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**Session IV: New Directions in Cotton Breeding and Consumer Reception**
**11:00 March 17, 2016**

**Mr. Allen Terhaar, in the Chair**
**Cotton Council International, Washington, DC, USA**

**Dr. Rafiq Chaudhry, Head Technical Information Section, International Cotton Advisory Committee (ICAC), Washington, DC USA**
**"Cotton Breeding: Developments and Opportunities."**

Plant breeding serves as the backbone of research developments. Breeding is comprised of variety development, variety maintenance (including variety approval and certification), and seed production, and these activities have continuously changed. Traditional breeding, which involves selecting superior plants within a population, testing and production takes a minimum of 12 years to develop new varieties for commercial application. Besides taking a long time and requiring extensive resources, traditional breeding cannot guarantee that desired traits will be incorporated into new varieties.

Traditional breeding programs are severely constrained because of quarantine regulations and scientific habits that make it nearly impossible to exchange germplasm among scientists internationally. Therefore, traditional breeding is in crisis. Other crops have international germplasm banks established by international research centers. However, the cotton industry does not have an international research center.

The private sector is increasingly involved in important components of the breeding chain, and the role of the public sector has diminished. A mix of different approaches to seed breeding is needed, and there must be agreement as to who is responsible for what in the breeding chain. Decades ago when seed breeding was dominated by the public sector, there was more interaction among breeders and greater exchange of germplasm among breeding programs. There is a need to reinvigorate the public sector in breeding to facilitate germplasm exchange.

The mapping of the cotton DNA will be beneficial for traditional breeding activities, but this breakthrough cannot be fully utilized without more exchange of germplasm among countries.

While scientific centers and seed breeding systems will be changing their modalities, they cannot ignore the fast approaching molecular breeding technologies. Marker assisted breeding and empowerment over directed breeding is the new norm of cotton breeding. Conventional breeding will be replaced with molecular breeding, a joint venture of breeders and molecular biologists.

Plant breeding started about 10,000-12,000 years ago when man observed that if a seed falls on the ground it germinates and produces a new plant (Roupakias, 2014). It was only 100 years ago that researchers were still struggling to accept the Mendelian Law of Inheritance and the Law of Independent Assortment. The principles of Mendelian genetics were ignored for almost 25 years due to the hesitation to admit the existence of genes or to accept that heritable characters are genetically controlled and cannot just be transferred as being acquired. The genes assort independently without any outside influence.

The extensive research done on cotton became more formal and was easier to understand after it was discovered that there are genes that carry a blueprint of the characters to be expressed under a given set of growing conditions. Such discoveries, unimaginable in the early years of cotton research, were severely questioned and remained shelved for about half a century. The theory of evolution did not satisfactorily address many concerns, and it was practically impossible to give up the long-held belief in the inheritance of acquired characters. Fortunately, however, the law of inheritance of characters and the independent assortment of genes were rediscovered and applied. Thus began the science of formal breeding we know today.

If consumers oppose biotechnology because of a lack of knowledge or a lack of education, that is not the fault of the technology, that is the fault of the consumer. They have a responsibility to acquire education and knowledge. Likewise, if resistance has developed, it is the fault of the technology users who did not follow the limits that accompany the technology. Consumers should differentiate between the technology and the product. The product may be good or bad, but you cannot condemn or reject the whole technology because you don't like the product.

**Dr. Kater Hake, Vice President for Agricultural Research, Cotton Incorporated, Cary, North Carolina, USA**
**"Cotton Breeding Both High Tech and Natural."**

How do we define "natural?"

Single-cell life existed on this planet for 2.5 billion years before the oxygenation events of approximately half a billion years ago that sparked the Cambrian explosion of multicellular diverse life. Was Cambrian explosion natural?

There is a consensus that we have entered the Anthropocene because geologist digging in the dirt one thousand years from now will be able to find the spike in CO2 in sediment cores. A bit deeper they will find the radioactive layer from atmospheric testing; deeper still the soot layer from coal powered textile production; deeper still the shift in pollen grains as we deforested Europe for agriculture. As they dig deeper they will find layers of soil containing evidence of when primitive man used fire to cook on a regular basis one-half million years ago, or they will find evidence that man used fire at least one million years ago to herd and harvest animals. The technology of a thousand years from now may be good enough to find the layer of early stone tools made 3.3 million years ago that predate man but allowed our ancestors to eat meat. Are any of these events natural? Today, a Big Horned Sheep can be fitted with a GPS collar and tracked by wildlife biologists to protect them from Mountain Lions. Is that natural?

