Worldwide Impact of BT Cotton: Implications for Agricultural Research in Pakistan

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ABSTRACT

Since 2010 many BT varieties have been approved in Pakistan and also have been adopted by the farmers commercially as well. Not only is the adoption and production lower than the other BT adopter countries of the world but also development plans are slower. Pakistan needs more resistant varieties that should be susceptible to agronomic conditions of the country and safer for the environment. Effort has been made in this publication to explain the BT cotton trends in other countries of the world and also originated the need of modifications in Pakistan. More importantly, this manuscript explores the need on how BT can be effectively utilized in Pakistan. Audiences for this manuscript involve research department, extension agents along with public and private sectors and the end users (cotton growers). All researchers, policy formulators, donor agencies, authoritative groups and farmers have a responsibility to fully consider the diversity of BT.

Keywords: BT cotton, Pakistan, Genetically Modified Crop.

INTRODUCTION

Cotton is known as “white gold” and hold the significant importance as none of the country can flourish its textile industry without having cotton. This critical importance of cotton supports the farmers growing cotton worldwide as it creates urges among farmers to grow more cotton for greater return. To get the maximum return growers forget the environmental safety and they utilize more and more chemicals to boost the production. Genetically modified Cotton (BT) is the solution to this dilemma as BT is insect resistant and being adopted globally. BT not only saves the cost of the production through lesser chemical application but also keeps the beneficial insect safer. China, India and USA are the major adopters of the BT cotton and getting various benefits. Pakistan is ranked 4th in cotton production worldwide but adopted BT very late infect, year ago for commercial purpose. Globally, farmers are getting positive impacts and in Pakistan growers are also having positive remarks as BT has substantially reduced the chemical application. Moreover, BT cultivation is environment friendly which is directly or indirectly beneficial for human health. In this regard following the other countries, Pakistan has a need to reexamine the limitation, restriction and viability of BT, in the country.

Development of BT Cotton: A Global Outlook

The world is facing a lot of modifications turning into the modern era and various innovations are being created worldwide. Agriculture is the main sector worldwide and development in this sector is of key importance. In this case, the faction of genetically modified crops into the developing world continues to be a matter of widespread interest and some controversy. This association has been led by BT cotton, which incorporates one or more insecticide-producing Cry genes from the soil bacterium Bacillus Thuringiensis. From the introduction of genetically modified crops (GM) in 1996, their adoption has increased significantly till now (James, 2008). Since then, 25 countries had commercialized the genetically modified crops. Among various countries Mexico was the first adopter in 1996 followed by the China in the following year, Argentina and South Africa in 1998 while India adopted in 2002. Among West African countries, Burkina Faso commercialized BT cotton in 2008. Pakistan is a significantly agricultural country and has adopted BT cotton in 2010 commercially (Drennan and Rehman, 2013). Perlak et al. (2001)
revealed by quoting that BT cotton produces an insecticidal protein (Cry1Ac) from the soil bacterium Bacillus Thuringiensis (BT) which is naturally occurring and protects the cotton from certain lepidopteran (caterpillar) insect pests. Coker 312 cotton was transformed to express the Cry1Ac gene from BT, resulting in cotton plants that were resistant to attack from major lepidopteran pests (Perlak et al., 1990). Many years of development followed to deliver the trait in germplasm varieties that meet the strict agronomic requirements of growers worldwide (Perlak et al., 2001). BT cotton was among the first genetically modified (GM) crops to be used in commercial agriculture (Matthews and Tunstill, 1994). USA and China were the countries where BT was grown on commercial basis in the mid 1990s and till today the technology prevails on about 30-40% cotton area of both countries. The major reasons for this success were that adopters of these countries realized significant pesticides and cost saving in most of the cotton cultivation regions (Carpenter et al., 2002; Pray et al., 2002; Huang et al., 2002a). In USA, BT cotton commercialized by Monsanto is known as Bollgard cotton. For the safety of this product, several researches and testing were conducted and results found demonstrated the safety and advantages of transgenic cotton (Betz et al., 2000). After safety measures emergence prior to commercialize the transgenic cotton, human and environmental safety of Bollgard cotton was evaluated by regulatory agencies. In this regard studies conducted revealed that Bollgard cotton fractions were found sustainable equivalent to conventional bred cotton and BT protein was depicted as safer for human and animal consumption as well.

