

Biotechnology & Cotton Supply: Today and Tomorrow



By: Michel Tahar

Biotechnology & Cotton Supply: Today and Tomorrow

By: Michel Tahar

Increasing demand for fiber from a growing population will call for more innovative technologies in global cotton production in the coming years. Biotechnology and genetic modification have already delivered significant benefits to cotton producers and this will continue. Modern biotechnology, combined with new breeding techniques, has the potential to significantly increase productivity per unit area of land, optimize the use of crop inputs, improve fiber quality and processing and contribute to the sustainability of cotton production.

According to Allen Terhaar, Executive Director for Cotton Council International, "By the year 2050, the world population will have increased by some 3 billion souls, up to 9 billion people inhabiting this planet and they'll all need food and fiber to survive."

"By 2050, the world demand for fiber will increase four to five fold" he added in an article published in South West Farm Press June 10, 2009¹. Of course not all this demand will translate directly into demand for raw cotton. Nevertheless, according to the International Cotton Advisory Council (ICAC), cotton production must increase to meet a global demand that is forecast to increase by close to 60% between 2000 and 2030².

The challenges facing global cotton production in the coming years are many: limited arable land and water, competition for land with food, feed and energy crops, increasing interest in biofuels, rising consumer demand for more food, improved health, nutrition and lifestyle, environmental and ecological pressures (e.g. biodiversity, climate change), changing customer needs, rapidly evolving technologies and last but not the least sustainability considerations.

If cotton industry is going to meet these challenges, it is essential to make cotton production more efficient and sustainable. In order to achieve this, an integrated approach is required that includes solutions ranging from seeds with higher yield potential, to optimized crop input management and new crop protection solutions.

Starting with the seed – advancements in breeding and biotechnology

Cotton breeders the world over are striving to achieve a set of common goals. In general, the objectives of breeders are:

- to improve yield and yield stability,
- to improve fiber quality (length, strength, micronaire, uniformity),
- to improve agronomic characteristics (regional adaptation, specific, boll type, maturity),
- to increase resistance to various pests (disease, insect, nematode) and
- To identify heat/drought tolerance traits.

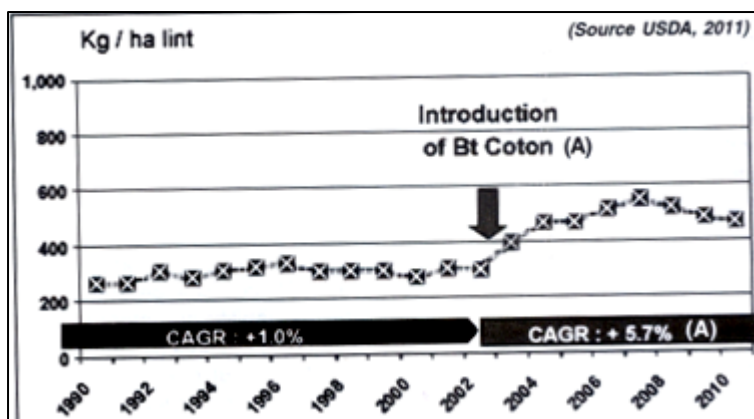
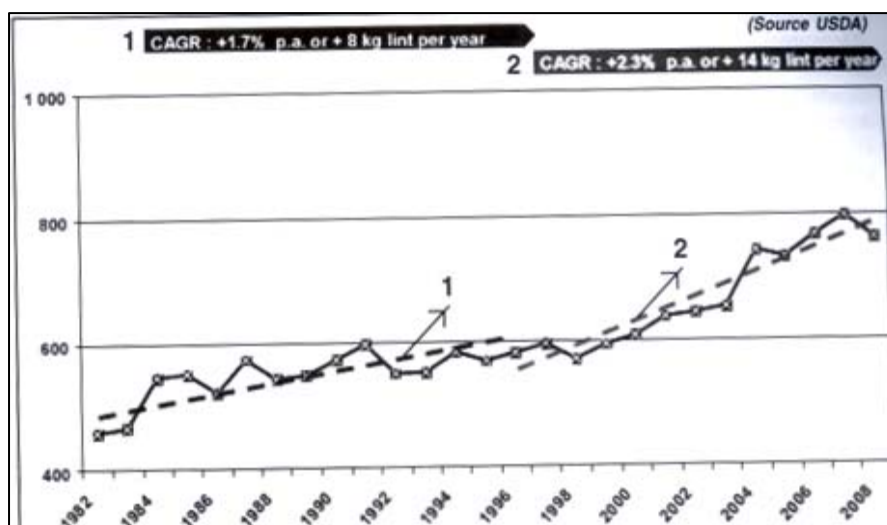
Cotton breeders have made remarkable progress in increasing crop yields for over a century. Between 1982 and 1995, cotton lint yield increased 1.7% per year.

