scheffler is active in professional organizations including National Association of Plant Breeders, Crop Science Society of America, ICAC and ICRA. Dr. Scheffler was the recipient of the 2014 National Cotton Genetics Research Award, the 2016 USDA Secretary of Agriculture's Abraham Lincoln Award, the 2022 ICAC Researcher of Year award and is a 2022 Crop Science Society of America Fellow.

Although there is no total replacement for in person meetings and collaborations, there are ways that we can form and maintain meaningful partnerships using modern communication technologies and networking options. The COVID-19 pandemic forced us to find new and novel ways to communicate and maintain partnerships and we can now use some of these to remain more connected globally and more effectively work together to solve threats to cotton production internationally.

Growing up my entire world was a farm in Iowa, but attending U.S. public agricultural universities really opened up my world. At university, I studied and worked with students from over 40 different countries without ever leaving the USA. Then the opportunity to spend four weeks in China on a university study tour, gave me the opportunity to learn that both cultural and agricultural practices could be very different from what I knew, but still be effective and useful. The next step in my career journey was spending twelve years overseas learning new techniques and skills from a great group of international scientists. First at a Max-Planck-Institute breeding for improved potato chip color. Then in the UK conducting some of the first GMO field trials and writing release protocols used in the UK, Europe and the U.S.. Finally learning about plant transformation and developing GMO high linolenic flax to make linoleum flooring. There I also learned for the first time that scientific evidence is not always enough to convince the public about the benefits of new discoveries and technologies. In Europe, negative public perception of GMOS overrode all scientific evidence to the contrary. This truth is not limited to GMOs and something that we need to always be cognizant of as we carry out any scientific project.

In 2000, I started working with cotton for the first time at the USDA in Mississippi, USA.

There were already five scientists at my research center working on fiber quality and yield, so I was assigned adding value to cotton seed and developing DNA markers for marker assisted selection (MAS). As an additional research emphasis, I chose to work to enhance cotton's natural defense mechanisms (often called Host Plant Resistance). All my research has been very people powered and my success is due to the great team of co-workers and collaborators that have worked with me throughout my career.

The USDA-ARS Mission is to solve problems for U.S. growers, but to do this effectively we need international partnerships to successfully solve threats to U.S. agriculture as well as mitigate global production problems. It is also vital to be proactive. It can take 5 to 10 years to develop cotton varieties with resistance to pests or diseases, so we don't want to wait until the problem has already become a major threat. My first international USDA Project was with Uzbekistan, where we collaborated to develop, and are currently using in breeding programs, verticillium wilt resistant cotton that matures in only 110 days. This germplasm is important for cotton growers in the U.S. and Uzbekistan where verticillium wilt is a problem and early season frost often kills later maturing cotton. Through this project I learned some valuable lessons that I feel are important in general for successful collaborative projects. The most important lesson I learned is never to assume I know the best way to approach a research problem before observing and listening to the people I will be working with and the people we are trying to help. It is sometimes challenging, but we should always try to understand the reality of the situation for the farm families we are serving. Even if we think they are not being as effective as they could be, there are often good reasons for their current cultivation techniques or seed selection. Try to understand the "backstory" before charging forward. It is important to develop good relationships with government officials in the area you are working. They should not dictate what you do, but their support is critical especially for long term sustainability of any project. It is also necessary to fit your actions to the circumstances. For example, purchasing the most modern equipment for capacity building is no good if the country's infrastructure is too poor to support it or there is no way to obtain supplies for the equipment. Make sure what you are doing will actually help!

An example of a successful large international project was one started in 2009, with Pakistani and United States government officials meeting and identifying several agricultural problems of mutual interest. One common threat identified was Cotton Leaf Curl Disease (CLCuD). From this meeting the Cotton Productivity Enhancement Program (CPEP) was started. Many scientific institutions and governmental agencies worked together to make this project a success. During the ten years of the project, CPEP included 13 projects & over 70 scientists, Post Docs, Students, Support Staff and Farmer Organization Cooperators that all played essential roles in making the project successful. To keep the project on track, online meetings were conducted regularly with biennial in person meetings held in Pakistan. Written reports and onsite visits were also part of keeping the projects coordinated and on track. The initial program needed to be organized quickly and this was possible because of previously established good relationships between U.S. and Pakistani scientists developed over many years. Through organizations such as International Cotton Researchers Association (ICRA), we can continue to develop and maintain international relationships among cotton researchers globally.

Through CPEP we identified genetic resistance to CLCuD and made seed freely available to breeders globally. Pakistani breeders used the resistance source and in 2021, released the first commercial varieties for Pakistan. Diagnostic tests to detect, identify and track the virus were also developed as well as best management cultural practices to mitigate the effects of the disease.

However, all this research is worthless unless these best management practices can actually be used by the farmers to mitigate the effects of CLCuD and improve their productivity. A survey of Pakistani farmers revealed that there were approximately 1.2 Million total farmers and most of the farms were less than ten hectares. Also, throughout Pakistan many small-holder farmers were illiterate. Based on this information, we knew that the extension model commonly used in the USA would definitely not work, so what was the best way to engage and assist these smallholder farmers? As part of our project, we consulted Pakistani experts who were already working directly with Pakistani farmers and together developed effective methods to reach the farmers. Part of our answer was to establish Farmer Field Schools (FFS). The FAO created the original FFS, then Pakistani scientists developed programs specific for Pakistan in cooperation with Pakistani farmer associations.

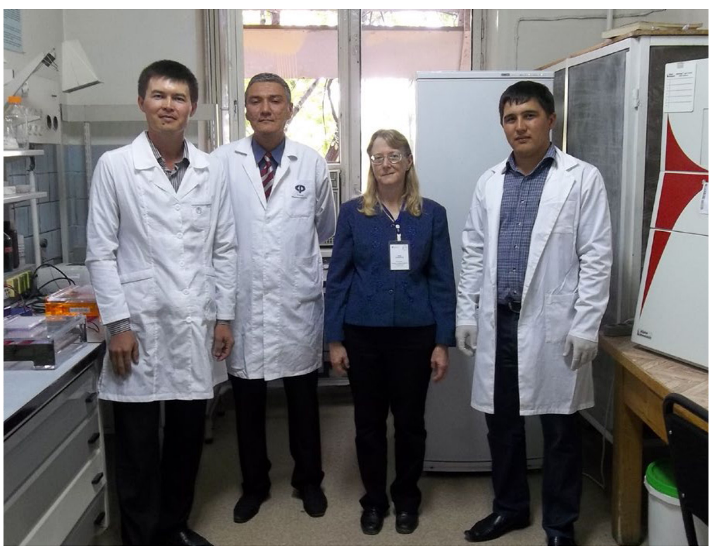
Using the FFS model, local people that had some education and were classified as "early adopters" were trained as the facilitators for the FFS. In their own villages, the farmers met weekly with the facilitators during the cropping season for hands on activities. They tried new techniques alongside their current methods, observed the results and then decided together whether they should make changes. Often, they did not entirely accept the new method, but found ways to make it even better and used this modified method. The next year they tried the new method on some of their land and tested for themselves how it worked under the guidance of the facilitator and the other farmers in the local FFS. Over 5,500 farmers have participated in these Farmer Field School Programs. Worldwide women and children are the farm workers. If women can earn money, they are more likely to use it to help the family unit. However, cultural norms may make it difficult for women to fully participate in mixed gender groups. Wherever we do our research projects, we need to be aware of cultural Norms and traditions in the places where we work. Because of the situation in Pakistan, using Women Open Schools (WOS) gave the women in our outreach efforts their own participatory learning programs that taught skills to make their lives safer and economically more secure.

Commercial cotton production demands uniformity, but cotton as a genus is variable with many valuable traits that will help it adapt to the changing climate. A valuable USDA resource is their collection of cotton germplasm and obsolete cultivars. It is an important source of naturally occurring novel traits that can improve cultivated cotton. As part of our CPEP collaboration, USDA sent 5,000 accessions to Pakistan to add to their own existing collection. Now the United States and Pakistan can do other projects of mutual interest. For example, they are currently working to screen our collections for heat tolerance, a trait of interest worldwide. The seed is being tested in hot dry areas of Pakistan and the information will be shared through publications.

One of the sources of resistance to CLCuD found in the USDA cotton germplasm collection was from Brazil. Because these germplasm lines were photoperiod sensitive and difficult to grow, in 2016, we formed a collaboration with the United States, Pakistan and Brazil to transfer this resistance to upland cotton. Included in this collaboration were other diseases of mutual interest such as Cotton

Blue Disease (CBD) caused by cotton leaf-roll dwarf virus (CLRDV). This proved to be very beneficial as in 2017 Cotton Blue Disease was first reported in the U.S. It spread quickly and by 2019 the virus was found in ten states across the U.S. cotton growing region. With the help and expertise of our Brazilian collaborators from Embrapa, we were able to move forward quickly and form a team of researchers with differing expertise including pathologists, entomologists, breeders and agronomists. This team is currently working to find ways to mitigate the effects of the disease, develop cheap and effective diagnostic tests and identify resistant cotton germplasm. So far, the best resistant sources have come from South America and Africa.

Based on all my previous collaborations, I believe there are several essential components that make for a successful collaboration. One is to create the possibility for longer term projects, not just a quick two years and then done and gone. Sustainability is also critical and should be a goal of the project from the beginning, always trying to build into the project ways to keep it going after the initial project is completed. Most importantly the project has to be mutually beneficial to both partners. If the partnership is only in one direction, it is hard to get buy in or sustain it.



The question then is how can we find partners with common interests and work together for our mutual benefit? One of the first points of contact for me, and anyone can do it as well, is to email the USDA ARS Office of International Research Engagement and Cooperation (OIREC). They have an overview of all the research projects being done by USDA scientists and can also find a scientist that has the expertise you are looking for in a partner.

https://www.ars.usda.gov/office-of-international-research-engagement-and-cooperation/office-of-international-research-engagement-and-cooperation/. They have also divided the world into regions and have someone assigned to each, so if someone is living and working in a particular region and wants to know what other research is happening through the USDA, they can contact the Regional Specialist whose names and regions covered are also listed on the OIREC website. There are also a number of collaborative programs administered by the USDA Foreign Agricultural Service. To get more information about these individual programs, go to the FAS website https://www.fas.usda.gov/programs. I have personal experience with the USDA Borlaug Fellows Program which targets young scientists. Under the Pakistan Borlaug Program, 15 fellows completed the program and went on to positions at universities, research institutes, private companies and governmental posts. These are our next generation of successful partners and global leaders. While online meetings using sites such as Zoom or Teams are essential to conduct international collaborative projects, in person, scientific exchanges are important to promote the most effective research. Throughout my career, scientists have come and worked at my institute and just as essential I was able to visit my partner's research locations to learn first-hand from them.

Being able to share seed is an important part of successful cooperation. Unfortunately, cotton is not on the list of crops covered under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). However, the protocols and material transfer agreements developed for the treaty could be used for our own partner cotton seed exchanges. If you can't exchange seed, exchanging DNA or dried tissue could be a way to collaborate, especially for sequencing and genotyping projects and marker assisted selection (MAS).

While sharing seed and DNA is an important goal, we can still make progress together now by combining forces and sharing our information and research results. So how do we find other partners and venues to exchange information? One way is by belonging to professional organizations such as the National Association of Plant Breeders (NAPB) and their partner the African Plant Breeders Association (APBA). There are many other organizations, and hopefully we can find and network through more of them. Fortunately, as cotton researchers we have our own valuable organization the International Cotton Researchers Association or ICRA. A good place to start finding out what is happening in cotton is the ICRA Forum http://www.icracotton.org/. It has a number of discussion groups. For example, the Disease Control discussion group. If you click on the link http://forum.icracotton.org/t/disease-control, there are a number of posts from other ICRA members starting from the most recent. If you are looking for information about a topic or a person with similar interests etc. then you can create your own post.

These are only a few observations and ideas for how you can enhance your own research through new partnerships. Many of you are ICAC / ICRA members and also have a wealth of experience conducting collaborative research throughout the world. I am hoping that you will share your experiences and ideas with all of us through ICRA.

New developments in cotton fiber quality determination

E.F. Hequet[1], C. Turner[2], and A. Sayeed[2]

[1]Paul Whitfield Horn Distinguished Professor and Associate Vice President for Research
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Dr. Hequet is a Paul Whitfield Horn Distinguished Professor in the Plant and Soil Science and the Fiber and Biopolymer Research Institute as well as Associate Vice-President for Research at Texas Tech University (TTU). He joined Texas Tech University in 1997. He holds a Ph.D. and a "Habilitation à Diriger des Recherches" from the University of Haute Alsace in France (must have this diploma to be full professor in Europe). Before joining TTU, his experience progressed from cotton breeding at experiment stations in Africa, to head of CIRAD's Cotton Technology Laboratory in Montpellier - France, to Director of the international cotton program for CIRAD. Since he joined TTU, he has developed a very successful research program as witnessed by his effective grant writing, publication record, and research awards. He is one of the leading experts in the U.S. in research on cotton fiber quality.

