The ICAC Recorder

Cotton Vision 2030

Raja Reddy, USA

ICAC Researcher of the Year 2020

Dr. K Raja Reddy is a Research Professor in the Department of Plant and Soil Sciences at Mississippi State University. He is an accomplished researcher in the realm of agricultural science, a respected teacher and mentor to many, while also a leader among his peers.

Dr. Reddy has trained over 35 visiting and 15 postdoctoral scientists and 30 students (15 Ph.D., 11 MS, 5 Undergraduate and others as committee members) from across the world in multiple areas such as crop stress physiology, climate change, crop modeling, remote sensing, and global food security.

He has a very impressive publication record with a high citation index of 11,160. Dr. Reddy's research interests include the impact of anthropogenic climate change, remote sensing, and crop modeling applications on agricultural resource management through the lens of environmental plant physiology. He has over 32 years of research experience at Mississippi State and is responsible for and credited with many critical discoveries across multiple facets of agriculture. His research includes the impact of climate change on cotton and other crop physiology, growth, and development of several outstanding foods, fiber, and native grassland s and forages crops of global importance, cotton, soybean, rice, corn, sorghum, peppers, sweet potato, switchgrass, Bahia grass; remote sensing and stress physiology; and crop model applications.

In addition to his research obligations, he developed a capstone graduate-level course, "environmental plant physiology," that interfaces research, teaching, and learning based on research work he conducted using state-of-the-art sunlit plant growth chamber facilities at Mississippi State.

Dr. Reddy has received several recognitions and awards: Fellow of the American Association for the Advancement of Science, the Crop Science Society of America and the American Society of Agronomy; the Ralph E. Powe Award, the Highest Research Honor at Mississippi State University; and the Outstanding Research Award in Cotton Physiology, presented by the National Cotton Council of America.

How Can Cotton Combat Climate Change?

Since cotton is grown under a wide range of climatic conditions, the challenges and strategies are different under those climatic conditions. Changes projected in climate, including carbon dioxide, that will deeply affect lint yield and fiber quality, thus producing cotton growers' livelihoods. The recent review by Bange et al. (2016) provided an excellent summary, outlining many of those challenges and opportunities in a changing climate facing cotton production.

In temperate climates, early-season cool temperatures and sometimes waterlogging are typical, and therefore, we need to develop cold- and waterlogging tolerant cultivars, focusing on early-season vigor. Systematic evaluation of germplasm for early-season vigor through various phenotype platforms will benefit the industry. Early-season drought and other stresses are also common in subtropical and tropical climates. On the other hand, a regional-scale increase in seasonal cloud cover and warming temperatures is an unobserved silent threat to crop quality, including in cotton. Cotton breeding strategies should focus on improving traits associated with multi-stress tolerance. A simple breeder-friendly trait and numerical stress-specific cultivar scoring system would help cotton breeders or producers select cultivars tolerant to multiple abiotic stresses with high-yielding capabilities in the niche area.

Cotton is grown in a wide range of environments and is often subjected to high temperatures and/or low precipitation during flowering and boll-filling periods. Such uncontrollable extreme stress events cause lower yields and poor-quality fiber. The use of sensor-based management systems such as efficient irrigation systems will alleviate the drought and high-temperature conditions where irrigation is available to a certain extent. Therefore, developing drought- and heat-tolerant cultivars will be needed to combat these yield-limiting stresses sustainably. However, there is no easy way to evaluate stress tolerance among cotton cultivars, as canopy level traits are affected differentially by growth stages.

Moreover, most morph-physiology-based phenotyping techniques are weakly correlated with reproductive tolerance or yield potential due to the indeterminate nature of cotton. Measuring pollen germination ability traits are informative but are tedious and low throughput. Thus, the integration of automated machine learning technologies to count and estimate pollen viability may expedite ongoing reproductive stress tolerance breeding. Another solution to address reproductive stress tolerance would be developing biomarkers such as metabolite or hormonal markers to overcome the phenotyping limitations for genomic studies. Multidisciplinary teamwork is required to develop drought- and heat-tolerant-ready cotton cultivars. Another aspect is increasing light- and carboxylation-use efficiencies and increasing potential photosynthesis. Strategies to develop such cultivars will positively affect cotton production, especially for a wet climate region where high cloud cover is coupled with warmer night temperatures. Besides, the development of breeder-friendly remote-sensing indices as surrogates for canopy and flower temperatures, pigment composition, water content, and ground cover are the pre-requisites for cotton improvement for stressful environments.

Also, mechanistic simulation models that simulate seed cotton yield and fiber quality will aid many policy decisions in a changing climate (Reddy et al., 1997; Thorp et al., 2014). As pointed out by Bange et al. (2016), multi-faceted, system-based approaches are needed to assist policy and to adapt cotton production in a changing climate. More importantly, we are responsible for educating the general public about climate change and its implications on food, fiber, and ecosystem services. This will lead to changes in the society-level perceptions leading to innovative and transformative policies.

