The ICAC Recorder

Cotton Vision 2030

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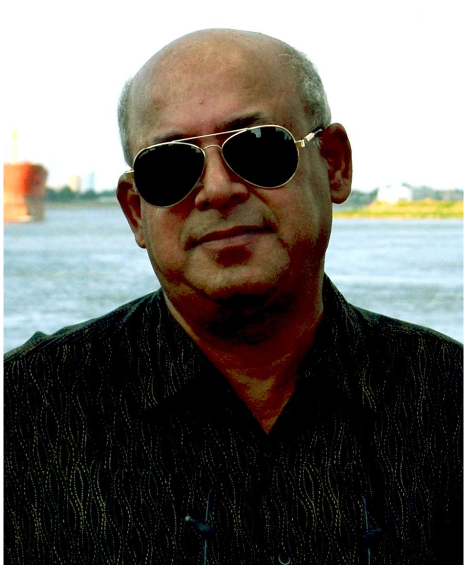
ICAC Researcher of the Year 2011



Dr. Sukumar Saha has thirty-five years of professional experience. He worked as an agricultural extension worker for eight years in India before immigrating to the USA. After working as a Research Assistant Professor for five years at Alabama A&M University, Dr. Saha assumed the present position with USDA/ARS in 1997. He demonstrated outstanding stature and received significant recognition as an international authority in cotton genomics and cytogenetic resources that are being used by the scientists in the USA and around the world. In recognition of his contributions to cotton, he was awarded "2010 Outstanding Research Award in Cotton Genetics" at the Beltwide Cotton Conferences organized by the National Cotton Council of America every year. Over 5,000 researchers/farmers attend these conferences. Dr. Saha made a major contribution in developing PCR-based SSR markers (JSPER and MGHES), a critical first step for the use of PCR-based marker technologies in cotton breeding programs. MGHES markers were first publicly available EST-SSR markers for use as a tool for marker assisted selection program and molecular mapping in cotton. He also made a significant contribution in the discovery of molecular markers associated with important traits in cotton. Dr. Saha is one of the two lead scientists providing leadership in the release of 17 interspecific chromosome substitution lines in cotton. This research will provide a tool to overcome the problems of interspecific introgression and in the discovery of some novel genes or traits whose effects could not be detected in the donor Pima 3-79 line. Dr. Saha helped to establish one of the most advanced molecular biology lab in the Central Asia and trained Uzbek young scientists. He is one of eight founding scientists who initiated International Cotton Genome Initiative organization (ICGI) to facilitate collaborative research work on cotton genomics at the global level about eight years ago. As the chairman of the Germplasm Work Group of ICGI, Dr. Saha provided leadership for the first time to document the current status of world cotton collection in collaboration with the curators from the major cotton growing countries and this report has recently been published in Crop Science as the cover page paper (2010. 50:1161-1179). Dr. Saha's research productivity is well documented in about 130 publications, including 77 peer-reviewed journal articles in many prominent journals, one germplasm release notice, a co-edited book, additional multiple papers and abstracts in presentations at conferences.

The Three Big Challenges for Cotton Sector in the Next Decade

In my opinion the three biggest challenges facing the cotton sector in the next decade are:

1. Overcoming a major hurdle to improve fibre yield and quality to compete with synthetic fibre to maximise profit in the global textile market.
2. The threat of emergence of new resistant pests and diseases in many cotton growing areas of the world.
3. The effects of climate change due to global warming — with unpredictable drought, heat, cold, heavy rain — will pose a serious threat to cotton production.

Multinational, interdisciplinary, collaborative research leveraging state-of-the-art technologies will be critical to tackling these challenges.

Novel Production Technologies that Can Break Yield Barriers

- Novel transgenic technologies will play a major role in breaking the yield barrier in future cotton production. The new clustered regularly interspaced short palindromic repeat (CRISPR) transformation technology in developing improved cotton lines will play a major role in cotton production.
- An integrated method of Big Data science and precision agricultural technology will play a major role in developing information-based farm management system with efficient use of resources. This will help in the capability of researchers and farmers to decipher scientific action for improving productivity.
- Traditional farm management systems will be complemented with advanced technologies such as robotic tractor systems, smart phones, and satellite-based farm management systems using precision technologies to improve fibre yield and quality.