The focus of the dominant international textile industries is on finer yarns and ring spinning. Therefore, textile mills emphasize cotton growths with fiber profiles adapted to this market (fibers that are long, uniform, mature, fine, strong, and with low contamination levels). At the same time, increasing labor costs in Asia, where most of the cotton spinning industry is located, are forcing spinning mills to consider potential alternative spinning technologies such as airjet or vortex spinning. If cotton could be adapted to these spinning technologies, its throughput would make it competitive with rotor spinning (faster than rotor). It could produce yarns competitive with ring-spun yarns in some market segments such as the 30Ne, which is the primary target market for U.S. cotton (the range of possible yarn counts is narrower than for ring spinning). However, because of poor fiber length distribution compared to synthetic fibers, cotton is not the fiber of choice in the airjet/vortex spinning market. The current solution to deal with this issue is to modify the distribution of fiber length with combing. The drawback is that it lowers mill throughput and increases waste, resulting in lower profits for the spinning mills. The Vortex or Airjet spinning industry is emerging. This technology is an opportunity for U.S. cotton as ring spinning is not a viable option for the local transformation of the raw material because of labor costs.

The cotton market is global and competitive. Long-term data show that cotton fiber is losing market shares to other staple fibers, but its consumption in pounds keeps increasing. Therefore, cotton must respond to industry needs in terms of price and quality.

Several non-HVI fiber properties are essential to predict yarn quality accurately (non-exhaustive list below):

1. Elongation
2. Fiber length distribution
3. Complex fineness-maturity

In this presentation, we will discuss fiber length distribution and fineness-maturity only. Results on elongation are presented in a separate document (WCRC7 book of papers). We conclude with our preliminary on the spinnability of cotton in Vortex spinning.

Fiber length distribution

HVI fiber length measurement follows the fibrogram principle proposed by Hertel (1940). HVI measures UHML and ML from the fibrogram curve and reports UHML and UI (UI = (ML/UHML)*100%).

As illustrated in Figure 1, a large part of the fibrogram is ignored.

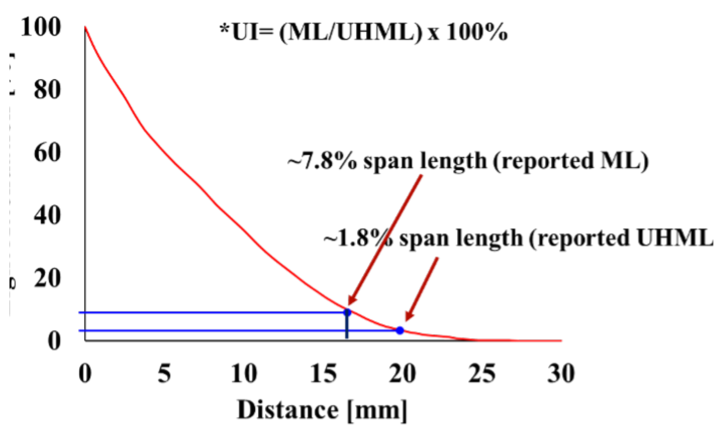


Figure 1. An illustration of the reported fiber length measurement with HVI

In our research, fiber length information captured by the whole fibrogram was summarized by three principal components (PCs). Partial least square regression prediction models were designed to evaluate the predictive power of the fibrogram fiber length variation and compared them with current HVI lengths.

Model 1: HVI non-length parameters + current lengths

Model 2: HVI non-length parameters + Fibrogram

The results show that the fibrogram holds additional fiber length information that is not captured by typical HVI length parameters (UHML and UI).

This information is important to explain variations in yarn quality as illustrated in Figure 2.

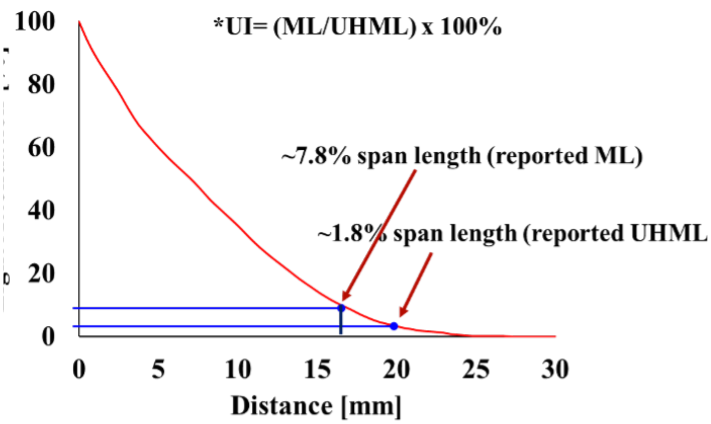


Figure 2. Yarn quality predictions.

A major research program is ongoing to determine the feasibility of using the HVI fibrogram rather than the AFIS in yarn prediction models. Preliminary results demonstrate that the HVI fibrogram is at least as good as the AFIS fiber length distribution in predicting yarn quality.

Fiber fineness and maturity

In spite of the importance of maturity and fineness for the textile industry, there is no direct or indirect measurement method that is both fast and reliable. Several years ago, facing the lack of standards of reference for maturity, it was decided, in cooperation with Cotton Incorporated, to create a set of reference cottons for maturity measurements based on fiber cross-section analysis. To achieve this task, we selected 104 cotton bales representing the two principal cultivated species.

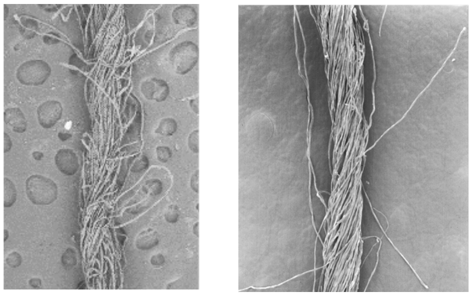
Image analysis of the cross-section of cotton fibers constitutes an excellent reference method for maturity and fineness measurements, but this technique is too slow to be of practical use in commercial operations. The primary goal of creating this set of 104 cottons with known maturity values is to establish calibration equations for high-speed instruments (e.g., AFIS, Cottonscope, etc.).

The effect of maturity on dye uptake is well-known. Similarly, we know that fine and mature fibers make it possible to spin a finer yarn. But maturity and fineness of cotton fibers are also essential qualitative characteristics if one wants to better understand the facility of rupture of fibers when they are subjected to stress. It is intuitively obvious to hypothesize that immature fibers (having a thin, poorly developed secondary wall) will be fragile. Thus, they are likely to break during multiple mechanical stresses involved in transforming the fibers from the field to the yarn. These generate short fibers and neps (an entanglement of fibers). An increase in the short fiber content will result in yarn defects and decreased productivity.

The results obtained so far demonstrate that immature fibers are weak and tend to break when submitted to mechanical stress. Maturity has a major effect on the propensity-to-break of individual fibers. Mechanical processing modifies the fiber length distribution. The intensity of the change is partly dependent on the level of maturity.

Vortex spinning

If cotton could be adapted to vortex spinning, its throughput would make it competitive with rotor spinning. It could produce yarns competitive with ring-spun yarns in some market segments such as the 30Ne, the primary target market for U.S. cotton. But, because of poor fiber length distribution compared to synthetic fibers, cotton is not the fiber of choice in this market.



Vortex spun yarn Ring spun yarn

Our research shows that fiber length distribution has a large impact on Vortex yarn evenness and a limited impact on Vortex yarn tensile properties and hairiness. Therefore, if we want to target the Vortex market, breeders must improve length distribution (HVI or AFIS?). In addition, increasing fiber tensile properties (strength and elongation) and decreasing fiber diameter would be necessary.

It sounds like a difficult goal to reach, but we begin to see elite lines that, in terms of fiber quality and spinning performance, are competitive (Wayne Smith, Texas A&M).

Acknowledgments

We thank Cotton Incorporated for its support of our long-term research goals.

Regenerative Agriculture: Tools to Increase Cotton's Profitability

Kater Hake and Gaylon Morgan
Cotton Incorporated, Cary, North Carolina, US

Kater Hake is the Vice President of Agricultural and Environmental Research at Cotton Incorporated where he is responsible for the cotton production research program. Kater leads a team of 6 project managers who develop and support innovative problem-solving research with a network of 300 public sector scientists to increase the profitability and sustainability of cotton farming in the United States. Kater came to Cotton Incorporated from a long career in cotton research and management. Most recently he was the Vice President of Technology Development at Delta & Pine Land Company. He has also held positions at Texas A&M University, The National Cotton Council, and the University of California. He holds 3 degrees from the University of California at Davis and at Riverside.

Textile consumers are asking for cotton grown using Regenerative Agriculture principles. Although there is no global consensus regarding these, in the United States (U.S.) a coalition (Field To Market) of 26 grower organizations, 17 Brands and Retailers, 12 members from Civil Society and 53 companies that support farmers https://fieldtomarket.org/the-alliance have adopted a definition of Regenerative Agriculture.

Using a systems-based perspective, Regenerative Agriculture sequesters carbon in the soil and intentionally improves soil health, biodiversity, water quality and air quality while ensuring the viability of farm production.

Principles of Regenerative Agriculture

The principles of a regenerative agriculture system are based in Indigenous ways of land management and are adaptive to local physical conditions and culture. These principles include:

- Minimizing soil disturbance
- Maintaining living roots in soil
- Continuously covering bare soil
- Maximizing diversity with emphasis on crops, soil microbes, and pollinators
- Integrating livestock where it is feasible

This Regenerative Agriculture definition focuses on soil and differs from Field to Market's approach to Sustainable Agriculture which more broadly encompasses human health, social, and economic impacts.

Field to Market defines sustainable agriculture as meeting the needs of the present while improving the ability of future generations to meet their own needs by:

- Increasing productivity to meet future food, feed, fiber, and fuel demands
- Improving the environment
- Improving human health
- Improving the social and economic well-being of agricultural communities

The current interest in soil derives from the dual role of soil in climate change. Soil is a key element of agriculture's ability to provide food, feed, and fiber despite adverse rainfall and temperatures; soil can also sequester carbon that helps mitigate some greenhouse gas contributions to climate change. However, global cotton farmers should also adopt Regenerative Agriculture principles for its enhancement of farmer profitability. The U.S. journey towards Regenerative Agriculture principles has been largely driven by farmer profitability. Although it has included advancements and setbacks, this journey can inform other production regions that wish to avoid some of the setbacks that the U.S. has experienced.

The cost in fuel, equipment, and labor of winter and in-season tillage was a strong motivator to reduce tillage. University farm budgets from 24 years ago in the largest cotton producing state, Texas, list 12 different tillage operations that consumed nearly a quarter of the annual production budget through harvest. https://agecoext.tamu.edu/resources/crop-livestock-budgets/by-commodity/cotton/1998-cotton However, reducing tillage left cotton vulnerable to weed competition during the critical weed free period of 2 to 3 months after planting. Weed Science 1970 18:149-154, JMAU 1990 15:257-258, CIRAD 1997 Douti, Djagni & Jallas, Phytoparasitica 2002 30:105-111, Weed Research 2004 44:404-412, Indus. Crops & Prod. 2011 34:1198-1202. Preplant and at-planting herbicide combinations were employed to suppress weeds during this critical weed free period. Since herbicides need to be tailored towards specific weed species, soil characteristics, and production systems, both field experience and regional research was needed to support their effective use. One early example was the timing of preplant "burndown" herbicides to provide a weed free start at planting. Some growers prefer an early burndown to prevent a "green bridge" that insects could use to infest seedling cotton. Other growers prefer a late burndown to maximize residue and remove excess moisture. Herbicides could also injure seedling cotton when excess rain after planting leached herbicides into the cotton root zone or splashed it on the seedling leaves. Herbicides also selected for more tolerant weeds such as Conyza canadensis (aka horseweed and mare's tail).

The introduction of glyphosate tolerant cotton in 1997 appeared to be a near perfect solution to weed control and the need to reduce tillage costs. The breath, effectiveness, and ease of post emergence weed control provided cotton producers the confidence to adopt reduced tillage and no-till on large acreage fields across the midsouth and southeastern U.S. Soon it was observed that the first-generation glyphosate tolerance, which was limited to just cotton's pre-squaring period, could result in yield loss if glyphosate applications continued into cotton's fruiting period Crop Science 2004 44:234-240. The second-generation glyphosate tolerant cotton, along with glyphosate tolerant soybeans, removed this timing limitation and allowed growers to use glyphosate in a field as their dominant weed control method over multiple years and crops. This reliance on one herbicide mode of action led to glyphosate resistant weeds starting approximately 7 years after glyphosate tolerant crops were introduced www.weedscience.org. Initially these weeds were suppressed with higher rates of glyphosate which was facilitated by the reduction in herbicide price associated with patent expirations. https://www.agecon.msstate.edu/whatwedo/budgets/archive.php . Higher rates did not prevent herbicide resistance which expanded to include weeds with multiple modes of action herbicide resistance, which now includes weed resistance to 11 modes of action www.weedscience.org.

In 2007, the use of corn grain for biofuels stimulated grower prices in corn, soybeans (corn's main rotational crop), and sorghum (a crop that replaces corn in feed uses). These 3 crops were agronomically viable rotations for cotton and now were economically viable allowing profitable rotation for cotton across the U.S. With these rotations, cotton growers saw ancillary benefits: new herbicide modes of action, soil health improvement, and residue protection from wind damage to seedling cotton, and summer heating of bare soil. Managing diverse residues required even greater field specific experience and research. The success of rotational crop residues stimulated an interest in cover crops to smother small seeded weeds during the critical weed free period after planting. Cover crops required even greater field experience and research to address the challenges of water use and stand establishment. Solutions were found in soil moisture monitoring to optimize cover crop termination to preserve soil moisture and the adoption of no-till planters using high quality seed and fungicides.

