REVIEW ARTICLE

TEXTILE PERFORMANCE OF TRANSGENIC COTTON FIBER

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Abstract: Cotton is the world's largest textile fiber crop and has been used for producing garments, paper products, cottonseed oil and other purposes for many years. It belongs to genus *Gossypium* of *Malvaceae* family and includes about 50 species. Out of these 50, only four species are commercially cultivated which produce spinnablefiber, two of these Gossypium arboreum, Gossypium herbaceum are are diploid (AA) while Gossypium hirsutum and Gossypium barbadanse are tetraploid (AADD). Cotton being white gold for textile industry faces a severe problem of low fiber quality. The most effective way to increase fiber quality and yield is to clarify the genetic factors conditioning fiber quality. A genotype which is developed by the techniques of genetic engineering is referred to as transgenic. The first transgenic plant (Bt cotton) was created by genetically altering the cotton genome to express a microbial protein from the bacterium *Bacillus thuringiensis*using Cry 1 Ab and Cry 1 Ac genes in 1987 in U.S.A. by Monsanto, Delta and Pine companies. Advantages of Bt cotton are improved fiber length, fiber strength, uniformity index, micronaire, maturity, and fiber elongation.

Keywords: Cotton, Fiber quality, Genes, Genetic modification, Transgenic

INTRODUCTION

Fibers from various natural sources have been the exclusive raw materials for textiles and related products for many centuries. However, their dominance was lost with the advent of synthetic polymeric fibers. Breakthroughs in chemical engineering, polymer chemistry and innovations in marketing have enabled man-made fibers to achieve a market share of 62 %, while cotton has shrunk to 32% (John,1998).

Cotton being white gold for textile industry faces a severe problem of low fiber quality. Fiber quality refers to the economic weight of lint physical property and is often measured by fiber length, strength, elongation, uniformity, and micronaire reading. While fiber yield is the major emphasis for cotton breeding projects, fiber quality is one of the most notable properties of cotton improvement at present. With technological advances in the textile industry, particularly advances in spinning technology, have led to increased emphasis on breeding cotton for more uniform, longer, finer and stronger fibers are required to produce more competitive products with higher efficiency, thus growers who can produce cotton fiber with the premium characteristics will be more competitive. The most effective way to increase fiber quality is to clarify the genetic factors conditioning fiber quality. DNA molecular marker technologies provide a method to define the genetic factors affecting fiber quality. The first genetic map for cotton was constructed by Reinisch et al. (1994), using restriction fragment length polymorphism (RFLP) markers.

Today, the natural fiber industry, especially cotton, must use newer technologies, such as genetic engineering, to increase yield and quality. Furthermore, they can reduce the cost of production and decrease the adverse impact on the environment. Plant breeding relies on the exchange of part of the gene pool from one cultivar into another compatible one. Several decades of painstaking plant breeding have resulted in improved cotton varieties for agronomical and fiber traits. To these varieties, can be add new agronomical and fiber traits through genetic engineering e.g., insect and herbicide resistance can be added to different elite commercial varieties.

Transgenic Cotton (Bt Cotton)

A genotype or individual which is developed by the techniques of genetic engineering is referred to as transgenic. In other words, genetically engineered organisms are called transgenics. A transgenic may be a plant, an animal or a microbe. The first transgenic plant was developed in 1983 in tobacco in U.S.A. In cotton, the first transgenic plant was developed in 1987 in U.S.A. by Monsanto, Delta and Pine companies.

Bt Cotton refers to transgenic cotton is produced by inserting a foreign gene or genetically modified gene from naturally occurring soil bacterium *Bacillus thuringiensis*, into cotton. The primary reason this is done is to induce the plant to produce its own Bt toxin to destroy the bollworm, a major cotton pest. The gene causes the production of Bt toxin in all parts of the cotton plant throughout its entire life span. When the bollworm ingests any part of the plant, the Bt cotton toxin pierces its small intestine and kills the insect.

The transgenic cotton is of two types viz.

(1) Bollgaurdand

(2) Roundup ready cotton.

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The former confers resistance to bollworms and the latter is resistant to herbicides. The area under herbicide resistant transgenic cotton is resticted to USA. However, bollworm resistant Bt transgenic cotton has spread to several countries. Transgenic disease resistant cottons have not yet been developed.