Promising Recent Advances in The Science of Genomics, Genetics and Plant Breeding

- CRISPR technologies in developing transgenic cotton lines: The development of genetically modified (GM) crops with current transgenic technology is very costly and time-consuming because of the stringent regulatory system to prevent any harm to humans, animal health, and the environment. Recently the Food and Drug Administration (FDA) in USA approved some CRISPR-edited crops without the requirement of the same stringent GM regulations because they did not contain any foreign DNA as is the case with traditional GM crops. The CRISPR-Cas9 system is a gene editing system using site-directed nucleases to target and modify DNA with great accuracy. The CRISPR technology was discovered based on the adaptive immune mechanism present in bacteria against invading bacteriophages and exogenous plasmids (Wang *et al,* 2019). This was first revealed in *Escherichia coli* in 1987 (Ishino *et al,* 1987) and later on officially named by the Dutch scientist who discovered the CRISPR related (CAS) genes, (Jansen *et al,* 2002; Wang *et al,* 2019). In 2005, three different research groups simultaneously discovered that specific short sequences of many CRISPR spacers were highly homologous, with sequences originating from extra chromosomal DNA suggesting an association between CRISPR and specific immunity. (Pourcel *et al,* 2005; Bolotin *et al,* 2005; Mojica *et al,* 2005). About 10 years later CRISPR-Cas9 has emerged as one of the most promising tools in transgenic research (Shan *et al,* 2013; Cong *et al,* 2013; Kaboli *et al,* 2018). The CRISPR fragment consists of short palindromic repeated DNA sequences that are regularly spaced with foreign DNA sequences from bacteriophages (viruses) that have previously attacked the bacteria. The CRISPR molecule also includes CRISPR-associated genes, or Cas genes. These encode proteins that unwind DNA and cut DNA are called helicases and nucleases, respectively (Barrangou *et al,* 2007). Scientists make use of the CRISPR-Cas9 systems' recognition of specific DNA sequences and apply it in the process of development of improved crops. Instead of viral DNA as spacers, scientists design their own sequences, based on their specific gene of interest and apply it in the process of development of improved crops. A short and simple review was published on the use of CRISPR technology for crop improvement, for more detailed information please refer to http://www.isaaa.org/resources/publications/pocketk/54/default.asp. The next generation of technology on the development of transgenic cotton lines resistant to abiotic and abiotic stresses, such as drought or newly emerging disease or pest problems. New genomic technologies complemented by advanced phenotyping systems using precision technology will help to identify some major factors associated with economically important traits at the molecular level. It is important to mention that the rapid change in the textile technology — from high throughput rotor spinning and subsequently to air jet spinning machine, as much as eight times faster than their old counterparts — demands high fibre strength for efficient spinning. Normally the production rate of air jet/vortex spinning is about 3-5 times higher than rotor spinning and 10-20 times that of ring spinning (https://www.textileschool.com/455/air-jet-spinning/). Cotton fibres with improved qualities such as greater strength and longer staple are necessary for spinning yarns in newer technologies reducing waste the spinning process. Textile manufacturers are currently using air jet spinning machines requiring improved fibre qualities so improved fibre quality is one of the most important selection criteria to make cotton fibre competitive with synthetic fibres in the global textile market. In addition, to improve productivity and fibre quality, the breeding program should address the problem for rapid adaptation to climate change. It is important to collaborate with other breeders from different climate regions and incorporate germplasm into breeding programs from other regions experiencing the 'future climate' condition. It is important to mention that the breeding and dissemination of new and improved germplasm will remain primarily a public sector responsibility because the commercial seed industries are putting their resources primarily in developing transgenic lines with new gene(s). Therefore, it is critical to maximise the resources for public breeding programs because of the need for faster varietal replacement considering rapid environmental changes and the emergence of new diseases and pests. Cotton breeders will have to shift selection parameters from improving only yield to improving yield and fibre qualities as well as make plants more resilient against emerging threats from new pests, diseases and environmental changes.

Contribution of Genomics Research for Yield Enhancement and Fibre Quality Improvement

Genomic research with use of new high-throughput sequencing technologies will unveil at the molecular level many important genes associated with improved yield, fibre qualities and other economically important traits. The revolution in sequencing technology with new methods of the second-generation sequence technologies including 454, ABI SOLiD Illumina and the Ion Torrent system and the latest third revolution in sequencing technology from Pacific Biosciences and Oxford Nanopore Technologies of sequencing of a single DNA molecule without the need to stop between read steps whether enzymatic or otherwise, will play a major role in next generation of genomic technologies. Integrating these advanced sequencing technologies with high-throughput phenotyping system to decode the mystery of genetic factors associated with economically important traits will have a big impact in genetic manipulation of economically important traits and marker-assisted selection (MAS) of plant breeding program.