Although the tractor time required to profitably manage reduced tillage and no-till systems with crop rotations is reduced, the grower management skills are increased. Some of the components that growers must consider in making field specific decisions include: weather forecast, soil moisture, disease risk, planter capacity, residue amount and persistence, preemergence herbicides, weed seed bank management, regulatory constraints, multi-strategy weed control (physical and chemical), nutrient timing and placement, crop rotation, erosion risk, market availability and prices, soil compatibility, and equipment availability.

The agronomic complexity of cotton farming in the U.S. has largely been driven by weed control. Growers now employ a multi-strategy weed management system of weed seed reduction, cover crops paired with herbicides that prevent weed emergence, and rotational herbicides. Agronomy Journal, 113(6), 5373-538 Fortunately, the most pernicious weed in U.S. cotton, Amaranthus palmeri (aka Palmer amaranth), has low seed viability when left on the soil surface. Based on research across the U.S., soil surface Palmer amaranth seed viability within 12 months drops from 90% to 15%. Weed Science 2018 66:446-456 Because of this, no-till cotton growers experience more rapid weed seed reduction than conventional tillage growers.

No-Till Farm in Coffeeville, Mississippi

Of the principles of Regenerative Agriculture, three have been strongly adopted due to their enhancement of grower profitability: minimizing soil disturbance, maximizing diversity with emphasis on crops, and continuously covering bare soil. The maintenance of living roots is challenging where sparse rainfall and cold temperatures limit root growth during the winter. Most challenging is the integration of livestock due to the labor required for rotational grazing.

Several lessons from the U.S. cotton journey (both advancements and missteps) towards Regenerative Agriculture might benefit other cotton growing regions.

- Constant innovation is needed to address challenges that were not anticipated
- Close collaboration between farmers and researchers develops economic solutions because farmers cannot adopt long term practices on their farms unless they are profitable
- Research and production practices need to be tailored for local conditions
- Farmer knowledge and experience is essential to successful adoption of Regenerative Agriculture practices

The cotton industry is fortunate in that the interests of textile consumers are increasingly aligned with those of cotton farmers. This alignment is especially true for the current interests in Regenerative Agriculture, often referred to as Climate-Smart Agriculture, for its benefits in both adapting to the rainfall and temperature adversities of Climate Change and in mitigating the Climate Change by sequestering carbon out of the atmosphere and minimizing further greenhouse gas emissions.

Changing Paradigms in Technology Transfer for Bridging Gaps in Smallholder Cotton Farms

Charudatta Mayee
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Dr. C.D. Mayee is a renowned cotton scientist and is currently serving as the President of the South Asia Biotechnology Centre (SABC), New Delhi and Chairman of AFC India Limited (Formerly Agricultural Finance Corporation of India), Mumbai. Born in a farming family of Maharashtra, Dr. Mayee obtained his agricultural degrees from Maharashtra and PhD from IARI, New Delhi in Plant Pathology. Dr. Mayee served as Vice Chancellor-MAU Parbhani; Director-Central Institute of Cotton Research (ICAR-CICR) Nagpur and Agriculture Commissioner, Govt. of India, New Delhi before retiring as the Chairman, Agricultural Scientists Recruitment Board (ASRB), Ministry of Agriculture & Farmers' Welfare of the Government of India. Though specialized in Plant Pathology, Dr. Mayee committed himself for the growth of Indian Agriculture. He guided 20 PhD and more than 38 MSc students, wrote books and monographs, published over 200 scientific publications in journals of repute and served the cause through development of the subject. He was elected as fellow member of several scientific committees and associations including Vice President of National Academy of Agricultural Sciences (NAAS), and also invited as a member of international societies including ISAAA and ABNE, Africa. Dr. Mayee was Alexander Humbold Fellow of Germany. He is recipient of several National and International awards for agriculture development.

Cotton is grown in 80 countries across the world. The crop provides major source of income and livelihood for small holders in arid and semi-arid areas in Asia and many African countries. While developed countries like USA, Brazil and Australia produce cotton in large farms (average farm size of 450 to 1339 ha) and achieve higher productivity with access to precision farming techniques to manage cotton production, developing countries in Asia and Africa face numerous problems for technology uptake and adoption in view of small holdings and subsistence farming. It is in this context the approach to technology transfer for small holder farmers holds the key to production enhancement in these countries. Communication, information sharing, and advisory services are thus very useful for small holder farmers to successfully manage cotton production. In India, out of the 8.0 million cotton farmers, 82 percent grow cotton on an average of 1.4 hectares of land. New extension approaches were adopted recently for technology transfer to small holder farmers, to boost their farm productivity and build their confidence in cotton cultivation. For example, technologies such as High-density planting system (HDPS) and mating disruption for management of pink bollworm have reached the small holder farmers in a short span of time using different information, education and communication (IEC) techniques. The new nutrient Unlock Technology of CROPTEC-SOLUTION, where three micronutrients (Zn, Bo and Fe) and two secondary nutrients (Mg & S) are coupled with the major nutrients (NPK) in one granule is likely to revolutionize the Integrated nutrient management (INM) technology in cotton once it reaches the small holder farmers.

Several new approaches have been found highly useful to create awareness about such novel technologies, instead of traditional modes of technology transfer.

Along with selective demos, group meetings, use of social media, dedicated websites, messages through travelling floats in cotton intensive areas during the season, circulation of posters, pamphlets, attractive cartoons booklets to farmers through village Panchayats, radio jingles, local televised information through public-private partnership initiatives were more effective either in controlling new outbreaks of pests, diseases or promoting adoption of new techniques of cultivation, irrigation or nutrient management.

Virtual Reality (VR) is now an additional powerful tool for technology transfer. It has the potential to bridge the gaps, cutting across the boundaries of distance, countries, languages etc. In cotton, pesticide usage increases not only the cost of production but also creates environmental issues. Recently ICAC along with GIZ developed VR tools for IPM in cotton and launched for cotton TOT in 8 African countries. This IEC digital tool can supplement the existing extension techniques for effective technology transfer to small holder farmers. In India, this will be added in our extension toolkit for IPM.

The paper describes the technology transfer campaigns that were successfully implemented to promote the adoption of HDPS, management of pink bollworm and sensor-based water and nutrient use in small-holder farms.

High Density Planting System – Next Revolution in Cotton Farming in India

Basavaraj M. Khadi
President, Institute for Studies on Agriculture and Rural Development (ISARD), Dharwad, India

Dr. Basavaraj M Khadi is presently serving as a President, Institute for Studies on Agriculture and Rural Development (ISARD), Dharwad and Member Programme Advisory and Monitoring Committee, ICAR – All India Coordinated Research Project on Cotton. He served as Director, Central Institute for Cotton Research, Nagpur (2005-08), Dean (Post Graduate Studies) (2008-12), Director of Research (2012-15) and Director of Education (2015-16) UAS, Dharwad, Karnataka and retiered from active service on May 31st 2016. Dr Khadi has 36 years of professional experience in the field of Crop Improvement. During the period, involved in the development of 10 cotton hybrids, 11 G. hirsutum varieties, two G. arboreum varieties, one G. herbaceum variety and five G. barbadense varieties. He registered 21 novel cotton germplasm lines with National Bureau of Plant Genetic Resources, New Delhi. Dr Khadi published 222 research papers, several books and other publications. Dr Khadi is the recipient of National, International awards and recognitions; Best FAO visiting Scientist to IR of Iran (2000); ICAR Team Research Award (2000 and 2006); Best Paper/ Poster Presentation Award (2004 and 2006); Sir C.V. Raman Young Scientist award (2002); ISCI Hutchinson Memorial award (1999); Rao Bahadur Ramdhan Singh Award for cotton research (2005); Dr. A. B. Joshi Gold Medal and Cash Award (2002), Dr. R. B. Ekbote Award (2013) for contribution in Genetics & Plant Breeding; UAS Dharwad Cash Incentive Award (1996; 2001; 2003) for handling Research Projects; UAS Team Award for best maintenance of ARS, Dharwad (1999 & 2000). Dr Khadi was recognized as a Fellow of National Academy of Agricultural Sciences (2010); National Academy of Biological Sciences (2009); Indian Society of Genetic and Plant Breeding (1995), International Society for Tropical Crop Research and Development (1992). He guided 13 Ph.D. and 22 M.Sc. (Agri.) students as Chairman and 34 Ph.D. and 47 M.Sc. students as member. Two students were awarded with prestigious Jawaharlal Nehru Award (ICAR, New Delhi).

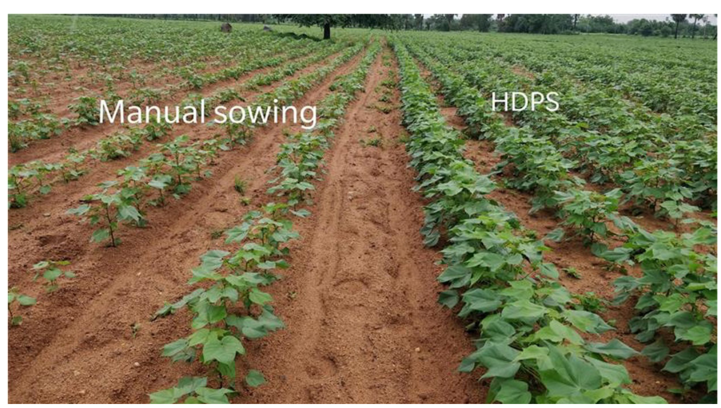
India has a long history of cultivation of cotton and which can be conveniently divided into Cotton Varietal Era (up to 1970-71), Hybrid Cotton Era (1972-2001) and Bt Hybrid Cotton Era (2002 onwards). Among 53 *Gossypium* species available, four are cultivable and all four were cultivated commercially in India prior to Bt Hybrid cotton era. At present the major cultivable area falls under *G. hirsutum*. Apart from this, different categories of cotton; surgical, very short, short, medium, superior medium, long and extra-long staple cottons were produced and were suitable for spinning 6s – 120s, even up to 200s counts yarn during varietal and hybrid cotton era. But now, only one category of superior medium - long staple (28 - 30 mm) cotton is produced in this Bt cotton hybrid era and which has become difficult in producing different categories of yarn, especially opened spinning industry is suffering due to non-availability of different categories.

During the varietal era, cotton area was to the extent of 6.58 million ha with a production of 8.37 million bales (1.42 m t) at a productivity of 152 kg lint/ha, whereas during hybrid cotton era the cotton production and productivity almost doubled (17.65 million bales, 3.0 m t & 330 kg lint/ha, respectively with slight increase in cotton area (9.29 m ha). Introduction of Bt cotton hybrids in India of course reduced the cotton bollworm damage, but increased production and productivity of cotton (6.77m t, 565 kg lint/ha respectively). The productivity reached maximum of 565 kg/ha during 2013-14 and later started declining. This is envisaged due to the development of resistance of pink bollworm to Bt toxins.

The present production of cotton is 36.22 m. bales (6.16 million ton) on an area of 12.65 million ha with productivity of 466 kg lint/ha. The projected requirement of cotton is estimated to be almost 50 per cent more by 2030 (8.95 million ton), nearing to double during 2040 (12.12 million ton) and during 2050 it will be almost 150 per cent more (15.29 million ton). In order to achieve these projections, the productivity of cotton in the country should be enhanced to 746, 1010 and 1274 kg lint/ha during 2030, 2040 and 2050 respectively.

Strategies to achieve the future projected requirement of cotton production in India

Development and promotion of high yielding Bt cotton and *G. arboreum* varieties having early maturity (140-160 days), big boll size (>4.0 g *G. hirsutum*, > 3.0 g *G. arboreum*) with higher harvest index (0.4-0.8) and higher ginning out turn (>35% *G. hirsutum*, > 40% *G. arboreum*) suitable for HDPS enabling machine picking.



In India, cotton is grown in 157 districts and among them, 26 are most efficient, 16 efficient, 75 less efficient and 40 inefficient cotton producing districts. To increase cotton production and productivity in different districts, especially less efficient districts, it is required to promote short to medium duration Bt cotton and high yielding *G. arboreum* varieties under HDPS to facilitate double cropping and minimising tillage. It is also needed to follow crop residue management for better soil health, mechanization to reduce cost of cultivation and in irrigated area drip- fertigation cum mulching technique for higher productivity and production in cotton.

Cotton cultivation in India is completely labour oriented; especially picking and harvesting requires maximum labour followed by weeding, pesticide application, sowing and fertilizer application. There is an imminent need to reduce the cost of labour by contract and collective farming and mechanization of these cultivation practices.

Cultivation of cotton under HDPS requires proper plant canopy management by application of certain PGRs and defoliants and also required to follow precise water, nutrient, weed, pest management and adoption of drip-fertigation cum mulching in irrigated area to enhances the cotton productivity.