Exciting Novel Innovations and Game-Changing Technologies

Developing smartphone-based applications that integrate GIS and sensor-based information into a predictive simulation capability will be game-changing technologies for resource-rich production systems. Besides, transformative phenotyping technologies will aid in developing climate-resilient cotton cultivar development. Creating a global phenotyping network and developing a targeted environmental phenotypic library can help to streamline cotton phenotyping strategies. Deployment of rapid and automated phenotypic data collection and processing tools would help develop multi-stress tolerant donors. Creating transdisciplinary centers of excellence combining the above- and the emerging technologies will transform the cotton industry in the coming years. For an immediate benefit, resource-poor countries should adopt management systems from resource-rich countries proven to boost yields. Collaborative public and private system biology research help to develop climate-resilient cotton.

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

The challenges I faced during my career may differ from the challenges the young scientists face in today's environment. However, those lessons that I have learned and implemented may provide insights for aspiring young scientists. I am a life-long learner and student and a very hands-on researcher. During my graduate studies, I took applied plant physiology and botany as my domain subject areas. My graduate work focused on controlling less productive semiarid shrub species through herbicidal means and is practiced widely today to control weedy native plants and replace them with more productive species adapted to that part of the world. Later I worked at the Biology Department of S.V. University, Tirupati, India, where my colleagues and I compiled medicinal and wild edible plants by learning systematic botany. We documented the use of about 216 formulations of plant products for medicinal purposes in the region. Their use had been handed over from generation to generation by oral communication. Thus, there was no written record or only limited documentation of plants used for medicinal purposes, and our work filled that void.

Then, an opportunity came to enhance my career opportunities to study abroad, and I joined the USDA-ARS Crop Simulation Research Unit and Mississippi State University, Mississippi, USA. Before that time, I was not even aware of crop simulation models and never learned or worked with computers. I had to learn agricultural systems and cotton for the first time quickly. I attended all Beltwide Cotton Conferences and learned a lot about cotton research and, more importantly, the people and their contribution to cotton science. That helped me tremendously to jump-start my career in cotton physiology. I also learned how to read FORTRAN code, the logic behind modeling, and understanding the whole-plant system. Even though my systematic botany expertise helped me understand the object-oriented logic in crop simulation modeling methodologies, I regretted not having opted for a high-rigour mathematics choice at a very early age. However, I realized that the logic and basic understanding of cotton growth to abiotic stress conditions and modeling cotton processes don't need complex algorithms.

I had the good fortune of working with a team of scientists and modelers, and that teamwork paid dividends to mold my career in cotton science, modeling, and agriculture. I was also fortunate to work with the state-of-the-art sunlit plant growth chambers facility known as the soil-plant-atmosphere-research (Spar, https://www.spar.msstate.edu/) system. This is a biologist's dream facility that keeps me designing new experiments to test many hypotheses that is not easy to test in other facilities in crop stress physiology arenas. Our laboratory generated the most comprehensive quantitative functional database for cotton and other crop's growth and development as affected by environmental stress conditions from seed to fiber quality in the world. That work improved the GOSSYM/COMAX and other cotton models (Reddy et al., 1997; Thorp et al., 2014) for field applications and policy decisions. I want to point out that I had only a ruler and a small leaf area meter in the laboratory, and we used those to upgrade existing and new subroutines in the model. The lessons that I learned working with cotton are that now I could develop a similar database for any given crop in the less than five years that I did for 15 years or so in cotton.

Funding was essential to expand my research and teaching programs. Expanding our program to a new field, extending to climate change areas is very logical, but embracing new areas needed collaboration and learning new domains such as remote sensing, phenotyping, genomics, and the molecular areas was also important. Few other things that enhanced my career and program were embracing diversity and inclusiveness in hiring Postdocs (>15), visiting scientists (>35), and students (>30 students) from around the world. They brought culture and ideas to enhance my program, and thus I din't need to take a sabbatical for international exposure or to learn new things. Mentoring students and letting them understand the work ethics, conference participation, competing for various categories for presentation and other awards, and networking are foundations for a successful career. Besides, I have emphasized the importance of community service and engagement for leadership development and request them to be part of my community service projects and more.

Finally, I learned that telling our science stories through scientific journal publications and books is not enough to reach the general public. During my career, I had opportunities to work with excellent writers who featured our research work many times at Mississippi State University, Mississippi State, MS, USA (https://www.mafes.msstate.edu/discovers/article.asp?id=13), the Crop Science Society of America through their CSS News or science news (https://www.agronomy.org/news/science-news/preparing-plants-our-future-climate/) or through briefing the capabilities of our facilities and science to the visitors and administrators again and again. These stories gained more importance and momentum that I could communicate in a journal paper, reaching millions of people across the web and different audiences.

I hope that my life journey will inspire other young cotton scientists to emulate some of the proven and successful career activities during my journey from farmer's son in southern Indian State of Andhra Pradesh to the ICAC Cotton Researcher of the Year Award by peers. Of course, my mantra behind my success story is a healthy and supportive family.

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