In India, a few resistant genes against Fusarium and Verticillium wilts have been isolated and are being transformed into cotton. Chinese scientists have isolated 'GO' gene and have transformed them into cotton which have shown resistance to both the wilts. Chakravarthy*et al.* 2014.studiedthat the genetically engineered cotton varieties, expressing *Bacillus thuringiensis* cry genes, proved to be highly successful in controlling the bollworm complex. Various other candidate genes responsible for resistance to insect pests and pathogens, tolerance to major abiotic stress factors such as temperature, drought and salinity, have been introduced into cotton via genetic engineering methods to enhance the agronomic performance of cotton cultivars. Furthermore, genes for improving the seed oil quality and fiber characteristics have been identified and introduced into cotton cultivars.

Tang *et. al.* 2015. constructed a genetic map and QTL are detected based on an intraspecific recombinant inbred line population derived from a cross between Upland cotton cultivar/line Yumian 1 and 7235. A total of 25,313 SSR primer pairs, including 5,000 developed from G. raimondiiBAC-ends sequences, were used to construct the genetic map which finally contained 1,540 loci, spanning 2,842.06 cM, with an average of 1.85 cM between adjacent markers. With 4 year fiber quality traits data, variance analysis revealed that they were significantly affected by genetic and environmental factors. The genetic map and stable QTL are valuable for Upland cotton genome research and breeding projects to improve fiber quality.

What is Bt?

The Bt is a short form of ubiquitous soil bacterioum*Bacillus thuringiensis*.*Bacillus thuringiensis* discovered by Ishiwatari in 1901.This bacterium is gram positive and spore forming that forms parasporal crystals during stationary phase of its growth cycle.The synthesized crystalline proteins called 'endotoxins' are highly toxic to certain insects. They kill the insect by acting on the epithelium tissues of midgut of caterpillars. These protein often appear microscopically as distinctly shaped crystals and constitute about 20-30% of dry weight of sporulated cultures. These proteins are characterized by their insecticidal activity and are therefore grouped into four classes i.e.Lepidoptera-specific (Cry I), Lepidoptera and Diptera-specific (Cry II), Coleoptera-specific (Cry III) andDiptera-specific (Cry IV).

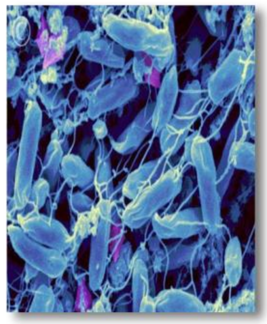
Different strains of Bt produce more than 25 different but related insecticidal crystal proteins (ICPs). These are toxic to larvae of different insects including disease vectors and many agricultural pests. Cotton bollworms belong to the order Lepidoptera and therefore are sensitive to Bt Cry I and Cry II proteins, which are specific to them. Other beneficial insects are unaffected by these proteins. The gene bank data base of Bacillus Genetic Stock Centre (BCSC) have given a list of Cry(Crystal), Cyt(Cytolytic) and Vip genes either synthetic or modified versions from *B.thuringiensis.*

Structure of Cry protein

Domain I	7 α-helix Helps in membrane insertion
Domain II	β-prism of 3 antiparallel β- sheets Helps in receptor recognition
Domain III	β-sandwich of antiparallel β - sheeets

Crystal structure of Cry protein

Thesecrystalproteins (Cry proteins) are insect stomach poisons. Insects stop feeding within two hours of a first bite and, if enough toxin is eaten, die within two or three days. *BT* crystals, sometimes referred as insecticidal crystal proteins (ICP), are protein crystals formed during sporulation in some *Bt*strains coded by *cry* genes.