How Can Cotton Combat Climate Change?

The following specific strategies will be very critical for agriculture, including cotton production, to mitigate the problem of global warming:

- Develop a collaborative coordinated strategy among major scientists and policy makers of cotton growing countries to address the serious threat from climate crisis because the effects of climate change are interconnected across environmental, social and economic dimensions affecting sustainable cotton production at the global level.
- Enhance the research capacity in an effort to understand the effects of climate change and eco-friendly farm management systems in future cotton production such as conservation agriculture, no-till farming system and crop rotation based on the local needs,
- Develop a range of options for solutions against a climate crisis based on interdisciplinary approaches of genetics, plant breeding, plant physiology, agronomy, and crop management, to maximize the benefits from climate change, and,
- Bring awareness at the social and political level urgently to develop climate-smart strategies for agriculture.

Novel Technologies to Fight Insect Pests, Weeds and Diseases

Using CRISPR technology, transgenic resistant cotton lines can be developed against biotic and abiotic stresses. Genomic research using advanced sequencing technologies will open up a new paradigm to understand the complex QTL traits at the molecular and cellular level and provide tools for MAS to improve yield, fibre qualities, and other economically important traits. As discussed in the previous section, advanced phenomics technologies using computers, satellites and smartphone-based app systems with the help of advanced precision techniques, will pay a major role in farm management to combat against climate change and emerging pest and disease problems.

Cotton Transgenic Technologies and the Way Forward

The next generation of cotton transgenic technologies will be dependent on the use of advanced CRISPR technology. This will save significant regulatory costs, time, and make the system more efficient for the targeted trait. Please see my comments in the previous section and consult the review paper by Lino *et al* (2018) for more detailed information with reference to CRISPR technology.

Role of Robotics, Electronics and Communication Technologies for Cotton

Robots have great potential in cotton farming and field management. They can replace many components of farm management, including planting and harvesting, replacing some of the work of conventional large tractors. For example, ordinary heavy tractors make the soil more compact, affecting soil health due because compact soil is less able to absorb and hold water along and nutrients. Using lightweight robots can overcome some of these problems. Cotton harvesting depends on hand picking of the bolls in many developing countries such as India, Pakistan and Uzbekistan. There is great potential for small size robots with automated technologies to replace hand harvesting for use in large scale operations, like the automated robot systems used in fruit harvesting in USA and some other countries. Robots have great potential to complement much work of farm management in a timely manner, saving cost and time. For example, a robot can take images with a camera at a specific stage of the farm field and send the photo to farmers, and farmers can instruct through a smart phone using a specific app to the robot for farm operation, using precision technology such as spraying in the field to a specific field area, avoiding unnecessarily polluting the environment, and saving resources. Also, during harvesting, another small robot can go to the field to pick and collect cotton bolls with potential for multiple harvesting from the same plant at different times with potential of improving yield and fibre quality. A recent report shows that FarmLogs, a Silicon Valley startup program (founded by Jesse Vollmar in August 2012), replaces the volume of paperwork in farm management with a simple smartphone app that allows the farmers to analyse the economics of their land and plan for the future. Users pay a minimum monthly fee (a farm of less than 400 acres pays about $20 per month). This company obtained about $1 million in seed funding recently to expand its staff and develop the app further for the new farming season. The app improves to track everything needed in farm management from tillage, to planting, to irrigation, to scouting, to spraying, to harvest, to soil sampling. The app service also connects a working farm to make the farmer aware of completed and uncompleted tasks. Fields are divided using map data, allowing farm owners to analyse each section of their farm for profit comparing between and within crops. Other similar start-up companies are coming out to help farmers based on a mobile-friendly website instead of an app. The new technological changes will help the small individual farmer grow vast quantities of food and fibre crops in the shortest period of time. The transgenic crops are not only environmentally beneficial due to a shift in herbicide use and reduction in pesticide use, they will also have potential for developing lines tolerant to biotic and abiotic stresses, as well as nutritional enrichment.