### Table 1: BT Cotton, the way it took roots across the world

<table>
<thead>
<tr>
<th>Country</th>
<th>Status and Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Introduced in 1996. By 2002–3 accounts for around 30 percent of total cotton crop. This increases to 80 percent in 2004–5 with the release of Monsanto's Bollgard II variety</td>
</tr>
<tr>
<td>Brasil</td>
<td>Field trials approved in March 2005. Smuggling of BT cotton seeds from Argentina and Paraguay is widespread. At least 5 percent of the 1.3 million tons produced in the 2005–6 season comes from “black market” BT varieties.</td>
</tr>
<tr>
<td>Colombia</td>
<td>Imported by Monsanto in 2002, without environmental clearance. Legal action results in the suspension of the authorization.</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>Monsanto began field trials without regulatory oversight in 1992. By 2004, 638 ha were planted, mainly for the export of seeds.</td>
</tr>
<tr>
<td>Egypt</td>
<td>Commercial introduction approved in 2006.</td>
</tr>
<tr>
<td>Guatemala</td>
<td>Field trials.</td>
</tr>
<tr>
<td>India</td>
<td>Commercial introduction in 2002. In 2006–7, Monsanto begins sales of Bollgard II</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Introduced in South Sulawesi Province in 2001. Two years later it is withdrawn after its failure to perform triggers farmer protests.</td>
</tr>
<tr>
<td>Kenya</td>
<td>Field trials.</td>
</tr>
<tr>
<td>Mexico</td>
<td>Approved in 1996.</td>
</tr>
<tr>
<td>Paraguay</td>
<td>Approved in 2005.</td>
</tr>
<tr>
<td>Philippines</td>
<td>Field trials.</td>
</tr>
<tr>
<td>Senegal</td>
<td>Irregular field trials later abandoned.</td>
</tr>
<tr>
<td>South Africa</td>
<td>Approved in 1997</td>
</tr>
<tr>
<td>Thailand</td>
<td>Field tests in 1997. Abandoned after mass protests.</td>
</tr>
<tr>
<td>USA</td>
<td>Approved in 1996. Currently covers about 40% of the cotton area.</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Field trials.</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>Planted by Monsanto in 1998 without official permission. Crop was burnt when discovered by authorities.</td>
</tr>
</tbody>
</table>

Source: [http://www.grain.org/article/entries/582-bt-cotton-the-facts-behind-the-hype](http://www.grain.org/article/entries/582-bt-cotton-the-facts-behind-the-hype)

### The Development and Spread of BT Cotton in Pakistan

Pakistan stands among the top four cotton producing countries of the world and farmers in Pakistan are in better intentions to adopt transgenic BT cotton. National economy of millions of farmers is depended on production. Moreover, millions of people are indirectly dependent as they are connected with entire value chain, from weaving to textile and garment exports. Being the worlds’ fourth largest cotton grower and third largest exporter of raw cotton;
Pakistan is a leading exporter of yarn globally. Therefore, it has become vital to boost the cotton production which is already half of the potential.

Various biotechnology institutes are working in Pakistan to produce genetically modified transgenic seeds of major crops such as cotton. Like Pakistan Atomic Energy Commission (PAEC), National Institute for Biotechnology and Genetic Engineering (NIBGE), Nuclear Institute of Agriculture and Biology (NIAB), Agricultural Biotechnology research institute Faisalabad, Cotton research institute Faisalabad, Cotton research institute Multan, Centre of Agricultural Biotechnology and Biochemistry (CABB) UAF and National center of Excellence in Molecular Biology (NCEMB) at Punjab University Lahore are committed to cope with such problems; significant amount of financial resources and manpower have been committed by the Government of Pakistan for developing genetically modified (GM) local cotton varieties. However, commercial release of any genetically modified crop in Pakistan including cotton needs clearance from EPA/NBC Environment Protection Agency/National Bio-safety Centre; http://www.environment.gov.pk), IPO (Intellectual Property Right Organization; http://www.ipo.gov.pk) and Ministry of Food and Agriculture. Development of infrastructure for the new bodies resulted in the delay of approval process of BT cotton by various public/private sector (Zafar, 2007).