Cotton evolved on the Pangean Continent (a supercontinent that existed between 300 million and 175 million years ago). Continental plate tectonics resulted in the separation of what are today Africa and South America out of Pangea, with old world and new world cotton species developing independently in each continent from common parents. Over the last 6,000 years, man has taken wild species in which lint was less than 1% of total biomass production by weight to modern varieties in which seed cotton accounts for 40% of plant biomass. Modern breeding took cotton yields from an average of 175 kilograms of lint per hectare in the 1800s, with no trend increase for decades until the 1920s, to approximately 800 kilograms per hectare today, with an average gain of 7 kilograms per hectare per year.

The two essential steps in plant breeding are **selection** based on observation of yield potential, and **diversity** of germplasm exchanged among plants which results in natural mutations and natural crossings. Selections are based on yield trials, statistical analysis, measurement of fiber quality and gene measurement. Diversity enables crossing elite-by-elite, induced mutations, the introduction of wild germplasm and the use of biotechnology.

As an example, the trait of host plant resistance can be induced through the crossing of wild cotton germplasm with a commercial variety using marker aided selection. In a similar fashion, the techniques of biotechnology enable scientists to transfer distant genes from Bacillus thuringiensis into commercial cotton varieties.

Additional progress in breeding will occur with genomic selection used to select varieties with traits for multiplication, and the tools of genome editing, organelle editing and metabolic editing used to take advantage of greater genetic diversity.

Metabolic engineering can be used to make cotton plants more efficient in the use of nitrogen and water or to remove gossypol from cottonseed but not from leaves and stems. Reduced-gossypol cottonseed, which could provide half the protein requirements for one billion people, is on track for regulatory approval in the United States by 2017.

Genome editing tools can be used to produce healthier pollinators, allergen-free foods or improved fiber quality. Genomic selection tools can be used to speed the breeding process.

Agricultural research is under threat because of our success in creating safe and cheap food that taxpayers take for granted. Research is a long term process that requires specialized equipment, skills, and years to create one new fact.  We need to maintain our research capabilities to cut input costs, control ever-changing pests, and to expand the utility (and hopefully the price) of cotton, all while pushing yields up, since this is where future profits will likely come from.

Agricultural research is borrowing ideas from medical research, and last year researchers created the most important tool for long term development of cotton – a map of the cotton genome. The DNA instruction code for cotton is similar to the human genome and is really close to the corn genome. Some of the beneficial knowledge we are gaining from medical science is helping to speed incremental improvements in cotton quality and reductions in environmental impacts.

International discussions are ongoing to permit products of the advanced technologies to move in international trade. Some analysts predict that the developing world will leapfrog biotechnology by using the tools of genome editing to create new commercial varieties that will not be categorized as "GMO."

**Dr. Dirk Zimmermann, Sustainable Agriculture Campaigner, Greenpeace Deutschland, Hamburg, Germany**
**"Plant Breeding as an Integral Part of Sustainable Agriculture."**

Greenpeace is working on agricultural issues because of concerns that human activities are exceeding planetary boundaries in terms of the nitrogen and phosphorous cycles and the loss of biodiversity. Greenpeace understands that sustainability includes economic and social aspects, but its focus is on the environment. Cotton accounts for 25% of world pesticide use, and the cotton industry needs to focus on this. (Editor's note: in 2014, cotton accounted for 5.7% of world pesticide sales by value and approximately 7% by volume. Dr. Zimmermann seems to be ignorant of the facts of pesticide use on cotton.)

Greenpeace believes that sustainability has nothing to do with the use of GE crops and pesticides. GE crops are problematic because they result in increased herbicide and insecticide use. Weeds and insects will develop resistance to biotech traits, and secondary pests will develop.