However, plant breeders' men continually work to achieve and respond to changing needs and market demands. For example, changes in agricultural practices might drive the developing genotypes with special agronomic characteristics. Environmental factors are also changing and can pose new challenges for breeders to develop genotypes and resistance to new or evolved pests growing conditions or disease pressures.

Plant breeders therefore face an endless task of continually developing new crop varieties that both incorporate desirable characteristics and deliver yield gains expected by farmers. However, despite the 7-9 kg/ha/yr gain in lint yield observed so far thanks to conventional breeding and integrated crop and pest management, it is clear that we will not be able to meet future projected demands without boosting yields even more. That requires the breeders have the ability to optimize the right tools or combination of tools needed to develop plant varieties with beneficial traits and high yields – too that include biotechnology.

Combined with conventional breeding, the adoption of biotechnology has speeded up the rate of world lint yield gain between 1996 and 2008, resulting in a 14 kg/ha/year average increase.

In 2010, according to the International Service for the Acquisition of Agri-Biotech Applications (ISAAA), biotech cotton represented as much as 64% of the global cotton area, being used on around 21 million hectares in both industrial and developing nations³. Biotech cotton has been widely embraced by farmers since its introduction in 1996 and is currently being adopted by Central and Latin American countries very quickly, as well as countries such as Pakistan, South Africa and Burkina Faso. It is anticipated that other African countries will adopt this technology in the coming years. Whilst the USA and Australia were the first countries to adopt this technology, today



India has the largest biotech cotton area with 9.4 million hectares (85 percent of cotton area) planted by 6.3 million farmers. India started the adoption of insect-resistant cotton (so-called Bt cotton) in 2002 and the consequences on yield improvement has been spectacular. Before the introduction of this technology, the growth rate for lint yield was 1 percent per annum and India was an importing country for raw cotton. Between 2003 and 2010, lint yield increased at a growth rate of 5.7 percent for annum and India became an exporting country for raw cotton.

	2002	2004	2006	Average
Insecticide Use	-50%	-51%	-21%	-41%
Yield	+34%	+35%	+43%	+37%
Total Cost	+17%	+11%	+24%	+17%
Gross Revenue	+33%	+37%	+40%	+37%
Profit	+69%	+129%	+70%	+89%

(Source Sadashivappa and Qaim, 2009)

Like in other countries, Indian farmers growing Bt cotton benefit from insecticide savings, higher effective yields through reduced crop losses, and profit gains, in spite of higher seed prices⁴.

Today, two primary types of genetically modified agronomic traits are commercialized in cotton and available to farmers: insect resistance traits for Lepidopteran control and herbicide tolerance traits for efficient and effective weed management.

Specifically, since 1996/97, five insect resistant products and five herbicide tolerant products have been approved and commercialized for cotton:

- Insect Resistant Products: Bollgard® (Monsanto), Bollgard 2® (Monsanto), Fusion gene (CAAS, China), XGene - Event 1 (JK Seeds, India), Widestrike® (Dow AgroSciences).
- Herbicide tolerant products: BXN (Rhone Poulenc Agriculture), Roundup Ready® (Monsanto), Roundup Ready FleX® (Monsanto), Liberty Link® (Bayer CropScience), GlyTol® (Bayer CropScience).