Crystalline protein

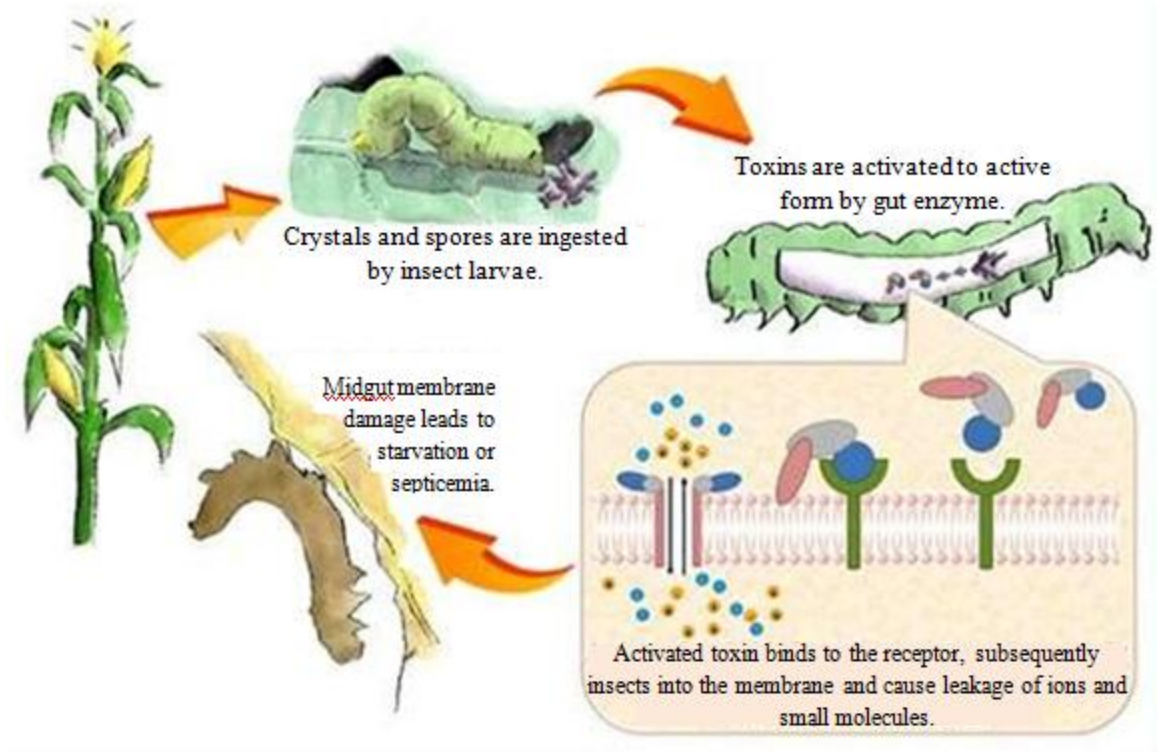
Rashid *et. al.* 2009conductedfield evaluation of second generation of transgenic cotton expressing *Bacillus thuringiensis* (Bt) genes cry1Ac and cry2A under CaMV35S promoter. Fiber analysis showed improved gin turn out 40% for transgenic lines in comparison to 32% for non-transformed lines.

How Btworks ?

Bts contain protein endotoxin crystals and living spores. With insect populations, the protein endotoxin acts as a selective stomach poison. Spores contribute to their toxicity by causing blood

poisoning and providing persistence in the insect's system.
When an insect pest ingests the crystal proteins from leaves treated with Bt, feeding stops within minutes after the crystals are made soluble in the gut. The *Bt* toxin dissolve in the high pH insect gut and become active. The toxins then attack the gut cells of the insect, punching holes in the lining. The *Bt* spores spills out of the gut and germinate in the insect. The affected larvae move slowly, discolor, then shrivel, blacken, and die within 1-3 days. Smaller larvae die more quickly.

Mechanism:



Wielgus*et. al.*, 2012.proposed that the genetic engineering and biotechnology give opportunities to improve the yield and quality of fiber crops precisely and more efficiently as compared with traditional breeding methods. From commercially available biotech crops, cotton is one of the most popular transgenic crops constituting 49% of total cotton production.

Technology of production

Main steps for developing transgenic crops:

1. Identification of effective genes
2. Gene transfer
3. Regeneration from protoplast/callus/tissue
4. Gene expression to the desired level
5. Back cross to produce varieties
6. Field test
7. Approval for commercialization

Perlak*et.al*.1991.transferred successfully the Cry 1 Ac gene to cotton via agrobacterium with CaMV promoter and the Cry protein produces by transgenic cotton was found highly toxic to bollworms.