Other concerns about GMOs and their deliberate release into the environment include the consequences of the introduced trait (e.g. herbicide tolerance) or the type of genetic material (e.g. antibiotic resistance genes). There may be unforeseen interactions between the new or altered gene(s) and the plants own genes; there may be genomic irregularities (e.g. fragments and rearrangements) and/or alterations to plant biochemical pathways can give rise to unintended and unpredictable effects in GM plants.

New breeding techniques will equal new forms of genetic engineering.

The main criterion for GE is that an organism's genetic material must have been altered using modern biotechnology to give rise to a novel composition, i.e. a sequence of nucleotides that did not arise by mating. If "new plant breeding technologies" result in a novel combination of DNA, they are GM. Many of these "gene editing" techniques are new, and it is not yet possible to fully evaluate the potential for unintended changes. Unintended changes to genetic material can still be expected and may give rise to plants displaying unexpected and unpredictable effects which can only be assessed under GMO regulation! Therefore, new GE (crops) need to be regulated as GMOs.

In contrast to GMOs, Greenpeace is very much in favor of Marker Assisted Selection because this "safe" biotechnology works. With MAS, plants can be developed with increased stress tolerance. MAS respects species barriers, meaning that all genes that are incorporated are present in the natural gene pool. MAS has fewer safety concerns because backcrossing and introgression have a long history of safe use.

Plant breeding is one part of sustainable agriculture. Mankind cannot continue to use highly industrialized agriculture as we do today. A UN report suggests that small farmers can double food production in ten years using agroecological methods. Agroecological farming increases diversity, shifts from high inputs to knowledge-based agriculture using agroecological principles (including free "ecosystem services,") increases resilience to erratic weather changes, reduces pests and diseases by diluting their hosts, increases productivity, prevents soil erosion, and increases soil organic matter. Agroecological methods maximize yields over many years while decreasing the severity of crop failures in bad years. Diversity is at the core of ecological farming.

In conclusion, non-GE-breeding is just one element of sustainable agriculture. Diversity and agroecology are the keys to sustainable farming systems

In response to a question from the audience, Dr. Zimmermann said that while it is claimed that humans have been consuming biotech foods for 25 years without a single incidence of side effect or ailment, no one knows whether there are side effects or whether there will be deleterious impacts in the future. There are serious environmental impacts that have been discovered. Greenpeace believes we should not risk food safety because we don't need biotechnology.

Dr. Zimmermann said that of the new breeding techniques discussed by Dr. Chaudhry and Dr. Hake, none would be acceptable to Greenpeace.

**Mr. Rainer Schlatmann, Free Journalist for Textile and Fashion, Langenfeld, Germany. "European Consumers' and Biotechnology."**

There are three areas of biotechnology: Red Biotechnology which refers to medical biotechnology. This is mostly accepted by consumers. White Biotechnology, which includes industrial biotechnology, is mostly accepted by consumers. However, Green Biotechnology, referring to agricultural applications, is mostly rejected by consumers in Europe.

Consumers' perceptions of green technology are influenced by intensive communication strategies of opponents of genetic technology. However, positive arguments by proponents of biotechnology are relatively infrequent.

The reasons for rejecting green genetic technology include 1) suspicion of authorities' decisions, 2) old clichés about agriculture and nature such as the story of Frankenstein, 3) fear of changes, 4) fear of uncertain risks, 5) fear spread by opponents of genetic engineering, 6) consumers are not convinced about the benefits of genetic technologies, 7) they lack knowledge, and 8) they lack science education.

Consumers fear genetic technology because they believe it is a relatively young science developed since 1996, and many processes remain unexplored. Consumers fear four main problems or threats, including 1) the potential for uncontrollable results of introducing changes in DNA, 2) negative consequences of genetic engineering may not be apparent for many years and in many places, 3) potential damage may not be immediately apparent, and 4) if and when problems develop it will not be possible to reverse the consequences.

Opponents of biotechnology point to the worldwide spread of resistant super weeds, the release of Bt poisons on arable land, they claim biotech traits are effective for only a limited time and that new species of bollworms are on the increase again, that new pests can thrive, that GMO plants are sensitive to growth pressures and that health risks cannot be anticipated.