Increasingly important to farmers is the availability of stacked or combined technologies, which deliver a greater spectrum of activity depending on the individual components of the stack and even more benefits to the farmer.

The primary or direct benefits of biotech cotton so far have been; an improvement of crop management, a reduction in production costs, an improvement of yield and profitability for the farmer, the possibility to grow cotton on areas where it would no longer be possible using conventional crop protection tools, an optimized use of chemicals, a reduction in sprayings and consequently in fossil fuel use and a reduction in farming risks^{5, 6}. The indirect benefits of biotech cotton have been a reduction of labor costs, an improvement in the population of beneficial insects and wildlife, an improvement of the quality of air and of the soil, less water waste and soil erosion, less labor time which can be dedicated to other activities and finally an improved economic outlook for the cotton industry^{5, 6}.

New Agronomic Traits of Interest:

Compared with other crops like corn or soybeans, cotton has one of the most innovative track records for biotechnology applications. By 2015, there could potentially be up to 27 commercialized events in the marketplace in the areas of herbicide tolerance and insect resistance - a key focus of most corporate research pipelines for next four to five years ⁷.

However, for the 2016 - 2020 period and beyond, it is anticipated that the range of biotechnology applications will broaden significantly, with new biotechnology developments for cotton focused on yield increase (e.g., harvest index, nitrogen use efficiency, hybridization), stress tolerance (e.g., drought, water use efficiency, novel Lepidopteran and sap-sucking insect control, nematode control, disease resistance, novel herbicide tolerance) and fiber quality (e.g., fiber yield & quality, bio-engineered fibers).

Water use efficiency and nitrogen use efficiency are among the most innovative and exciting technologies with potential to reach the market in the mid-term. Water and nitrogen use efficiency research efforts are focused on exploring ways to increase cotton yields using the same amount or less water or fertilizer inputs, thereby reducing cotton's resource needs and improving its longterm sustainability profile.

Water in particular is now a scarce resource and often also faces quality issues. Climate change will reduce water availability and storage, and warmer temperatures will increase the amount of water needed by crops. Currently it takes about one cubic meter of water to produce one kilogram of cotton fiber, but that may change overtime.

To solve the water challenges, we can improve the efficiency of irrigation systems but we can also look at plants themselves to try and improve their use of available water. In this respect, biotechnology experts and breeders are making some progress developing new varieties of cotton that require less precious liquid yet nonetheless produce high yields and good quality fibers. The improvement of water use efficiency is therefore a key target for cotton.

In the area of nitrogen utilization, the use of synthetic nitrogen fertilizers in crop production typically results in significantly more N₂O emissions ⁸. One of the consequences is that increased N₂O impacts climate change⁹. Solutions to the fertilizer efficiency challenge include increasing the nitrogen use efficiency in crops. This can be accomplished through changes in management (conservation tillage, timing of fertilizer application) and also through fertilizer technology and genetic improvements of crops. Biotech crops have the potential to contribute to the closing of the production gap through improving yields with lower inputs of water and fertilizers.

Fiber quality enhancements

The ultimate cotton improvement objective is fiber quality. In this area, researchers and plant breeders are also making exciting strides. In particular, there are some researchers looking at engineering the cotton fibers themselves to deliver certain quality characteristics that might be desirable to spinners and the value chain all the way to the consumer.

The approach that these scientists are taking is to improve cotton fiber quality properties via molecular breeding or genetically modified methods. The primary focus is to understand the mechanisms in the plant that control fiber initiation and elongation, and thereby use that information to engineer improved fiber formation and length either through molecular breeding or by genetic modification.