Li *et al*. 2004.reported that the transformation through vacuum infiltration and agrobacterium mediated transformation was a efficient way to introduce foreign genes into the cotton pollen grain. The acsA and acsB genes, which are involved in cellulose synthesis in Acetobacterxylinum, were transferred into pollen grains of brown cotton with the aim of improving its fiber quality by incorporating useful prokaryotic features into the colored cotton plants. Results was found that in the brown cotton ~15% increase in fiber length and strength by expressing acsA and acsB cellulose synthesis genes from A.*xylinum*.

Ahmed *et al*., 2018. studied that the conventional approaches like breeding have not much success in fulfilling the requirement of fiber quality. Current approach in molecular studies have helped to describe genes involved in fiber elongation such as CEL, CelA1, CelA1, Exp1, ACT 1, BG, Pel, SuS1, LPT3, GhE6, pGhEX1, GhCESA1, and aquaporins in addition to transcription factors like MYB, WRKY, AP2/EREBP, C2H2 and bHLH families, which might have vital role in fiber cell initiation. Besides these different genes, phytohormones also have a progressive role in fiber development.

Shah *et. al*., 2020.conducted a study onBt cotton in BSW–BTC with 45-days-old seedlings showed better performance for allometric (leaf area index, (LAI), net assimilation rate, (NAR), and crop growth rate, (CGR)), seed cotton yield, and fiber traits (fiber uniformity, fiber length, fiber strength, and fiber fineness) in comparison to other treatments. Most of the fiber quality traits were positively correlated with allometric traits and biological yield (dry matter yield at maturity) at both locations, except correlations of CGR and LAI with fiber fineness and fiber length and NAR with fiber length. As plant growth and fiber quality of transplanted cotton was significantly higher than conventionally grown cotton.

Effect of Bt Cotton on Lint Quality Characters

Among all Bt cotton, the staple length ranges from 29 to 31 mm.Staple elongation of Bollgard II was greater (6.6%) than conventional variety. Although micronaire values of all the transgenic and conventional varieties were less than 5.0 but the micronaire value of Bollgard II was the highest. The micronaire value of transgenic varieties was greater than conventional non Bt variety. Transgenic cotton varieties have fiber uniformity varied between 83 to 85.The fiber strength remained between 26-32 CN/tex.The staple strength of cotton fiber indicate that there was significant effect of transgenic cotton on fiber strength. Transgenic cotton engineered with fiber-related genes has been reported to enhance length, strength, color and other fiber-related properties (Richter 1998, May and Wofford 2000, Zhang et al. 2004, Li et al. 2004,Shangguan *et al.*, 2007, Qin *et al.* 2007).

Bajwa *et al.* 2013.studied that a fiber-related gene from a different source was expressed in cotton by they introduced fiber-specific gene from *Calotropis procera* into a local cotton cultivar and reported increased fiber fineness and strength as compared to the control variety.

Xiao *et al.* 2018.suggested that the plant hormones play a vital role in cotton fiber growth and development. In their experiment, application of exogenous GA3 not only promoted fiber length but also increased the thickness of cell wall significantly. Long length cotton fibers with thicker cell wall and increased dry weight per unit cell length were obtained after GA treatment.

Rajput *et. al.*, 2017.studied the effect of different transgenic Bt cotton on the fiber quality of different Bt cotton varieties. Three transgenic Bt cotton varieties CCR141, CCRI79 and Bollgard II were planted in the field of Institute of Cotton Research Chinese Academy of Agricultural Sciences during 2012 and 2013. Randomly 50 bolls lint sample were collected from top, middle and bottom of the cotton plants. The fiber obtained from the boll samples was used to measure the cotton fiber staple length (mm), staple elongation (%), staple micronaire value, staple strength (cN/tex) and staple uniformity (%) by using HVI equipment at Supervision, Inspection and Testing Center of cotton Quality, China. The result showed that fiber strength and lint quality characters of transgenic cotton varieties were significantly affected compared with conventional non Bt variety during 2012 and 2013.