Christian Schmidt, the German Federal Minister of Agriculture, said in September 2015, "My aim is a nationwide strict ban on green genetic technology in Germany."

Religious, ethical, developmental and environmental arguments can be marshalled to support or reject the use of biotechnology.

Religious arguments in favor include the view that the talents of mankind which are provided from the hands of God allow genetic engineering, and a culture of responsibility in farming and conservation through innovation allows humans to participate actively in divine creation.

Religious arguments opposed include the view that the wisdom of divine order of all creation cannot be ignored, temptation caused by human fantasies of omnipotence must be rejected, the Christian choice of freedom will be undermined in the long term by biotechnology, and the lack of reversibility excludes the choice of regret or penance.

Ethicists can argue that it would be unethical not to use the possibility of GMO crops to improve the food situation in the third world. However, opponents can argue that human intervention in nature using genetic technology contradicts ethical values und has limits. Genetic technology may be abused for reprehensible objectives.

Development policy arguments in favor of the use of biotechnology include the view that safeguarding global nutrition and the livelihood of eight to ten billion people in the future is possible by increasing productivity per unit of land. However, opponents counter that world hunger is not a production problem but a distribution problem, and biotechnology results in higher socio-economic dependency on international seed producers. Besides, in the long run there are no income-generating effects of the use of biotechnology.

Environmentalists might argue in favor of the use of biotechnology be saying that herbicide tolerance allows for efficient weed management with herbicide resistant plants and less fuel consumption, and efficient crop protection with virus resistant and insect resistant Bt plants resulting in a reduction in the use of pesticides. However, environmentalists opposed to the use of biotechnology may argue against the danger of monoculture, the development of resistance, increased use of pesticides, loss of biodiversity, lack of irreversibility, Bt crosses are less robust, and outcrossing is problematic.

In conclusion, there is an absence of active communication about the benefits of green biotechnology towards end consumers by the industry and its federations. Green biotech companies in general react with defensive arguments if they are criticized. In comparison to red and white biotechnology, the benefits of agricultural biotechnology are not clear. It is clear in consumers' minds only that there are risks, and so they feel uneasy.

In public newspapers or magazines, at first glance you find a majority of articles released by GMO opponents. Behind this: Editors should be informed actively by the industry so that they are able to write articles from another point of view and explore new arguments objectively as professional journalists.

Advances in genetic technology are discussed and released too much at conferences, but not much is done towards the public, consumers or schools and students. At first glance, internet research lead consumers firstly to the arguments of opponents.

Products processed with green bio or genetic technology will only succeed in the long term if consumers can be convinced to buy such products. The task may differ from market to market, depending on needs and habits, but the fact remains that products will always fail if they are not "most wanted."

European consumers will accept biotechnology if they understand the benefits of such a technology. Consumers generally reject the use of green biotechnology because they do not understand the benefits. If new breeding technologies are explained to consumers in beneficial terms, those techniques will be accepted. Many consumers don't understand agricultural biotechnology, and it might be useful to be more specific in identifying what is meant. Scientists need to do a better job of explaining their different tools to the public.

Questions

During the discussion following the presentations, audience members suggested that consumers need to be educated about the differences in technologies, such as new breeding technologies, and not just lump all new methods of crop development under the heading of "biotechnology."

Dr. Hake observed that the 27th slide in the presentation by Mr. Schlatmann, “Consumer Opinion of Vertical Gene Transfer,” showed that 25% of Europeans do not agree that vertical gene transfer is useful. 100% of Europeans benefit from vertical gene transfer (received from their parents) shows that there is a very serious education challenge ahead.

Dr. Mancini from the audience noted that many Europeans are knowledgeable about biotechnology but they oppose the use of biotechnology more from fear than lack of knowledge.

Dr. Hake commented on the difference between “process” (development of new genotypes through traditional breeding versus genetic engineering) and “product” (plants with enhanced desirable characteristics). Dr. Hake asked if European consumers would accept a product that was produced in two years with genetic engineering techniques if it were identical to another product that might require 1,000 years of traditional breeding to develop. Dr. Zimmermann responded that “process” is the focus of EU regulations, regardless of “product” to be developed.

The Chair thanked the panelists for their presentations and answers to questions, and he adjourned the session.