Current and Future Traits for Transgenic Cotton

Marc Giband (CIRAD / giband@cnpa.embrapa.br) (*)

Introduction

Since their first introduction on the market in 1996, transgenic (or genetically-modified [GM]) cotton varieties have been gaining a significant share of the acreage devoted to cotton cultivation. Increasing from the 0.8 million hectares of insect-resistant GM varieties grown in 1996, areas devoted to transgenic cotton varieties reached a total of 9 million hectares in 2004.

Traits that have been imparted to cotton varieties through genetic engineering include insect resistance, herbicide tolerance, and the combination of both these traits. While single *Bacillus thuringiensis* (Bt) crystal protein (*cry*) gene events were the only ones available for insect resistance for many years, "second generation" events carrying two Bt *cry* genes have been introduced recently. Varieties carrying other genes conferring insect resistance will soon be available.

Similarly, herbicide tolerant varieties were for many years restricted to a single herbicide. But recently, varieties tolerant to a second herbicide were introduced on the market.

Research related to the improvement of cotton is active in many areas, and this may allow the identification and characterization of genes (and gene combinations) responsible for the elaboration of important traits. Areas under investigation are those that relate to agronomical and economical traits, which include resistance to pests and diseases, as well as fiber and seed quality.

Key words: transgenic cotton, genetic engineering, traits

Distribution of transgenic cotton

Cotton was one of the first crop species to benefit from the advances in plant genetic engineering, and was one of the first species to gain approval for commercial release. In 1996, its introductory year, transgenic cotton was grown on approximately 0.8 million hectares in 3 countries (the USA, Australia, Mexico). In 2004, less than ten years after its introduction, areas devoted to transgenic cotton reached a total of 9 million hectares. This area represents 28% of the 32 million hectares devoted to cotton cultivation worldwide.

In 2004, transgenic cotton was officially grown in 8 countries (The USA, Australia, South Africa, Mexico, Argentina, Colombia, India, and the P.R. China), amongst which are some of the major cotton-producing countries.

In countries where GM cotton was approved for cultivation, the rate of adoption of these varieties by growers has been very high. For example, transgenic cotton accounts for 76% of the US Upland cotton that was plated in 2004, while in the P.R. China, this figure was of 66%, and of 85% in South Africa. In Australia, where the 30% cap for transgenic varieties was lifted with the introduction of "second generation" insect-resistant varieties (see below), the adoption rate has reached 80%. In India, one of the latest countries to have adopted transgenic varieties (in 2002), a five-fold increase in transgenic cotton planting was observed between 2003 and 2004.

Many more countries in all part of the world are evaluating the potential benefits of transgenic varieties, and are developing adequate legislations to test and allow the commercial release of such varieties. It is thus probable that many more countries will be growing transgenic varieties in the near future.
With the notable exception of some varieties developed by the Chinese Academy of Agricultural Sciences in Beijing, all transgenic cotton varieties that are presently grown were developed by the private sector.

Events and traits expressed by transgenic varieties
The traits that have been imparted to transgenic varieties include insect resistance, herbicide tolerance, and the combination of both. Among the 9 million hectares devoted to transgenic varieties, 4.5 million hectares (50%) are devoted to insect-resistant varieties, 1.5 million hectares (16%) to herbicide-tolerant varieties, while the rest (3 million hectares, or 33%) are devoted to varieties combining both traits.
The market for herbicide-resistant varieties was dominated by a single event (Roundup Ready® varieties, tolerant to glyphosate) until the very recent (2004) commercialisation of glufosinate-tolerant varieties (LibertyLink® Cotton) that were grown on a small scale in the USA. Although Buctril-tolerant varieties (BXN®) were also developed, they did not gain an as important market share.
Similarly, between 1996 and 2003, the market for insect-resistant varieties was restricted to a single event (Bollgard®, or Ingard® in Australia), even though a number of varieties containing the same gene had been made available. The gene (*cry1Ac* gene) responsible for the trait (commonly referred to as "Bt gene") was isolated from the soil bacterium *Bacillus thuringiensis* and encodes a protein that shows entomopathogenic properties towards a certain number of lepidopteran pests of cotton. Some of the Chinese varieties bear, in addition to the Bt gene, a second gene encoding a protease inhibitor isolated from cowpea (CpTi). These varieties target some of the major lepidopteran pests of cotton, including *Heliothis/Helicoverpa sp.*, *Pectinophora sp.*, *Earias sp.*, and *Alabama sp*. Nevertheless, they are not effective some other important lepidopteran (for ex. *Spodoptera sp.*) and non-lepidopteran insect species.
In order to broaden the range of species that could be controlled by transgenic varieties, "second generation" varieties were introduced in 2003. These varieties (Bollgard II®) express two different Bt *cry* genes (*cry1Ac* and *cry2Ab*), thus offering better protection against the above-mentioned species, as well as a certain level of protection against *Spodoptera sp*. In addition to broadening the host spectrum and adding additional protection, such "2 gene varieties", if deployed adequately, may help in delaying the development of (insect) resistance to the expressed toxins.
In 2005, another "2 genes" event (Wide Strike®) will be commercialized after having obtained approval. This event also carries two Bt *cry* genes (*cry1Ac* and *cry1Fa2*), each one with a different spectrum of activity. The major cotton pests that are targeted by these varieties are basically the same ones as those targeted by Bollgard II®.

Future traits for transgenic cotton
Within the very close future (2006?), new transgenic varieties should be released. These include Roundup Ready Flex® varieties, with improved tolerance to the herbicide glyphosate, and VipCot® insect-resistant varieties. These latter varieties express a gene (*vip3a*) that encodes a protein ("Vegetative Insecticidal Protein") with a broad spectrum of activity against many cotton pests. Although

being isolated from *B. thuringiensis*, the VIP protein is different from the CRY proteins expressed in the other insect-resistant varieties.

Input traits, such as pest (and eventually disease) resistance, or herbicide tolerance are the areas where significant progress is likely to take place in the near future. Indeed, these are trait that offer potential returns to both the growers and the developers of the technology.

Some other traits, including resistance to abiotic stresses, although important may they be, are much more complex to apprehend, and are thus longer term goals for cotton improvement through genetic engineering.

The improvement of seed and fiber quality through genetic engineering has also received some attention. The modification of cotton seed oil quality and the development of gossypol-free seeds are traits that have been targeted.

But one of the areas that is received a growing interest is that of fiber improvement. Early efforts aimed at improving fiber quality through the introduction of single genes (targeting, for example, fiber color or fiber thermal properties) did not lead to significant results. More recent efforts in the areas of molecular genetics (genetic mapping and QTL analysis) and of fiber functional genomics are aimed at a better understanding of the molecular event that underlie the elaboration of the various components of fiber quality. The conjunction of these different approaches should lead to the identification of key genes in fiber development, and to a better understanding of how fiber development impacts on fiber quality. With this information in hand, it may be possible to modify some of the fiber characteristics to impart enhanced - or even new - properties important to the cotton industry.

Nevertheless, these “output” traits have a much more complex genetic basis that the “input” traits that have been conferred to transgenic cotton to date. It is thus probable that the commercial application of these scientific achievements will take more efforts and time.

(*) The author acknowledges the support from FACUAL for his stay at EMBRAPA-Algodão, Campina Grande