Anonymous 2020.analysed lint after mechanical gin, which was showed that staple length and micronaire has not been affected by transformation procedures. Fiber length is controlled to a large degree by variety, however, area to area, variety, environment and climate affect the staple length. Mechanical gin and lint cleaning can also reduce length if lint moisture is below 5%. Maximum fiber length could be achieved if care is taken during the fiber elongation phase in the first 20 days of peak flowering. During elongation, length is decreased by high temperatures, very severe water stress, and potassium deficiency. It is increased by moderate temperatures during that same period.

Improved fiber quality

Worldwide, the fiber of cotton suffers from competition with synthetic fibers used in the manufacture of yarns and textiles, because of its poor characteristics. Improvement of traits such as fiber length, strength and uniformity employing various candidate genes driven by fiber-specific promoters would enhance the competitiveness of cotton vis-a`-vis synthetic fibers.

John and Keller 1996.developed transgenic cotton plants synthesizing a thermoplastic polymer, poly-D-(-)-3-hydroxybutyrate (PHB), by fiber-specific expression of PHAB and PHAC genes from A. *eutrophus*. The results showed that the fiber from these transgenic plants exhibited improved thermal and insulating properties.

Li *et al.*, 2009.Two cotton genotypes, Simian 3 (SM 3) and WC, were co-transformed using a mixture of four *Agrobacterium tumefaciens* cultures of strain LBA4404, each carrying a plasmid harboring the following genes, *Bt + sck* (for *Bacillus thuringenesis* protein and modified Cowpea trypsin inhibitor), *bar* (forglufosinate), *keratin*, and *fibroin*. Results indicated that there were increases in length (28.36%) and strength (8.32%) of cotton fiber by expressing silkworm fibroin (fbn) gene.

Jiang *et al.*, 2012.reported the characterization of a novel sucrose synthase (SusA1) gene from a superior quality fiber germplasm line 7235 in Gossypiumhirsutum. By association analysis, GhSusA1 was highly correlated with fiber qualities in (7235·TM-1) recombinant inbred lines based on polymorphism of GhSusA1 between 7235 and TM-1. Theresults were found that the identified GhSusA1 as a key regulator of sink strength in cotton, which is tightly associated with productivity and hence a promising candidate gene that can be developed to increase cotton fiber yield and quality.

Zhu *et al.*, 2006.conducted a study on vegetative insecticidal protein gene vip3Aa7, under the control of its native promoter and cry3A promoter, was subcloned into B. thuringiensisacrystalliferousBMB171 to generate BMB8901 and BMBvip respectively. It was found that the cotton fiber quality was improved after introducing plant-derived genes such as expansins.

Bhatti and Bardak 2020.observed association for fiber quality traits in a global germplasm collection of upland cotton using SNPs. 32 QTLs found connected to different fiber traits such as fiber length, fiber strength, uniformity index, micronaire, maturity, fiber strength and fiber elongation.

Koli*et.al*2014.screenedsixteen cotton (Gossypium sp. L.) genotypes based on different genetic backgrounds for fiber length, fiber fineness, fiber strength, fiber uniformity, fiber elongation, maturity ratio and short fiber index. Analysis of variance depicted considerable variation in these seven main fiber quality traits among sixteen cotton genotypes. The fiber length ranged from 19.70 mm to 33.50 mm with mean value of 26.16 mm. Fiber fineness was variable with average micronaire reading 3.6. Differences in fiber strength also ranged from 18.76 to 29.80 g/tex. Uniformity ratio ranged from 42 to 58. Differences in fiber elongation were also observed which ranged from 4.8 to 6.8. Maturity ratio ranged from 0.76 to 0.86. The character short fiber index showed wide variation ranged from 6.2 to 18.2. On the basis of fiber analysis for quality traits three cotton genotypes viz., PA-255, DCH-32 and RHCb-001 can be used in future breeding programme for the improvement of fiber quality traits.