Bioengineered fibers with certain properties could add value to weaving and textile processing and ultimately could be of real value to the consumers. With this field of application, the benefits for biotechnology will not stop at the farm gate, but will impact the entire value chain and will offer benefits from seeds to fabrics.

One potential application of bioengineered fibers is improved dyeability. Cotton yarn must be dyed in most cases. Because of the poor reactivity of cotton with chemicals (cotton fiber and dye have the same electric charge and tend to magnetically repel), dyeing cotton is one of the most expensive processes of the entire value chain requiring high energy and water consumption.

These challenges encountered during cotton processing might be addressed by novel bioengineered cotton fibers. By modifying the reactivity of cotton (i.e., changing the fiber charge), it is possible to create cotton fiber that is more reactive to dyes. Early research has already shown that this modified fiber can improve dyeability, and although the technology is still years away, it shows tremendous promise that one day new varieties of cotton could potentially eliminate or reduce the need for energy-intensive processing steps and contribute directly to more sustainable and environmentally friendly production of cotton textiles.

Conclusion

To date, biotechnology has delivered valuable farmer benefits, with insect resistance and herbicide tolerance providing growers the ability to effectively and efficiently manage pests and weeds. Continuous innovation creating novel insect resistance and herbicide tolerances is addressing the ongoing challenges of pest and weed control as well as resistance management, and exciting developments are expected in the near future.

At the same time, other promising applications of biotechnology are in the pipeline, and should be available to farmers in the medium & longer term:

- In the next technological wave (2016 - 2020), Lygus control, drought tolerance and water use efficiency, yield enhancement are anticipated.
- In the subsequent wave (2021 - 2025), additional insect control (other than lepidopteran), nematode control, disease resistance, heat and salinity tolerance, nitrogen use efficiency, improved fiber quality and bio-engineered fibers could be expected.

Cotton production continues to benefit from the application of biotechnology including genetic modification. Biotechnology can be used to deliver quality enhancements in cotton textiles, although the full realization of the improvements will be in the next 10 to 15 year timeframe. In the shorter term (5-10 years), biotechnology will continue to be

applied in order to increase yield and reduce costs, to the benefit of industrial and farm segments.

References:

1. Terhaar, A. 2009. South West Farm Press June 10, 2009.
2. Chaudhry, R. (International Cotton Advisory Committee). 2009. Global context of cotton production. September 21 - 25, 2009.
3. James, C. 2011. ISAAA Brief 422010: Executive Summary. Global Status of Commercialized Biotech GM Crops: 2010.
4. Sadashivappa, P., and M. Qaim. 2009. Bt cotton in India: development of benefits and the role of government seed prices interventions. *AgBioForum* 12: 172-183.
5. Graham Brookes and Peter Barfoot, Global Impact of Biotech Crops: Income and Production Effects, 1996 - 2008, *AgBioForum*, 13(1): 76-94. 2010.
6. Julian Raymond Park, Ian McFarlane, Richard Hartley Phipps and Graziano Ceddia, 2011, the role of transgenic crops in sustainable development, *Plant Biotechnology Journal* (2011) 9, pp. 2-21.
7. Stein, A. J. and Rodriguez-Cerezo, E. 2009. The global pipeline of new GM crops. JRC European Commission (EUR 23486 EN 2009)
8. <http://www.epa.gov/nitrousoxide/sources.html>.
9. <http://www.epa.gov/nitrousoxide/scientific.html>.

About Bayer CropScience

Bayer is a global enterprise with core competencies in the fields of health care, nutrition and high-tech materials. Bayer CropScience, a subgroup of Bayer AG with annual sales of EUR 6.830 billion (2010), is one of the world's leading innovative crop science companies in the areas of crop protection, nonagricultural pest control, seeds and traits. The company offers an outstanding range of products and extensive service backup for modern, sustainable agriculture and for nonagricultural applications. Bayer CropScience has a global workforce of 20,700 and is represented in more than 120 countries.

Originally published in the New Cloth Market, February, 2012.