Discouraging mono-cropping of cotton by crop rotations and remunerative cotton based inter cropping systems with pulses, cereals, vegetables, oil seed and green manuring crops to maintain soil fertility and sustainable cotton yields. Adoption of double cropping system in irrigated and rainfed (under residual moisture) cotton area with short and medium duration Bt cotton and G. arboreum varietal cultivation.

Weed management can be achieved by application of pre and post emergent weedicides, 2-3 inter cultivations. Adoption of HT- Bt technology if approved in India may help in proper weed management.

Incorporation of resistance/tolerance is essential to enhance the region wise cotton productivity, viz; tolerance to Leaf Curl Virus, Whitefly, Jassids and pink bollworm in northern region; Pink boll worm, Jassids and drought in Central and South India and to Mirid Bug and Flower Bud Maggot in South India by adopting new technologies; introgression, MAS, RNAi, CRISPR- Cas 9 for breeding biotic, abiotic stresses resistance, better fibre quality cotton genotypes to increase the production, productivity and reduction of cost of production.

Recent Breakthrough Innovations in Cotton Research

Ibrokhim Abdurakhmonov
Center of Genomics and Bioinformatics, Uzbekistan

Prof. Abdurakhmonov received M.S. in plant breeding (2001) from Texas A&M University, Ph.D. (2002) in molecular genetics, DSci (2009) in genetics, and full professorship (2011) in molecular genetics and biotechnology from Academy of Sciences of Uzbekistan (ASU). He founded (2012) and is currently leading the Center of Genomics and Bioinformatics of Uzbekistan. 2010 -TWAS prize, 2013 - "ICAC Cotton Researcher of the Year 2013". He was elected as TWAS Fellow (2014), as a member and Vice-president of the ASU (2017) and appointed (2017) as the Minister of Innovative Development of Uzbekistan. He is an "Honored Innovator and Rationalizer of the Republic of Uzbekistan", awarded by the President of Uzbekistan in 2021. He was honored as the 2022 Ambassador of Silk Road Friendship (Individual), awarded by CICEC Global People Magazine, China.

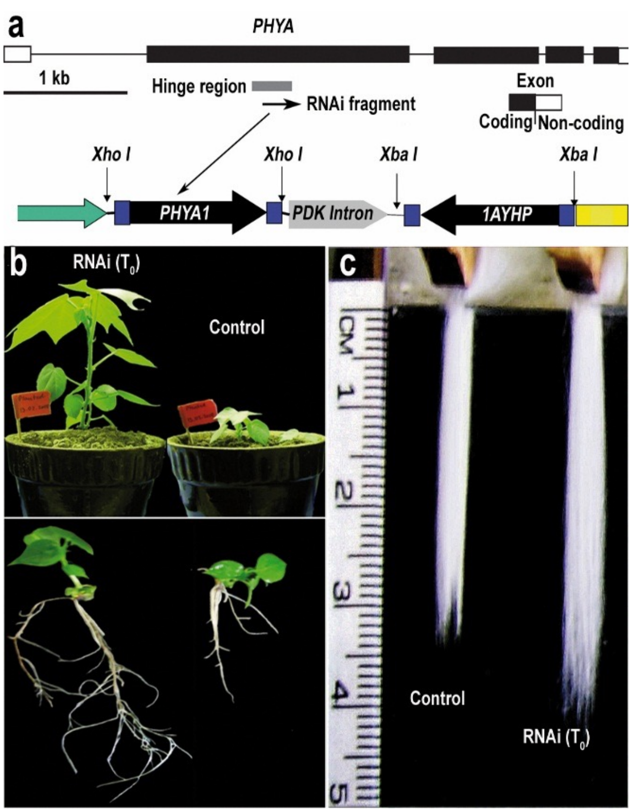
Global challenges, both in the pandemic period and the climate change era, demonstrate out-of-box thinking and developing non-standard and fast-track solutions in every aspect of the socio-economic development of our life. As cotton is considered a globally known cash crop, future cotton science, and farming require innovative 'game-changing' technologies and scientific approaches to mitigate possible challenges that the cotton industry might be encountering in the era of global climate change challenges.

I highlighted the latest views and available agro - biotechnologies with some examples of Uzbekistan's practice and its perspective directions that should be useful for the world cotton community. In particular, I outlined major challenges for sustainable cotton framing in the era of global climate change including increased biotic stress pressure (emerging new pests and diseases), drought and salt stress as well as abnormal heat pressure with highly fluctuated and increased night temperature issue affecting great yield lost in many countries including Uzbekistan. Concentrating on the past 5-year research publication analysis, the main focus of cotton science efforts has been shown that help researchers to re-orient some of the research programs, if applicable. In that, I highlighted that in-depth analysis and review of the past 5-year publications of nearly 2000 peer-reviewed publications showed the shift of cotton research more on biotic stresses, plant development, and abiotic stresses.

As possible solutions to the highlighted challenges, I presented some approaches that we are taking in Uzbekistan. These include mainly RNA interference and marker-assisted selection (MAS)-derived cotton cultivar development, targeting fiber quality, yield, and early maturity as well as wilt disease resistance, salt, and drought/cold tolerance characteristics. Some of our new efforts on RNAi of novel cotton genes including cotton Eskimo-1 (ESK-1), cotton hypocotyl-5 (HY5), and phytochrome B (PHYB) in addition to PHYA1-derived RNAi cultivars have been presented. I also highlighted the drought and salt tolerance of PHYA1-derived RNAi cultivars widely grown in Uzbekistan, in particular in salty land close to the dried Aral Sea basin. FOV-resistant 'bulletproof' RNAi genotypes have been also briefly highlighted.

To mitigate the carbon dioxide sequestration process using cotton framing, I also highlighted the importance of the development of the early maturing and deep rooting cotton cultivars with increased suberin type of polymer accumulations in the root, helping to trap CO_2 by cotton framing in the future. Several novel technologies including novel bio stimulators and biofertilizers to cope with global climate change challenges in Uzbekistan cotton farming have been also presented. Lastly, I presented the newly established Cotton Council under the President of the Republic of Uzbekistan highlighting it is function and inviting all interested international scientists or parties to participate in this endeavor.

First Uzbek GE cottons targeting multiple effect genes using RNAi



RNAi VARIETIES

Porloq-1 Porloq-2 Porloq-3 Porloq-4

RNAi Variety Controls

MARKER-ASSISTED SELECTION PROGRAMMES

Identified markers were successfully utilized in Marker-assisted selection program for development of first MAS-cotton varieties

Ravnaq-1

Ravnaq-2

Baraka

Sakhovat

Tafakkur

Advances In Cotton Integrated Pest Management

Khalid Abdullah
Ministry of National Food Security & Research,
Government of Pakistan, Islamabad Pakistan

Dr. Khalid Abdullah graduated from Gomal University, Entomology as major and did his masters from Agriculture University Peshawar in the same subject. Dr. Abdullah did another master from New Mexico State University Las Cruces NM, USA in Agriculture Biology. Dr. Abdullah joined Agriculture Research Department and did his PhD in Agriculture Entomology. He served as research scientist for 22 years in agriculture department, before joining Federal Government as Cotton Commissioner. Dr. Abdullah serving number of committees/forums in different capacities and represented Pakistan at number of international forums. He is an active member of International Cotton Researcher Association since its inception and coordinating International Cotton Advisory Committee for input on behalf of Government of Pakistan.

Cotton and textiles are the mainstay for the economy of Pakistan contributing >60% in the foreign exchange earnings (US$ 12-15 billion annually), 0.8 ~1.5% in the national Gross Domestic Product and adds 2.4 ~ 7.0% value in agriculture sector. Cotton cultivation in this part of the subcontinent dates back to 3000 BC, as cotton fibers were found during excavations at Mohanjo Daro in Sindh, an ancient civilization of the Old Indus Basin. Though all four provinces cultivate cotton, but 74% is cultivated in the Punjab province, 25% in Sindh province while about 1 percent area under cotton lies in other two provinces of Khyber Pakhunkhwa and Balochistan. Pakistan used to grow cotton on 3.2 million ha but other competitive crops like maize, rice and sugarcane replaced its area and it reduced to 2 million ha for the last 5 years.

Pakistan Central Cotton Committee (PCCC) is the major institution responsible for research and development of cotton in the country. PCCC was constituted in 1948, just after Independence. Initially PCCC had a Technological Research Institute to conduct research on fiber, yarn and cloth where as crop research would have been outsourced to Agriculture Department of provinces. The PCCC is financed by the funds collected by levying of cotton cess on industry. PCCC later in 70s established its own research centers in different ecological zones. With the passage of time provincial research system was evolved, Pakistan Atomic Commission (PAC) established its agriculture research facilities to use radioactive technologies, biotechnology and genetic engineering in a food and fiber crops. Public sector universities have relatively good infrastructure and human resource and have been doing research on cotton but for practical purposes, their contribution is not crossing the bar of expectations. Recently private sector has started investing in cotton R&D and established laboratories.

Wheat is a staple food grain in Pakistan and is a priority crop. Since earlier cotton varieties were long duration (180-220 days), cotton farmers used to keep half of their farmland fellow for wheat in 50s. So, it was a research task to reduce duration of cotton crop to fit in wheat-cotton cropping pattern. Low ginning outturn (GOT), and short staple length of local varieties were other areas where researchers were working. Resultantly short duration cotton verities made it possible to plant wheat and cotton on same piece of land and helped to double the area under cotton in a decade. The GOT improved to more than 37% and fiber length to 28mm.

Beside variety development, scientists were working on crop agronomy to address the germination issue by introducing bed & furrow sowing technique, which helped to save over 40% of irrigation water and improved field germination rate (Fig. 1).

Figure-1. Flatbed v/s bed and furrow cotton planting saves 40% water and addresses low germination issues

Untill 80s, the research centers established under PCCC were working on basic research and testing the new varieties under different ecological zones. During this period PCCC and other institutes conducted number of classic studies like establishing economic threshold levels of different pests, pest scouting techniques (Fig. 2), de-linting techniques for machine sowing, spray techniques and off-season pest management especially for bollworms and whiteflies. Scientists have designed and developed number of planting machines with multiple functions like fertilizer dressing, pre-sowing herbicide application, seed sowing and bed making etc.

The import and sale of pesticides was in public sector during early years. Later, it was de-regularized with the promulgation of Agriculture Pesticide Ordinance 1971.

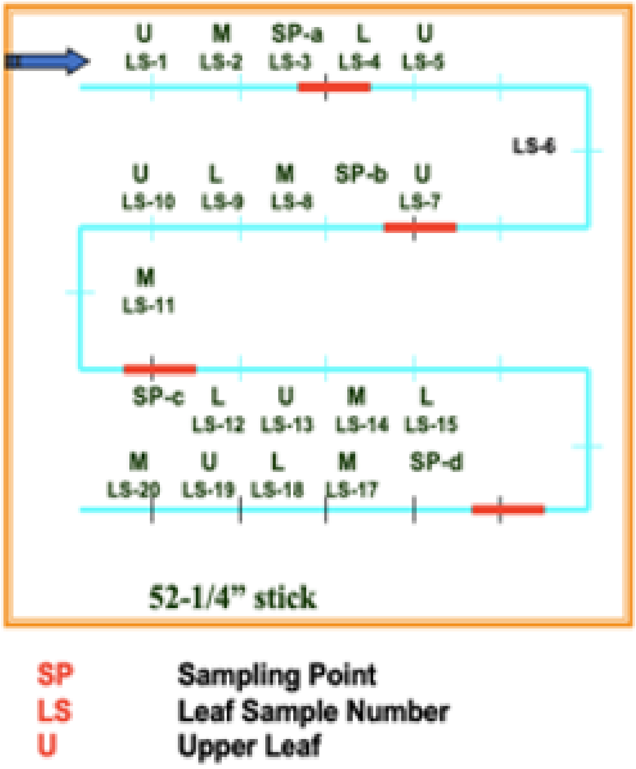


Figure-2. Pest scouting technique devised for square fields

Use of pesticide resulted in enhanced cotton productivity so was the cost of production. Later, in 80s generic scheme of pesticides was launched which attracted local pesticide business and helped lowering the cost of pesticides. Private sector did massive outreach activities and farmers' training on pest identification, pest scouting and spray techniques. With lowering cost of pesticides, its use increased dramatically and enhanced the cotton production but on the other hand resulted in development of resistance in cotton bollworm (*Helicoverpa* sp) and whitefly during 1988-1998 and caused annual decline in cotton production by 1.5 to 2.0 million bales of 170 kg each. Bollworms infestation was worst during 1988, 1990 and 1998. During this period, research focused on insecticide resistance management, studs on weak links in insect biology, management of alternate hosts and off-season management to reduce pest pressure, exploring biological control agents and pest monitoring using pheromones. Massive campaigns on integrated pest management helped farmers to build capacity in identification of different stages of eggs and larval instars, beneficial insects and use of pest scouting data for making management decisions.