Different agricultural research institutes of Pakistan produced different BT varieties of cotton i.e. “IR-FH-901”, “IR-NIBGE-2”, “IR-CIM-448” and “IR-CIM-443”; and recently released NIAB-886 and NIAB-777. These BT varieties have been strictly screened and evaluated by PAEC on the basis of their potential to follow the bio-safety recommendations. After that, Cotton Research Institute Faisalabad released FH-113 and FH-114 BT genetically modified varieties which were also screened by the Pakistan Agricultural research Council. Although Pakistani BT cotton varieties hold good staple length (22mm-30mm) and fitness and germination vary from 55% to 80%, but mixing or impurities were less than 2% (Anonymous, 2010).

Current Status of BT in Pakistan

BT cotton was developed in Pakistan using Monsanto’s transformation event MON531 (Cry 1A), afterward, other varieties were developed using a domestic isolated gene. In 2010, Pakistan formally approved ten cotton varieties and one cotton hybrid for commercial use, resulting in the first officially commercial cotton crop cultivated in 2010-11. Meanwhile, non-officially it has been cultivated since 2002 in Punjab and Sindh Provinces. In February 2012, the Punjab Seed Council (PSC), a provincial seed approval authority, formally approved 11 biotech and 3 conventional cotton varieties for cultivation in the Punjab region. At the federal level, no new varieties have been approved since 2010; the process has been stalled due to political reasons. This has hindered production as over 15 promising cotton varieties have completed field trials and are waiting for the completion of their risk assessment, some of them have been waiting as long as 2 years, clearly exceeding the stipulated time frame of 90 days, applicants should expect a response outlined in the regulations (Drennan and Rehman, 2013). Farmers are adopting BT in Pakistan but still production is lagging behind as Showaltera et al. (2009) demonstrated that in terms of land holding size by Pakistani farmer is almost equivalent to that of Chinese farmers but immense yield gap exist among them. In terms of yield loss due to pests, Pakistan is more likely close to India. In some areas of Pakistan BT cotton was not much successful because of variant conditions and this situation was more likely important to production loss (Rao, 2007). No doubt, BT adoption is providing benefits to the farmers through extended production and lesser cost of production but in recent past cultivation of unapproved BT varieties raised severe agricultural problems. Seed used was not fully developed according to the Pakistani agronomic conditions and resultantly performance remained poor (Shafi-ur-Rehman, 2009). Among the raised problems of unapproved BT; CLCV was majorly dominant. In 2008, incidence rate of CLCV was 54.34 while after usage of unapproved BT cultivation it was exceeded to 83.1% in 2009 (Kakakhel, 2009). This outbreak caused a significant loss in production of cotton.

Adoption of BT Cotton in Pakistan

Pakistan is an agricultural country and farmers are every time indented to get more and more production and profit as well, so how it’s possible that farmers could delay the adoption of BT cotton. BT adopters are increasing day by day as we observed during a visit to cotton regions of Punjab recently. Several studies conducted on BT adoption has also found that adoption is increasing at pace. According to the results of study conducted by Sabir et al. (2011) BT cotton area was increasing fast in Punjab province. Moreover, in cotton zone 8.15% and in the central mix zone 6.5% wheat area was noticed to have undergone under BT cotton cultivation. Similarly, 4.5% area of sugarcane from cotton zone and 1.5% in central zone was found shifted to BT cotton cultivation. Past insight indicates that in 2006 just 4% of the cultivated area in Punjab was estimated to be under BT cotton adoption (Rao, 2006). Moving forward, Ali et al. (2010) reported that in Sindh province, 80% cotton area had undergone BT cultivation. Detailed study of districts visited indicated that; in Sanghar district greater than 90% farmers were in adoption of BT cotton.
Australian BT showed here the maximum susceptibility to CL Cv (60-100%). Government of Pakistan approved initially field trials for only six BT cotton cases, but it was estimated that 70% of the 2009/2010 cotton crop was planted to BT (Carroll, 2009). Abdullah (2010) proved that BT cotton was becoming more and more popular in Punjab, Pakistan and was growing at an exponential rate in the entire province. Although BT grown was not susceptible to the bollworm complex; however, the incidence of Spotted Bollworm remained consistent on BT cotton over a season without any apparent change. Nazli (2010) indicated that Pakistan was the only country where no commercial BT was approved in-spite of this BT was being adopted by the growers since 2005 but unapproved. Several varieties of BT have been approved by the Pakistan and BT-121 was one of them which have been declared as best by the (Ahsan et al., 2011). They declared in their results that BT-121 was the most suitable cotton variety for higher quality and yield as well. The study of Ali et al. (2010) was based on two surveys to identify the adoption of BT cotton in Punjab, Pakistan. According to the findings of the first survey in 2007-08, 90% adoption was found in Sanghar district while according to the second survey in 2009-10, 100% area was observed under BT cultivation. Moreover, the proportionate area of BT cultivation had exceeded to 80% than the 50% in 2007-08.