Impact of Bt cotton on textile industry

The impact of Bt cotton has been healthy overall, on the Textile industry. These measures have been helpful in rebuilding confidence amongst the entrepreneurs, resulting in stabilization of market forces and hence ensured supply of raw materials at feasible costs and reducing conflict amongst competing sub-sectors. Reducing the cost of production to a certain level through monetary and fiscal reforms and reduction of interest rate by the commercial banks is always very beneficial. Quick disbursement of duty draw back rebates further eases the working capital requirements for the Textile industry. However, the policy and its resultant impact on textile sector has failed to take advantage, to a desired extent, of opportunities offered in international market by new WTO regime. Hence, adoption of Bt cotton by farmers and consequent availability of cotton has a significant impact on textile sector in terms of overall growth and quality of production to meet domestic and international demand.

Bennett *et. al.*, 2004.measuring the economic impact of genetically modified cotton in Maharashtra State, India. The research compares the performance of more than 9,000 Bt and non-Bt cotton farm plots in Maharashtra over the 2002 and 2003 growing seasons. Results show that Bt cotton varieties have had a significant positive impact on average yields and on the economic performance of cotton growers.

Sumit, 2017.assessed the adoption, attitude, impact and constraints of Bt-cotton growers from 160 respondents selected from 20 villages of Hisar and Sirsa in the native state Haryana. The results revealed that medium level of adoption was present for manure and fertilizer application, pest and diseases management and post harvest techniques of Bt-cotton production. There was a positive and favourable attitude towards environmental aspects, economical aspects, social aspects and technological aspects of Bt-cotton production technology in the respondents. It was also concluded that farmers had perceived a positive impact of Bt-cotton on their health, social, economical and ecological aspects. Therefore, Bt-cotton should be expanded among all cotton growers to harvest benefits in term of higher yield and income.

Advantage of Bt cotton

- The Bt cotton has inbuilt genetic resistance to bollworms and is very effective in controlling the yield losses caused by bollworms to a considerable extent. The resistance is governed by a single dominant gene.
- The use of Bt cotton reduces use of pesticides resulting in reducing the cost of cultivation.
- It results in improvement of yield levels and also improves margin of profit to the farmers.
- It provides opportunities to grow cotton in areas of severe bollworm incidence.
- It promotes ecofriendly cultivation of cotton and allows multiplication of beneficial insects i.e. parasites and predators of bollworms.
- It also reduces environmental pollution and risk of health hazards associated with use of insecticides because in Bt cotton the insecticides are rarely used. An average reduction of 3.6 sprays per crop season has been reported in Bt varieties as compared to non-Bt.
- The Bt cotton fiber showed better quality with improvement in different fiber traits such as fiber length, fiber strength, uniformity index, micronaire, maturity and fiber elongation.

Disadvantages of Bt-Cotton

- **Cross Contamination:** Pollens from GMO plants they cross pollinate with grasses and weeds. This could develop “superweeds” that have the same resistance properties as the crops.
- **Not Enough Testing:** There has been very little testing and research done on genetically modified foods and the long term effects have not been discovered yet.

Khadi *et al.*, 2008.evaluated the Bt. cotton at Dharwad (Karnataka) indicated that Bt-cotton genotypes were far superior than non Bt genotypes. the yield produced was higher 41 to 66 per cent than DHH-11 hybrid. Among the three Rasi Bt cotton hybrids, RCH-2 Bt cotton was the top yielder and it gave 5-17 per cent higher yield than other Bt-genotypes. the results indicated that lint yield is increased because of increase in boll weight and boll number, which clearly indicates that Bt-gene offers protection against bollworm damage and which in turn contributes to the development of a number of healthy bolls.

Randhawa and Chhabra, 2013.expected that in the coming years, improved cotton hybrids, with stacked and multiple gene events for improved fiber quality, insect resistance, drought tolerance, and herbicide tolerance, would further significantly improve the cotton production in India. With the dramatic increase in commercialization of GM crops, there is an urgent need to develop cost-effective and robust GM detection methods for effective risk assessment and management, post release monitoring, and to solve the legal disputes.

CONCLUSION

By the year 2050, the human population is expected to reach 9 billion and as such require sustainable agricultural production to meet the demands of food and fiber. Cotton plants being the major source of fiber and seed oil, play a significant role in meeting the future needs of an ever increasing population. The commercially available insect-resistant and herbicide tolerant transgenic cotton cultivars, expressing Bt and herbicide-tolerant genes, have substantially minimized the production costs and contributed to higher yields.

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