Cotton leaf curl virus (CLCuV) disease also remained prevalent since early 90s (Fig.3). CLCuV first reported in 1967, started in sporadic form from 1988. The disease damaged 1.2 million acres in 1991-92, and production loss during 1990-2000 was estimated of about 7.1 million bales valuing Rs.70 billions. The disease was prevalent in Punjab only (Fig. 4) but later it spread to Sindh province as well. When first appeared, CLCuV infected all popular varieties and set an uphill task for researchers to revive cotton. Research institutions conducted extensive testing to look for the natural resistance. Disease incidence scale and levels of prevalence for field evaluation was standardized. Grafting techniques were used to test resistance and incubation period in different varieties. Field management of diseased-crop and nutrition requirements were evaluated. Cotton breeders were working with limited team of virologists in the country, screened entire germplasm available in the country on war-footings. However, scientists identified some advanced tolerant lines (CIM-448, CIM-1100) in 1996 to cover up the productivity loss. It was also discovered that different biotypes of whitefly (the vector) have varying capabilities of disease transmission. Alternate hosts with symptoms and non-symptoms were identified for field management.

In 2001, CLCuV mutated to a new strain of virus called "Burewala Strain of Cotton Virus (BSCV)", and hotspot of new strain was district Vehari: a cotton growing town 90 km south of Multan.

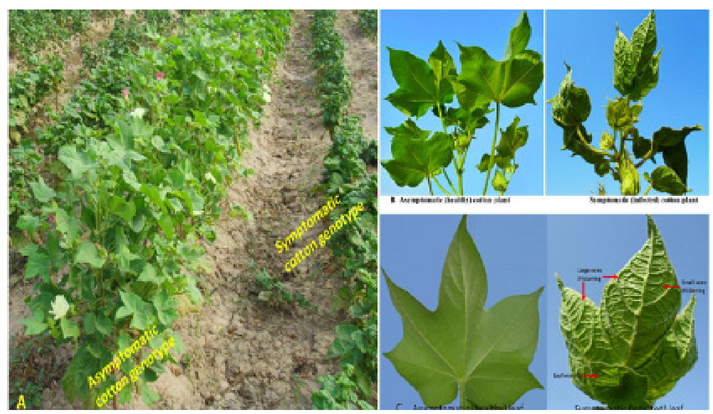


Figure-3. Symptoms of cotton leaf curl virus disease

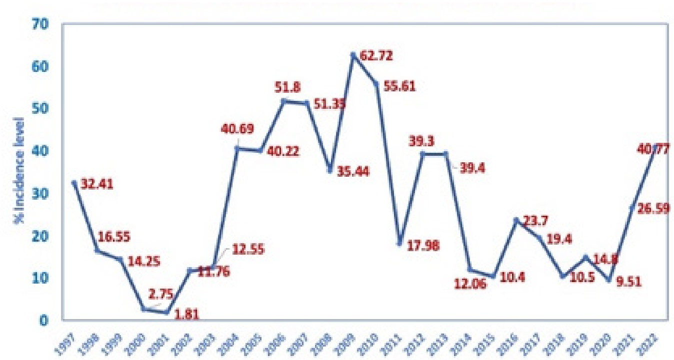


Figure-4. Incidence of CLCuD in Punjab (1997-2022)

Commercial varieties which had tolerance to CLCuV became susceptible to new virus strain. Parent genetic stock (LRA-5166, CP-15/2, Cedex) of varieties CIM 448 and CIM 1100 also showed BSCV symptoms at research institutes. More than 3000 germplasm was screened in Vehari (hotspot area). Desi cotton (G. arboreum) and wild species showed no symptoms of the disease. Cotton varieties i.e., CIM-608, Cyto-124, and Cyto-226 developed through interspecific hybridization of resistant blood [{2(*G. hirsutum* x *G. anomalum*) x 3 *G. hirsutum*} x {2 (*G. arboreum.* x *G. anomalum*) x 2 *G. hirsutum*}] x 2 *G. hirsutum* showed significant level of tollerence to disease. Breeding between different species of cotton is a tedious job, however scientists succeeded to transfer such tolerance into Upland cottons and evolved 10 cotton varieties relatively tolerant to BSCV with better yields. Simultaneously, other R&D facilities like NIBGE, NIAB and provincial agriculture departments were also conducting extensive studies on different aspects of virus and generated massive knowledge about it and gained collaborations from global scientists. Though a number of tolerant varieties have been developed, but CLCuV is still a number one threat for cotton productivity. Cotton growers, during this period also learnt "live with virus" with different management strategies which helped them get good yield out of the diseased fields.

Cotton mealybug, became a new major pest after the introduction of GMO cotton in 2005, probably due to change in pesticide spectrum. By 2007, the pest affected 40% of the cotton area in Punjab and production declined from 10.5 to 8.9 million bales. Wide range of host plants (about 154 plant species) and its rapid multiplication behavior resulted in infestation on larger area. Moving around of spray men or boom spray machines in infested fields triggers the spread of pest more than it controls. A voracious mealybug predator (*Cryptolaemus montrouzeiri*) imported from USA could not perform in field conditions however the conservation of an indigenous Aenasius sp through NEFR (Natural Enemy Field Reservoir) technology developed by CABI gave sustainable and effective control of this pest (Fig.5).

Figure-5. Natural Enemy Field Reservoir Technology (CABI)

Pink bollworm had been a serious pest of cotton in pre-GMO era and was managed by aggressive campaign through off-season management of cotton sticks, proper disposal of ginning waste and monitoring of emerging population in cotton fields by male disruptive techniques. The pest suppressed with the introduction of GMO cotton however, it re-appeared after five years of introduction of GMO cotton as Cry1Ac gene lost its resistance against this pest in 2015. Field infestation was rising since then and caused substantial loss to the cotton production (Fig.6), which was estimated to over a million bales every year and resulted in raising the cost of pest management. Different strategies were adopted for the control of this pest in different times. Pink bollworm was continued to control IPM wherein pesticides, sex pheromone-bands, light traps and off-season management of crop residues debris etc were the main components. IPM program was very effectively implemented for cotton bollworm and Pink bollworm, till 2010 when Bt cotton was introduced.

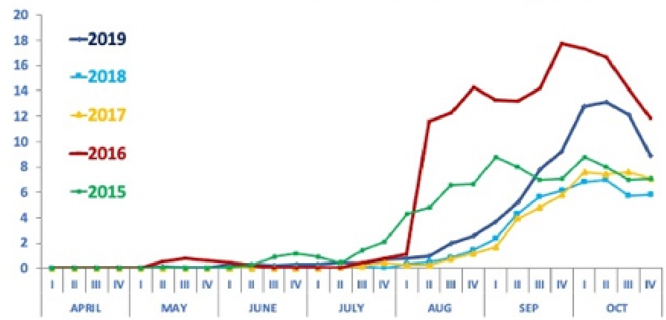


Figure-6. Infestation of Pink Bollworm (2015-2019)

Cotton growers have started planting cotton early in the season to escape vulnerable stage of crop from CLCuV and to get some bolls before July-August. Agriculture Department also showing leniency in enforcement of regulation about optimal sowing-time of cotton. Though the early-sown area remained less than 5% of the total but it provides a population build-up refuge for subsequent Pink bollworm generations. The suicidal emergence of Pink bollworm in March started surviving to infest the main crop i.e. August and September. During second surge of Pink bollworm when Bt gene lost its efficacy in 2015, different options like field management, monitoring, pheromone ropes etc were used. The Agriculture Department ran a campaign through involving all stakeholders and by imposing Section 144 for removal of residual bolls, upward stocking of cotton sticks and burning of ginning waste. NEFR technology used for mealybug was tested for the management of PBW in Sindh province and proved successful to build population of natural enemies like lacewing, Assassin bug, spiders, ladybird beetle, *Harpactorinae* sp. and *Acanthaspis* sp.

The Central Cotton Research Institute Multan of PCCC developed a machine, which removes all residual bolls from the cotton field after the last picking (Fig.7). From the collected bolls, the infested bolls can be used to culture in NEFR or buried in soil while more than 30% un-infested residual bolls yield seed cotton which gives income more than the running cost of machine. Cotton sticks from such fields can be stored for yearlong without fear of hibernating PBW larvae.

Figure-7.

Considering the ever-rising input cost and sustainability, PCCC has also started working on an idea named "Low Expenditure & Environment Friendly (LEEF)" planting technique (Fig.8).

It involves planting on permanent beds covered with organic mulch preferably with rice straw or maize stalks. The initial experiments showed significant reduction in soil temperature, lower water requirement, higher yields with reduced input and improvement in soil health.

It is believed that soil microbial activities and availability of soil nutrients will be enhanced in optimal soil temperature regime in LEEF fields.

Such production technology will also help to mitigate high temperatures and rains by improving soil health or its water holding capacity.

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Figure-8. Rice straw mulch in cotton field planted using LEEF technology

Management Practices for High Density Planting Systems: Physiological Basis

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Dr. Marcelo Paytas graduated as Agricultural Engineer at the National Northeast University, Corrientes, Argentina. He obtained a PhD at the University of Queensland, Australia in Cotton physiology and Agronomy. Dr Paytas is currently the Director of INTA (National Institute of Agricultural Research) Reconquista Santa Fe, Argentina. Researcher and project leader of the cotton team with focus on crop physiology and agronomy, biotechnology and genetic improvement. He is member of APPA (Association for the promotion of cotton production) which associates all representatives of the cotton chain of Santa Fe, Argentina. Coordinator of academic and technical agreements between INTA and other national and international organizations, mainly in South America. Member of SEEP (Social, Environmental and Economic Performance panel) of the International Cotton Advisory Committee. His main interest is to link and promote research and development together with the cotton industry through public and private interaction for sustainable production.

Historically, cotton production in Argentina was considered a driving force of the primary sector, the industrial sector and linked services. However, its production trend has varied markedly over the different decades. In the 1997/98 season, a historical production record was achieved, reaching a maximum area of 1.133.500 hectares nationwide, from which a period of accelerated decline in the planted area began, reaching 160.000 hectares in the 2002/03 season. There are several reasons that discouraged cotton production, including unfavourable prices, competition with soybean and adverse environmental conditions. However, in recent years the planting area has increased significantly. Through retrospective analysis, technological innovations can be mentioned: i) the development of "stripper" type harvesting machines with low acquisition and maintenance costs, and better prices than manual harvesting; ii) the development, research and extension associated with the expansion of a new planting system called "narrow rows and high densities" that managed to significantly stabilize production; iii) the successful organization of the public and private sector or "cluster" from the producer to the garment manufacturing.

The development of a technological cotton package (know how) was promoted under "narrow rows and high densities" system conferring to the mechanical harvesting. Efforts were concentrated on the optimal adjustment of the spatial configuration. Distances between rows of 52 cm and densities of 200.000 plants per hectare became the most implemented system by producers. The new production model led to increases about 45 kg.ha-1 of fibre yield per year from the 2005/06 season to the present in the Santa Fe province. Optimal planting dates that begin in October, end in November, and allow the critical stage of flowering to coincide with the best environmental offer. In this way, ensuring the increase observed in recent years as well as incorporating the concept of integrated fibre management. Other management practices were also important to be adjust such us plant growth regulators and defoliants products. Soil health studies that began with the implementation of soil analysis routinely by producers and research programs that adjust the doses and critical moments of the main nutrients. Service crops, rotations and cero tillage are components of the package. In the 2018/19 season, surveys indicated that 87% of the total area has been fertilized, being the highest recorded in the last 18 years (along with the 2007/08 season).

Studies related to physiological basis of the proposed planting systems and management practices for high density planting systems were essential. How do we achieve the implementation of innovations by the productive sector? The implementation of cotton development and competitiveness programs must consider a Training Programme so that the farmer and the technician get to know the innovations of the sector and implement them according to their particularities. Continuous communication and education through information and communication tools are essential. Over the last seasons, many farmers were trained through practical and conceptual summer courses and about 250 professionals attended our postgraduate training course organise between INTA and the National University of the Northeast.

The previous paragraph is not feasible without the organization of the sector. What are the steps that we begin to go through in Santa Fe? From the organizational point of view, it is essential to consolidate the association that brings together all the members of the cotton production chain. In the case of Santa Fe, it is called Association for Promotion of Cotton Production and it is almost two decades old. Within the framework of the association, sectoral policies are proposed that boost competitiveness through credits for production inputs, agricultural machinery, financing, and sanitary control.

It is possible to innovate in the field of research and development with key impacts on mechanization and agronomic management of cotton cultivation. The propose of high density plant system in Argentina is defined within an intensification model of production with a narrow window of sowing dates in favour to rotate with other important crops. Numerous challenges ahead include germplasm improvements, implementation of sustainability indicators and new institutional organizational actions.

Key highlights from papers presented in WCRC-7

4-7 October 2022. Cairo Egypt

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Dr. M.V.Venugopalan is a Ph D in Agronomy and is currently serving as a Principal Scientist (Agronomy) and Head, Priority Setting, Monitoring & Evaluation Cell at the ICAR-Central Institute for Cotton Research, Nagpur, India. He specializes in cotton crop simulation modelling, participatory and perspective land use planning, carbon sequestration and high density sustainable cotton planting systems. He is a fellow of the Indian Society of Agronomy, Indian Society for Soil Survey and Land Use Planning and Maharashtra Academy of Sciences and is an EC member of ICRA. He received the ICAR Team Award (2005-06) for research on C sequestration and was deputed to Malawi and Uganda as expert under Cotton-Technical Assistance Programme for Africa 2014.