Advice to Young Cotton Scientists: How to Gear Up for the Challenges of 2030

I am profoundly grateful to almighty God for giving me an opportunity early in my career as a graduate student at Texas A&M University to come in contact with Dr Norman Borlaug, the Noble Laureate Agricultural Scientist and Father of Green Revolution. I was deeply motivated by him to have a career as an agriculture scientist. He reminded his students in almost every class that we, as agriculture scientists, have a moral and professional duty to fight against hunger. Future agriculture scientists will face a unique challenge to produce almost double the food and fibre within the next decade, for a rapidly increasing global population under the great threat of a climate crisis due to global warming. The FAO predicts that we will need 70% more food and fibre in 2050 than we did in 2005, to feed and clothe the rapidly increasing population (http://investeddevelopment.com/2013/06/the-impact-of-technology-in-agriculture/ verified June 19, 2020). There will be no one-size-fits-all solution so they must be tailored according to local farming needs and problems. Sub-Saharan Africa and South Asia a projected have largest of population growth. It is also interesting to note the percentages of people involved in agriculture in these regions are about 60% and 50%, respectively, compared to USA, where less than 2% of the population is employed in agriculture.

A recent FAO News source shows that India is the second most populous country, with a population of about 1.27 billion. Agriculture plays the most important role in the Indian economy. It is the world's largest producer of milk, pulses and jute, and ranks as the second largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruit and cotton. Farming contributed 23% of India's GDP and employed 59% of the India's total workforce in 2016 (http://www.fao.org/india/fao-in-india/india-at-a-glance/en/ verified July 7, 2020). Recently, the Economics Times reported that India will have the youngest populace in the world in 2020, with an average age of 25, and 28% of its population will be 10 to 24 years in age (https://economictimes.indiatimes.com/news/politics-and-nation/india-has-worlds-largest-youth-population-un-report/articleshow/45190294.cms verified July 6, 2020). Agriculture, including the allied sectors, provides the largest source of employment in India. It is strange that after having achieved food sufficiency in production, India still represents a country with about a quarter of the world's hungry people and over 190 million undernourished individuals because of poverty and poor access to food. Women play an important role both in farm as well as non-farm activities as an extension of their household work with dual responsibility in the society. There is a recent trend in India of increased roles for women in agriculture, primarily due to an increase in rural-urban migration of men from the family to explore better earning sources and also growth in the production of labour intensive cash crops (http://www.fao.org/india/fao-in-india/india-at-a-glance/en/ verified on Jul 7, 2020). A young scientist from a developing country like India will face a daunting challenge on both professional and personal levels to solve problems in Agriculture. A country like India, with about 82% of farmers being small holders, will have to address improving research and management on multiple fronts in agriculture, such as increasing incomes of farming households, diversifying production of crops, empowering women, strengthening agricultural diversity and productivity, and developing policy with careful price and subsidy policies to encourage the production and consumption of nutrient-rich crops (http://www.fao.org/india/fao-in-india/india-at-a-glance/en/ verified July 6, 2020). It is important to mention that in last few decades consumers have migrated more to urban areas away from farmers in many countries, including USA. Most of the population are not aware directly of the effect of climate change in agriculture. Perhaps the greatest challenge facing agriculture is improving the consumer's perception on the unpredictable effect of climate change in agriculture. It will be the responsibility of future scientists to strengthen consumer education to make them aware of the effect of climate change due to global warming in agriculture. However, among these enormous challenges, the next generation of young scientists will also witness a revolutionary change in technologies such as the potential of smartphone-based agriculture management systems, revolutionary changes in plant biotechnology, application of advanced precision and robotic tools in agriculture, etc. It will be very important for young scientists to learn and associate with the technological changes in their career. I also suggest from my personal experience the following:

- Don't listen to detractors or believe that there's knowledge beyond your reach.
- Respect others.
- Work together across the disciplines as a team to solve a problem.
- Improve your 'emotional intelligence' — an individual's ability to manage his/her own emotion and the emotions of others in every-day situations.
- Be honest and love your work.
- Give your best to accomplish your goal without thinking about the expected result.
- Develop a habit of self-awareness of how to react in a difficult situation with others and change habits, learning from your mistakes.
- Young agriculture scientists will be at the forefront of an exciting but challenging and difficult period where the future of humanity will depend on them for a better future that produces enough food and fibre to feed and clothe the growing world population.

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