COTTON GENETICS AND PLANT BREEDING

"**CPD Index for Earliness Evaluation and an Algorithm for Estimation of Missed Experiment in Cotton Research**" Dr. Hosseini proposed a new index Combined Picking and Day (CPD) to evaluate earliness. CPD captured the actual genetic effect, nullifying the influence of the environment.

"**Adaptation of Advanced High-Yielding Cotton Lines to Subtropical Conditions In Argentina**" Dr. Dileo P. Nahuel evaluated the stability and adaptability of advance lines developed by INTA and commercial varieties using the AMMI (Additive Main-effects and Multiplication Interaction) model and observed that significant GE interaction. The AMMI-PC1 could explain 84% of these interactions. SP1 and SP 41255 were the most stable and adaptive genotypes respectively.

"**Coping for Sustainable Cotton Production through Developing of Climate Resilient Cotton Varieties in Mutant's Background in Pakistan**"

Dr. Manzoor Hussain described the mutation breeding efforts to develop genotypes that could withstand heat stress. The variety NAIB 878, was the most heat tolerant one on the basis of multiple traits-anther dehiscence, cell injury, stomatal conductance, transpiration rate, net photosynthesis rate and water use efficiency.

"**Determination of Genetic Diversity for Yield and Fiber Quality Traits among Some Cotton Genotypes (*Gossypium barbadense*)**, Dr. Abdelmoghny presented the diversity among 30 genotypes using Genetic variation, PCA, cluster analysis and path analysis. Biplot graphs showed significant positive relationship between yield and fibre quality (length, strength and uniformity). Path analysis indicated that seed cotton yield/plant was strongly influenced by boll weight and lint yield/plant.

"**Development and characterization of *Gossypium hirsutum* × *Gossypium arboreum* hybrids and backcross derivatives for response to some biotic stresses**" – Dr. Dharminder Pathak emphasized that two genes, either singly or in combination conferred jassid tolerance. Further SSR markers NAU 922 (Chromosome A5) and BNL 1705 (Chromosome A4) were associated with jassid tolerance.

Genotype × Environment Interaction and Sensitivity to Planting Date of Seed Cotton Yield in Senegal- Dr. Traoré ABDOU, significant genotype, environment and GE interaction for various traits. The seed cotton yield realized varied from 1225 (CS 50) to 938 kg/ha (Alen 51-106). Further, high rainfall favoured good yield. He recommended cultivar IRMA Q302 for the Senegalese cotton basin due to its high and stable yield across environments.

"**Heterosis and Combining Ability for Phenological, Yield and Fiber Traits of Cotton (*Gossypium Hirsutum* L.) Genotypes**" Dr. Wajid A. Jatoi summarized the results of evaluation of 4 lines, 3 testers and their 12 hybrids in Sindh, Pakistan. The effects of genotypes, parents, crosses, parents vs crosses, lines and testers and tester x line were significant for earliness traits, yield traits, yield/plant, 1000 seed weight, GOT and staple length.

"**Physical and Chemical Mutagenic Treatments for Cotton Improvement**" Dr. Martin Winkler presented the effect of different mutagens at varied doses on the germination, growth, morphology and damages/abnormalities in seedlings in an elite variety Guazuncho 3 INTA. He concluded that Sodium azide @ 4 mM concentration was a relatively safe mutagen but its effect was pH dependent.

"**Studies on Selection Efficiency, Performance Stability and Plant Type in Newly Developed Genotypes of Cotton (*Gossypium hirsutum*"** Dr. Rajesh Patil assessed the selection efficiency of planned crosses executed to arrive at plant types suitable for high density planting system (HDPS) and robust plant types for high input situations. He developed a compact genotype, L9T4-8-1 with stable yield across environments for HDPS.

"**Evaluation of Ten Egyptian Cotton Varieties and Experimental Lines for Yield, Quality and Bacterial Blight Resistance** – Dr. Maria Abdalla informed that the lines 94-B-2, 94-B-19 and 96-9 were early, produced high yield with good fibre quality and possessed tolerance to bacterial blight and hence could be recommended for extra fine count cotton production in Sudan.

"***Gossypium* diploid species genetics: Inheritance and linkage of bracteoles**", Dr. D. V. Patil informed that *G. herbaceum* was dissimilar to *G. arboreum* for bracteole trait and this trait could be a phenotypic marker. It could be used at flower induction stage for maintaining the genetic purity of the parents.

"**The Inheritance of Agro-morphological and Fiber Quality Traits in Cotton (*Gossypium hirsutum* L.) Line × Tester Hybrids**" Dr Nafize Ozkan showed that in F1 crosses, the heterosis for plant height, monopodia, boll number and radiation use was positive whereas heterosis for days to boll opening and yellowness was negative.

"**Genetic basis of blending breeding methods/steps spanning across mating system barriers to bring quick genetic gains in Cotton**" Dr. S. S. Patil emphasized the need for systems approach in plant breeding. He presented with examples, the genetic basis for innovative modifications at all the three levels of varietal development viz. creation of variability, selection and stabilization of transgressive segregants.

"**QTLs mapping linked with cotton leaf curl disease (CLCuD) resistance in cotton (*Gossypium hirsutum* L.) using microsatellite markers**". Dr Peng Chee described the use of 1350 DNA markers on a segregating population (ACC-55xS-12) to identify markers (NAU5418 and JESPR158) in F2 and (JESPR158, NAU3377 and NAU5418) in F3 to be significantly associated with CLCuD.

"**A Private/Public Sector Partnership to address *Fusarium oxysporum* f. sp. *Vasinfectum* race 4 (FOV4)**", Dr. Don Jones, highlighted the outcome of a private-public partnership between Clemson University, O&A enterprises and Cotton Incorporated. The outcomes included-4 highly FOV4 resistant lines, 3 biparental RIL F8 populations, a unique phenotyping approach to predict spore density in the field and a protocol to study transcriptomics and metabolomics.

"**Development, Production and Commercialization of Transgenic Extra Long Staple (ELS) Public sector Cotton Hybrid DCH-32 BG-II Bt in India**" Dr. V. S. Sangam discussed the challenges for development, seed production and commercialization of public sector Bt hybrids. He concluded that the transgenic BGII version of DCH-32 was accomplished without compromising the yield and fibre quality.

BIOTECHNOLOGY AND MOLECULAR BIOLOGY

"**Molecular cloning and expression analysis of Chitin synthase A and B gene in *Helicoverpa armigera* of cotton**" Dr. Raghavendra K.P described the structural features of the Chitin synthase A and B protein coding sequence from the *H armigera* strains of cotton. He described the alternative splice variants for chitin synthase, expression pattern of the CHS variants and differential structural features of the HaCHSA and HaCHSB genes.

"**Spatio-Temporal Cry1Ac Protein Expression and Bioassay Studies of Stabilized Transgenic Cotton Events**" Dr. Manjula Maralappanavar, summarised the development of transgenic events using two Cry1Ac constructs, the molecular characterisation and selection of the transgenic events. She presented the comparative evaluation data on spatio-temporal Cry1Ac protein expression and bioassay studies of event 32 and 78 with BGI and BGII checks.

"**Cotton Biotech applied to cotton boll weevil control: Advances and Challenges**" Dr. Maria Fatima Grossi described the application of transgenic cotton research for boll weevil management in Brazil to provide basic insights on the approaches to produce stabilized dsRNA viz., expression of dsRNA in organelles, high stabilization of dsRNA through architecture modeling based on viroid genomes. Dr. Grossi presented the results of development and evaluation of transgenic cotton for management of cotton boll weevil through RNA interference of chitin synthase 2 and vitellogenin using stabilized dsRNA and over expression of entomotoxic proteins (Cry10Aa toxin).

"**Cloning and characterization of Green Tissue specific Promoter from upland cotton (*Gossypium hirsutum* L. cv. Suraj)**", Dr. G. Balasubramani, described the importance of tissue specific promoters in transgenic research. He highlighted the functional validation results depicting green tissue specific activity of promoter elements RUBISCO small subunit's (rbcs) gene through development of deletion constructs and transgenic events of tobacco, their histochemical analysis and quantification of gus activity were presented. The 643bp upstream sequence of the RUBISCO small subunit's (rbcs) gene recorded higher expression compared to other deletion variants of the promoter sequence tested.

"**Evaluation of molecular markers linked to drought tolerance in Cotton**" Dr. J. Amudha screened a recombinant Inbred Line (RIL) population (129 lines) derived from interspecific cross of *G hirsutum* (28 I) X *G barbadense* (Suvin) using molecular markers linked to the QTLs of osmotic potential and physiological parameters such as canopy temperature, chlorophyll content, relative water content and proline content.

"**Comparative RNAi Efficiency in Cotton Sap Feeders through dsRNA Mediated Gene Knockdown**" Dr. Satnam Singh, described the results of RNA interference (RNAi) knockdown of target genes in sucking pests such as jassid, whitefly, thrips and mealybug. The dsRNA mediated knockdown of target genes varied from 56.2 to 77.1 % (SNF7, IAP, AQP1 and vATPase genes), 93 % (SNF gene) and 36-67% (CAL gene) in jassid, whitefly and mealybug respectively.

"**Identification and Characterization of a Zinc Finger Protein (Ghzfp) Gene Involved In Fungal Disease Resistance In *Gossypium hirsutum***" Dr. Upender Mahesh highlighted the role of a member of the Zinc Finger Protein (Ghzfp) gene family involved In Fungal Disease Resistance In *Gossypium hirsutum*.

CROP PROTECTION-ENTOMOLOGY, PLANT PATHOLOGY AND NEMATOLOGY

"**Development and Validation of an Adaptable IPM Module for Pink Bollworm (PBW**) in BG-II Bt Transgenic Cotton" Dr. Sashikant Udikeri presented the details of an IPM module comprising of Profenofos (ovi-larvicidal insecticide), *Trichogramma bactrae* (egg parasitoid) and mass trapping (pheromone traps) for the management of Pink Bollworm (PBW).

"**Emerging Issues in Cotton Insect Pests Management in India and Way Forward**" Dr. G. M. V. Prasada Rao elaborated the insect pest situation during the post-Bt era (2002 onwards). He highlighted the emergence of the American bollworm in Central and South India, whitefly in North India and the resistance development in PBW to Cry1Ac and Cry2Ab.

"**Management of Pink Bollworm (PBW) Using Behavior Modifying Chemicals in Bt Cotton**", Dr. S. B. Patil described the evaluation of SPLAT (Specialized Pheromone & Lure Application Technology) for the management of PBW. He concluded that there was a reduction in PBW incidence in the trials with SPLAT that in turn led to yield improvement.

"**Molecular Characterization of Local Strains of the Causal Agent of Cotton Bacterial Blight in Argentina**" Dr. Lorenzini Gabriel informed that bacterial blight caused up to 35% losses in yield in Argentina. The authors collected 36 isolates of *Xanthomonas* sp from North Argentina and their molecular characterization indicated that 2 isolated belonged to *Xanthomonas citri* subsp malvacearum. Further, phylogenetic analysis showed that these isolates group within the races 1,2,3,12 and 18. Dr Gabriel presented the use of molecular markers in resistance breeding.

"**Radiation Biology of a Cotton Pink Bollworm *Pectinophora Gossypiella* (Saunders) and Potential of Irradiation Mediated Inherited (F1) Sterility Technique for the Pest Suppression**", Dr. S. G. Hanchinal highlighted the reproductive behaviour of PBW moths treated with gamma radiation. He recommended 150 Gy as the optimum dose administered to P1 males and this dose induced 60% sterility in the parent generation and 82-85% sterility in F1 generation.

“**Within Plant Distribution, Dynamics and Ecocompatible Management of Thrips (Thripidae: Thysanoptera), an Emerging Pest of Cotton in India**” Dr. Rishi Kumar concluded that the population of thrips was more abundant on the leaves than other plant parts and the upper strata of the plant harbours more thrips than the lower strata. In north India their peak population occurred between 29 and 31 Standard Met Weeks. Among botanicals, castor oil @ 7ml/l could effectively manage thrips.

“**Using sulfur as a disinfecting agent for cottonseeds**” Dr Ghorban Ali Roshani recommended sulphur as an inexpensive and safe fungicide for seed treatment. Sulfur could control storage pests and sulphur treated cotton seeds could be washed and safely fed to livestock.

“**Interactive effects of abiotic factors on abundance of sucking pests on Bt cotton**” Dr. Poornima Matti examined the role of weather parameters in regulating the dynamics and abundance of sucking pests (aphids, jassids and thrips). She concluded that improved understanding of the role of maximum and minimum temperature on the sucking pest complex would aid in developing forewarning systems for their management.

“**Chemo-profiling of secondary metabolites from *Pochonia chlamydosporia* and identification of novel nematicidal biomolecule for the management of Reniform nematode, *Rotylenchulus reniformis***” Dr. Gulzar Banu informed that the fungus, *Pochonia chlamydosporia* was a potential bio-nematicide. Chemo-profiling the ethyl acetate fraction of *P. chlamydosporia* yielded 38 fractions. Molecular docking of the virulent protein target of Reniform nematode and metabolites revealed lavendustin-C as a metabolite with nematicidal activity.

"**Essential oils of *Ocimum gratissimum, Lippia multiflora, Cymbopogon citratus* and *Cymbopogon nardus* effective for the development of bio-insecticides in the context of organic cotton production**". Dr Christopher Kobenan tested bio-insecticides and concluded that nine essential oils extracted from aromatic plants, *Ocimum gratissimum, Lippia multiflora, Cymbopagon citrus* and *Cymbopagon mordus* were most effective against carpophagus pests (*H. armigera, P. gossypiella* and *T. leutotreta*) of cotton.

"**Controlled Release Emission Mating Interruption Technique (CREMIT)**: A novel and viable approach for area wide management of pink bollworm, *Pectinophora gossypiella* (Saunders) in Bt cotton ecosystem" Dr. A G Sreenivas described the CREMIT mating disruption technology for the management of PBW. CREMIT-PBW formulation applied @ 1250 g/ha, 750 g/ha and 500 g/ha effectively controlled PBW and provided seed cotton yield of 4.33 t/ha, 4.25 t/ha and 4.05 t/ha respectively as against 2.47 t/ha with conventional practice.

35. "**Pink bollworm, *Pectinophora gossypiella* (Saunders) resistance and management strategies to transgenic cotton in India**" Dr. Chinnababu V Naik highlighted the spatial spread and temporal increase in the resistance level against Cry1Ac and Cry2Ab in PBW. He suggested an IPM module and a resistance management module for controlling PBW.

"**Management strategy against pink bollworm, *Pectinophora gossypiella* (Saunders) in Bt cotton – What next?**" Dr. Y. G. Prasad gave an overview of the PBW situation in India and informed that the yield loss estimated due to PBW was 20-30%. He elaborated various initiatives launched by the government and private sector for its management. These include pest monitoring, crop window/ ETL based management interventions, mass trapping and mating disruption for area wide management of PBW.

"**Is Cotton Leaf Curl Virus Vectored by *Bemisia tabaci* sex-biased?**" Dr. Satnam Singh reported that the transmission of CLCuV by Asia II-I B race of B. tabaci was sex biased and females were more efficient in its transmission. He postulated that the higher density of endo-symbiont of *Aeronophonas* in females and higher expression of *Aeronophonas* produced CroEL protein genes in females may be responsible for the sex biased transmission.

"**Changing Pattern of Cotton Whitefly Infestation Vis-à-Vis Climate Change in India**" Dr. M. Sabesh provided evidence to hypothesize that there has been an advancement of the peak incidence of whitefly in North India due to climate change. He also emphasized the role of maximum and minimum temperatures in influencing whitefly infestation and outbreaks.

“**Seasonal population dynamics of whitefly, *Bemisia tabaci* (Gennadius) and abundance of their natural enemies in Bt transgenic and non-transgenic cotton**” Dr. Kedar identified 25 natural enemies of whitefly including 23 predators, 1 parasitoid, and 1 entomopathogenic fungi in the cotton ecosystem. The parasitoid (*Encarcia lutea*) and Coccinelid predators were the most abundant.

“**Genetics and Pattern of Inheritance of Cotton Leaf Curl Disease Resistance Genes in Upland Cotton (*Gossypium hirsutum* L.)**", Dr. Ghulam Sarwar described the major possible reasons for breakdown in resistance among cotton varieties to the cotton leaf curl virus CLCuV. He concluded that a single dominant gene/gene cluster of tightly linked resistance genes control CLCuV resistance but their expression is modified by suppressors.

"**Geographical distribution of the main cotton pests in six West African countries during the period 2019-2021**" Dr. Malanno Kouakou studied the geographical distribution of cotton pests in West Africa and concluded that the main pests in Benin were *Helicoverpa armigera*, *Earias* spp, *Diparopsis watersi, Spodoptera littoralis* and *Plyphagotarsonemus latus*. In Mali and Senegal the main pests were *Jacobiella fascialis, Bemisia tabaci, Anomis flava, Dysdercus spp* and *Haritalodes derogata*. In Cote d'Ivoire and Togo the dominant pests were *Thaumatotibia leucotreta, Pectinophora gossypiella* and *Aphis gossypii.*

"**The Development of Bollworm Resistance and Its Influence on Variety Performance and Profitability**" Dr. Guy Collins observed that there was no conclusive evidence from trials to prove that 3-gene Bt-varieties provided sufficient yield advantage and economic returns compared to the yield obtained with 2-gene Bt-varieties plus the cost of spraying diamides for the control of bollworms.

"**Investigating the natural mortality of *Aphis gossypii* (Hemiptera: Aphididae) on cotton crops in tropical regions using ecological life tables**". Dr. António Chamuene conducted life table analysis and found that biotic and abiotic factors caused 94.3% mortality in aphid populations, amongst which rainfall and predation were the key mortality factors. Further, conservation of natural enemies hold the key for regulating aphid population.

"**Effects of Ecological Approach on the Management of Cotton aphid, *Aphis gossypii* (Glov) in Selected Cotton Genotypes, Gezira State, Sudan**", Dr. A. M. A. Rudwan recommended an ecological approach to manage aphids. He observed a density dependent pattern between natural enemies and population of aphids. Tolerant varieties (Senil and Brazili) and late planting were recommended to manage aphids.

"**Effects of some Cultural Practices on the Management of the African Bollworm, *Helicoverpa armigera* Hun, Gezira State, Sudan**" Dr. Elmubarak highlighted the interaction between cultivar, sowing date, spacing and pest damage and suggested cost effective, environmentally benign strategy to manage African Bollworm. For reducing the incidence and damage due to African bollworm he suggested sowing of Senil cultivar during 3rd week of June.

"**Effects of Ecological Approach on the Management of Cotton Mealybug, *Phenacoccus solenopsis* (Tinsley), in Selected Cotton Genotypes, Gezira State, Sudan**", Dr. A. E. M. Hassan observed that the introduction of Genetically Modified (GM) cotton to control bollworms, resulted in the reduction of insecticide usage that led to an increase in the abundance of natural enemies which in turn controlled cotton mealybugs without insecticidal intervention.

“**Pathogenic Variability of *Rhizoctonia Solani* Isolates Associated With Cotton Seedlings in Bangladesh**” Dr Sima Kundu and Dr Kamrul Islam depicted the genetic divergence of *Rhizoctonia solani* associated with the damping-off in cotton seedlings. They classified the 50 isolates of *R solani* based on pathogenicity using mutivariate analysis into 5 clusters and concluded that the isolates from the hill regions were more pathogenic than those isolated from the plains.

CROP PRODUCTION-AGRONOMY, PHYSIOLOGY AND SOIL SCIENCE

"**Cotton Yield Under Different Nitrogen Rates and Sources Following Soybean Harvest In The Brazilian Cerrado**", Dr. Thais Crazor concluded that cotton grown after soybean on Typic Haplaustox of Mato-Grosso responded to higher N rates (144 and 192 Kg N/ha). For higher yield and better Nitrogen use efficiency he recommended Yara Bela Calcium ammonium nitrate @ 144 kg N/ha.

"**Effect Of Nitrogen Rate On Cotton Crop Growth, Yield And Fibre Quality**" Dr Kamrul Islam highlighted that the optimum nutrient index for CB-15 cotton variety was different at different locations. The optimum N dose for Sreepur (Gazipur), Jahangirpur (Jashore)and Sardarpur (Dinapur) were 160 kg, 200 kg and 160 kg N/ha. N doses positively improved fibre strength.

“**Effect Of Timing Of Last Irrigation On Growth, Yield And Water Productivity In Cotton Under Gezira Conditions**" Dr Bashir Ahmed conducted experiments for two years and found that excess irrigation did not contribute to yield, fibre quality or water productivity. Further, the last irrigation must be applied at 21 weeks after planting.

"**Enhancing Nitrogen Use Efficiency in Bt-cotton**". Dr. S. S. Hallikeri examined the interaction between yield, soil fertility and economics. Based on the results, he suggested a fertiliser schedule comprising of 75% recommended dose of N applied in 4 splits (sowing, squaring, flowering, boll development), 3 foliar sprays of 1% Urea and incorporation of intercropped sunhemp at 35-40 days after sowing.

"**Seedling Age Effect on Yield and Lint Quality of Cotton**" Dr. Akhteruzzaman reported the results of transplantation trials conducted at Sreepur (Gazipur). He recommended that to obtain better benefits, farmers can raise cotton seedlings on seed bed and transplant them at the age of 25 days.

"**Soil Fertility In Cotton-Based Cropping Systems In Côte d'Ivoire**" Dr. Emannuel Goran highlighted the soil fertility status of farms belonging to 4 major companies. Majority of the 150 soils were sandy, slightly acidic to neutral in pH, very low in organic matter, total N, P, K, Ca and CEC. The soils of SECO and CIDT companies were similar in characteristics and these were different from those of Ivoire coton and COIC companies.

"**Effect of sowing time and foliar application of potassium on seed cotton yield and fibre quality of ELS cotton**" Dr. Sankaranarayanan highlighted the production technology for extra-long staple (ELS) cotton hybrid (MRC 7918 BG II). For high yield, enhanced fibre quality and economic returns in Coimbatore, south India, he suggested planting on 4th August and foliar application of KNO3 at 75, 100 and 125 days stage.

"**Ginning traits, fiber and seed quality of cotton as influenced by foliar application of nitrogen, potassium and boron**" Dr. Tasdiqur Rahman found that foliar application of N:K:B @ 7.5:50:1 g/l significantly improved yield, fibre quality and seed quality on silty clay soils of Sreepur (Gazipur).

"**Effect of cotton residue incorporation with conservation tillage and integrated nutrient management on yield attributes and yield of Bt cotton (*Gossypium hirsutum* L.)**" Dr. W. N. Narkhede pointed out that on rainfed Vertisols, the bulk density and infiltration rates were higher in conventional tillage but organic Carbon improved under zero tillage. He recommended conventional tillage + 100% Recommended dose of fertilizers (RDF) + Cotton residue at@ 3t/ha + 12 kg dry mycorrhiza/ha to enhance yields.

"**Source-Sink Manipulation to Induce Reproductive Synchrony and Enhance Productivity in Cotton by Plant Growth Regulators**" Dr. A. H. Prakash suggested that deliberate shedding of initial squares would manipulate source- sink relations favourably, to shorten the fruiting window, induce compactness, increase yield, monetary returns and input use efficiency. To achieve this he suggested foliar spray of Ethrel @ 8.5µ moles at square initiation followed by a spray of Maleic Hydrazide @ 500ppm at 80 days stage.

"**Influence of Micronutrients on Morpho-Physiological and Biophysical parameters for enhancing the Productivity in Bt Cotton through Foliar Application**" Dr. K. N. Pawar highlighted the importance of secondary and micronutrients in cotton nutrition. He concluded that foliar application $MgSO_4$ (%) + $ZnSO_4$(0.5%) at 70 and 90 days stage improved physiological parameters (Photosynthesis rate, transpiration rate and relative water content), biochemical constituents (chlorophyll and protein) and increased seed cotton yield.

"**Influence of harvest splitting on the technological characteristics of cotton fiber and seed**", Dr. Kouakou Julien suggested split harvesting of cotton when 50% of the bolls are open in order to preserve the quality of cotton fibres and cotton seed.

"**Spectral characterization and mitigation of leaf reddening in Bt cotton genotypes though proximal sensor based nitrogen management**", Dr. Milind Potdar highlighted proximal sensor based Nitrogen management to manage leaf reddening and improve yield. He suggested Nitrogen supplementation at 1.1 – 1.5 RI (Response ratio- ratio of NDVI in a N-rich strip and the test plot) and 81 – 90 % SI (sufficiency index -ratio of SPAD) for best results.

"**Energy Use Efficiency for Cotton Production in the Mechanized Rainfed Areas Eastern Sudan**" Dr. Lotfie Yousif analysed the energy input-output and energy use patterns for cotton production in mechanized rainfed eastern Sudan. The total energy input for cotton production was 2234.62 MJ ha-1. Total energy output was 7802.10 MJ ha-1. Average net energy, energy productivity, and specific energy was 5567.48 MJ ha-1, 0.3 kg MJ-1 and

3.38 MJ kg -1, respectively. Herbicide energy input was the highest among energy input items.

"**Ecosystem level CO2 exchanges from a rainfed cotton production system using eddy covariance technique**" Dr. M. V. Venugopalan concluded that rainfed cotton in Central India was a net sink for atmospheric CO2. Around 2.14 tonnes of Carbon ha-1 was sequestered during 2021-22 season. The temporal and phenophasic C fluxes were influenced by phenological stage and the prevailing weather. Throughout the season (180 days), the cumulative GPP was 803.4 gC m-2, NEE was -213.8 gC m-2 and Ecosystem Respiration (Reco) was 589.7 gC m-2.

"**Improving Resource Use Efficiency and Soil Health by Integrating Rice Crop in Cotton**", Dr. Fiyaz Ahmad concluded that planting of cotton in rows 75 cm apart with 30 cm between plants in a row and intercropped with transplanted rice (in 3 lines spaced 15 cm apart with plant-to-plant distance of 10 cm) was more resource efficient and economical for farmers over other inter cropping configurations.

"**Soil Fertility Management in Cotton Growing Areas of PR-Pica Countries: Assessment and Prospects**" Dr Traore Amadow informed that the soils of cotton basins in PR-PICA countries were acidic and low in organic Carbon. He recommended a low acidifying Ca containing fertilizer formulation (14-18-18 + 6S + 1B + 2,5 CaO) along with localized application of 2t/ha of organic manure for improving cotton yields. Granulated rock phosphate and dolomite application also improved yields.

"**Recycling textile waste to develop Cellulosic Superabsorbent Polymer (C-SAP) and analyzing its impact in cotton cultivation**", Dr. S. S. Patil highlighted a product- Cellulosic sulphur absorbent polymer (C-SAP) obtained from recycled polyester cotton blends, that could absorb and retain soil moisture 20 times its own mass. This product had enormous potential to improve soil moisture status and enhance dryland cotton yield.

"**Remotely detecting cotton nitrogen (N) status in mid-south region of USA**" Dr. Tyson Raper pointed out that both active and passive narrow wavelength sensors were capable of detecting N stress. However early detection of N stress would be the key for N management.

"**Nitrogen and plant population effects on cotton yield and fiber quality**" Dr. Fábio Rafael Echer (Brazil) indicated that best yields occurred under low plant population (6.6 plants m-2) combined with 120 kg ha-1 of N or with high plant population (9.9 plants m-2) and low N rate. Increasing N rates results increased short fibers and decreased micronaire. The right combination of N rate and plant population can increase earliness through increased setting of bolls in lower fruiting nodes.

"**Effects of calcium sources and rates on cotton yield**" Dr. Fábio Rafael Echer described the importance of making calcium available and in the appropriate rate to cotton in order to avoid yield penalty. Ca availability in soil solution and uptake by cotton plants depends on the type of sources and their solubility. Both calcium sulfate and calcium nitrate applied at the rate of 30 kg ha-1 increased seed cotton yield.

"C**otton yield as affected by cover crops and potassium and nitrogen fertilization**" Dr. Fábio Rafael Echer showed that cotton yield was affected by cover crops and potassium and nitrogen fertilization. Highest yields were achieved when K@140 kg ha-1 K2O was applied at pre-planting in ruzigrass or post-planting after termination of ruzigrass + *Azospirillum* + Mucuna at 80 kg ha-1 of N

"**High cover crops diversity and controlled-released urea increase soil nitrogen and cotton fiber yield under moderate nitrogen rate**" Dr. Fábio Rafael Echer indicated that highest fiber yield was achieved in the mix of cover crops with 100 kg ha-1 of N (1400kg ha-1), and yield decreased in the highest N rate applied. Controlled-release urea (40% N + 8% S) can reduce the N applied rate by 30% under cropping systems of high cover crop diversity (MIX) as an effect of the increase in soil N availability.

SOCIAL SCIENCES-ECONOMICS AND EXTENSION

"**Cotton Farming Typology as a Guide for actions In Cote d'Ivoire and Beyond**" Dr Kone Siaka drew a typology of cotton farms in Cote d'Ivoire using a single criterion of cattle possession in relation with the tradition of hoarding. This typology could differentiate four types of farms according to their technical and financial performance in cotton production, the characteristics of farmers, that of their families as well and as their well-being through the possession of some durable goods.

"**Sustainable Cotton Production in Argentina: Addressing The Innovations and Challenges**" Dr. Marcelo Paytas highlighted various innovations (mechanisation agronomy) in sustainable rainfed cotton production. He stated that the challenges ahead include germplasm improvement, implementation of sustainability indicators and new institutional organizational actions.

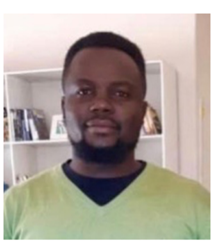
"**Issues and challenges in the Cotton Supply Chain and Way forward: An Indian Perspective**", Dr. Subhashree Sahu discussed various technical, social and economic challenges experienced by the cotton supply chain and suggested remedies to overcome them.

"**Cotton Small-holders' Innovation in Agribusiness Organization and Management to Increase Productivity, Case of Taiyiba in Sudan Gezira Scheme**" Dr. Nageeb Bakheit narrated the difficulties of cotton growers following the withdrawal of government support in Taiyiba Block Sudan, the main centre of irrigated ELS cotton. Later, innovative agribusiness solutions, including integrated farming systems, by small farmers groups led to increase in cotton yields and profitability.

"**Integrated Extension Management Module for Bridging up the Yield and Knowledge Gaps among Indian Cotton Growers**" Dr. Usha Rani discussed the yield gap through the analysis of data from frontline demonstrations. She concluded that knowledge gap was the main reason for yield gap and presented an "integrated extension management module" for bridging the yield gap.

"**Status and Implications of Seed Purity Seven Years After Bt Cotton Use In Burkina Faso**" Dr Larbouga Bourgou analysed the purity of seeds in producers' fields. He concluded that two factors viz contamination of Bt genes in conventional varietal seeds due to failure of seed production schemes and lack of purity in the original Bt seeds were the mainly responsible for the present situation of low yields.

"**Women's Wealth Status and Factors on Cotton Farms In West Africa**" Dr. Aboudou Faridath analysed the condition of women in cotton farms vis-a-vis their husbands who owned the farm in Burkina Faso, Benin and Togo. She concluded that the economic situation of women was generally weak but it was better in Benin, particularly in terms of animal assets. Further, men-women synergy in wealth accumulation was a visible sign of positive evolution.



"**Climate Smart Initiatives for Doubling Seed-Cotton Yields of Smallholder Cotton Farmers in Zambia**" Mr Martin Simasiku discussed the initiatives introduced by ICAC, ITC and EU focussing on - (i) Seed health, (ii) High density planting (iii) Integrated Pest Management and (iv) Soil health. He concluded that over 60% of the demo plots obtained more than 1500kg/ha where as more than 70% of control farmers' obtained less than 500kg/ha. Number of effective sprays was reduced by half in the demo plots as compared to control.

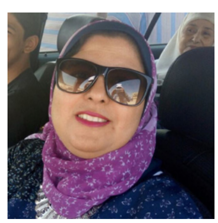
"**Are farmers in Cote d'Ivoire technically conservative in growing cotton?**" Dr. Tehia K. E. used an experiential action on transplanting to improve plant stand to verify whether farmers were technically conservative in adopting new techniques. He concluded that farmers were not technically conservative but were suffering from a lack of information due to inadequate technical assistance.

"**Using Technology and Training to help farmers grow clean cotton while reducing cost of inputs**". Dr Saqib Sohail elaborated the role of 'Artistic Milliner Cotton Initiative' in imparting traceability in the cotton supply chain. He concluded that by ensuring clean cotton practices in the field and arranging continuous trainings, it was possible to retain best agricultural practices.

POST HARVEST PROCESSING AND BY-PRODUCT UTILIZATION

"**Status of Current Cotton Fibre Quality Parameters in South Africa**" Dr Mathilda Westhuizen presented the fibre quality parameters of 4 commercial cultivars- DP1240 B2RF, DP1541 B2RF, Candia BGRF and PM 3225B2RF across 6 locations. She concluded that environment strongly influenced both yield and quality, DP1240 B2RF possessed the highest fibre strength and the quality of all the varieties was within the acceptable limits.

"**Fire Retardancy of Cellulosic Materials by using Waste Plant Bio-macromolecules**" Dr. Santhanu Basak introduced the idea of using bio-products (Banana pseudo stem and pomegranate rind extract) for imparting fire retardancy in cellulosic textiles. He also discussed the mechanism behind the thermal stability of the treated materials.



"**Fiber and yarn quality parameters of Some Giza Egyptian Cotton Varieties**" Dr Suzan Sanad described the fibre and yarn quality of new Egyptian cotton varieties-Giza 94, Giza 95 and Giza 96. She highlighted that Giza 96 could be spun at 100-120s counts.

"**Plastic Imaging, Detection, and Ejection System (PIDES) for Cotton Gins: Results from Commercial Testing and System Updates**" Dr. Greg Holt elaborated the PIDES system which when installed before the ginning process could remove plastic contamination to the extent of 80-97% depending on the size and colour of the contaminant.

"**Valuable and Exploitable Bioactivities Of Gossypol: A Multifunctional Compound From Cotton**" Dr. Manoj

Kumar described the various bioactivities of gossypol that can be exploited in the field of pharmaceuticals, medicine (anti-cancerous, anti-oxidant, anti-fertility, anti-parasitic anti-microbial and anti-viral) and health sector.

"**Dyeing performance of super-Giza 97 Egyptian cotton yarns**", Dr. Shereen Bahlool stressed that using natural dyes extracted from onion skin was economical and has positive environmental impact since an agricultural waste was being used for dyeing.

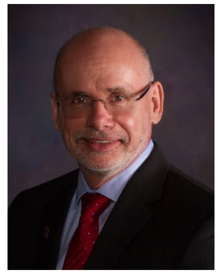
"**Development of Reference Materials for Checking the Micro-Ginning Machines for their Fiber Quality Preservation Performance**" Dr. Bruno Bacheller emphasized the need to develop standard seed cotton reference material with known fibre traits for performing periodical checks of micro-gins. Further, the reference material that the authors developed was found to be suitable for micro-gins employed to measure fibre quality.

"**Evaluation of Reactive Groups of Reactive Dyes on Dyeing of Egyptian cotton Fabrics**". Dr. Haana Saad tested reactive groups of reactive dyes and found that Procion Mx dye had the reactive group structure Di-chlorotriazine that offers higher reactivity at optimum conditions of 30°C at 60 mins. The highest dye fixation (%) was about 85% for all reactive dyes used. The fastness properties of cotton fabric for all reactive dyes used were good to excellent at the optimum dyeing process.

"**Effect of blending between upland and combing waste on cotton fiber and yarn quality**" Dr. Eman EL-Sayed concluded that the physical and mechanical properties of yarns produced from Giza95 were better than 100% upland cotton, 100% combed cotton waste and the other blended yarns.

"**Rotobar (Rotary Knife Roller Gin), A Boon to Long & Extra-long Staple Cotton**". Dr. Pravin Bhakte found that Rotobar Ginning (Rotary Knife Roller Gin) was the best ginning technology for long and extra-long cotton. USA, China and Egypt have understood the benefits of this technology and new ultra-modern ginning plants based on Rotobar Ginning technology have been established.

"**Isolation of gossypol degrading bacteria from *Spodoptera litura* and optimization of culture conditions for solid state fermentation of cottonseed meal**". Dr. S. M. D. Akbar reported that bacteria from isolated from the gut of Spodoptera litura, identified as *Lysinibacillus fusiformis* (L13) and *Bacillus xiamenensis* (L19) by 16S rRNA sequencing and phylogenetic analysis, were able to utilize gossypol as sole carbon source and thus can be used for biodegradation gossypol in cotton seed.



"**Developing HVI calibration standards for elongation measurements**". Dr Eric Hequet stressed on the importance of developing genetic stocks with improved tensile properties. He presented a protocol to produce HVI elongation calibration standards that showed stable elongation measurements for all HVIs tested.

"**Odour control in cotton fabrics treated with silver nanoparticle in aqueous extract from banana peel**", Dr. Salah Saleh presented an innovation-biosynthesis of nano particles in combination with natural plant extracts from banana peel. This composite had microbial resistance and could be treated on cotton textiles for odour control.

"**Cotton, more than what you wear: cottonseed oil and human health**", Dr. Susan Jaconis reiterated the culinary benefits of cotton seed oil. She also summarized the research being undertaken by Cotton Incorporated in collaboration with health experts to build robust evidence on the health benefits of cotton seed oil.

The ICAC Recorder

WINNER OF THE
ICAC RESEARCHER OF THE YEAR AWARD 2022

Dr Jodi Scheffler

Lead Scientist, Cotton Genetics Research Group. USDA Crop Genetics Research Unit, Stoneville, Mississippi USA
Adjunct Professor at Mississippi State University.

Dr Jodi Scheffler is Lead Scientist of the cotton genetics research group at the USDA Crop Genetics Research Unit, Stoneville, Mississippi USA and adjunct Professor at Mississippi State University. She worked for 12 years in the United Kingdom and Germany, before joining USDA in 2000. At USDA, she has been instrumental in identifying, developing and making available molecular markers for use by the cotton community. Her research focuses on increasing cottonseed use and incorporating traits that will improve host plant resistance (HPR). Internationally, she has worked with a number of research partners developing ultra-early cotton with verticillium wilt resistance and producing cotton leaf curl disease resistant cotton along with diagnostic tests and best management practices to mitigate effects of the disease. More recently, cotton leaf roll dwarf virus (CLRDV) has emerged as a threat to U.S. growers. Using germplasm from many geographic sources, she identified resistant germplasm and developed putative DNA markers to facilitate transferring resistance into elite breeding lines. She has always sought to build teams and seek out collaborators globally who had complimentary expertise so together their research could

Throughout her career she has advised students and mentored the next generation of scientists. She believes in starting early with STEM outreach activities in the schools and job training for high school and undergraduate student interns. Of the 44 students that have worked in her group, 39 have obtained a B.S degree or higher. Dr. Scheffler is active in a number of professional organizations including ICAC and the International Cotton Researchers Association (ICRA). Dr. Scheffler was the recipient of the 2014 National Cotton Genetics Research Award, co-recipient of the 2016 Federal Laboratory Consortium's Regional STEM Education Award and the 2016 Secretary of Agriculture's Abraham Lincoln Award.