Economic and Production Benefits

Sustainable agricultural production and maximum economic viability is not only the purpose of Pakistan research but also of entire world to develop the farming communities. In this regard worldwide efforts are being made. Creation of BT cotton was also the fruit of these efforts. Cultivation of BT cotton provided farmers with maximum benefits as according to the (Gianessi et al., 2002). BT cotton provided $20/acre net income increase in USA followed by the results of (Pray et al., 2002) where it was revealed that revenue of farmers has increased up to $549/hectare in three years. Moving forward, in South Africa, small farmers raised their production and reduced their cost of production followed by increase in net return of $25&51/hectare. This was all because of the advantages of BT cotton (Ismael et al., 2002). In India, BT is considered much successful as revealed by several researchers such as Gonsalves (2007). Sadashivappa & Qaim (2009) depicted the observation that BT farmers were able to reduce pesticides application by 40% meanwhile they were also able to get yield advantage of 30-40%. Farmers of Pakistan are also not of exception as they had attained various advantages from the BT cotton cultivation. During the recent visit of District Bahawalpur of Punjab Province we had informal discussion with BT adopters and majority of the adopters revealed that

“It was BT cotton which saved us from destruction otherwise we were even not able to maintain our cost of production through cultivation of conventional varieties. BT cotton saved expenditures and provided us with double production than the potential”

Insect Pest Attack

BT is genetically modified variety and holds the resistance against several insects and pests which saves the cost of production of farmers. Wu and Guo (2003) reported that BT cotton indirectly reduced the sucking pest attacks which ultimately save the spray application and generate the importance and viability of biological control among farmers. Following these results, Grain (2001) revealed the little awareness of lesser insect pest attack and lesser applications of insecticides; meanwhile, he also narrated that this effect may vary under different ecological conditions. It has been presented in several studies that BT cotton is highly selective because it kills only the harmful agents such as caterpillar. Moreover, beneficial insects such as honey bees, spiders, lady beetles, big-eyed bugs, pirate bugs, and parasitic wasps remain safe from any harmful effect of BT cotton. Beneficial insects are considered vital for the biological control meanwhile laboratory researches also have shown that Bt Cry1Ab has tendency to affect some beneficial insects such as lacewing larvae that eat BT killed caterpillars (Hardee et al., 2001). Comparative to non-conventionally grown cotton, BT is safer and more productive as it holds economic advantages in instances where effective insecticidal control is difficult for certain insects’ pests because of higher cost. BT cotton provides stronger resistance to the tobacco budworm along with fair resistance to the cotton bollworms which together are known as bollworm complex and cause severe loss to the cotton crop. Moreover, in Argentina this complex is major pest reducing the seed significantly (Pemsl et al., 2005). Moving forward, BT toxin also protects the cotton leaf worm, pink worm and to a lesser extent the army worms which accumulate affect the cotton crop (Pemsl et al., 2005). Regarding Indian situations BT was considered successful against the Lepidopterans and sucking pests while Mirids were considered major threat to cotton (Udikeri et al., 2008). Adoption of BT may result in a more efficient enterprise, while maintaining a high level of insect pest control. It’s obvious that insect pest control through chemicals is laborious, time consuming and labour intensive, in this case if BT is adopted it will control the insects being a resistant variety. Moreover, reduction of these resources may be diverted to other farm obligations (Hardee et al., 2001).
Effect of Insecticides on BT Cotton

It’s obvious that BT needs lesser number of sprays as BT is resistant to insects’ pests which not only reduce the cost of production but also enhance the quality. This has also been proved by many research studies (Carpenter et al., 2002; Edge et al., 2001; James, 2002). A study conducted in Maharashtra India demonstrated the reduction of insecticides/pesticides application on cotton. Results revealed that 45% of sprays were for sucking pests (vs. 24% for bollworms) and in Gujarat 76% sprays were for sucking pests (vs. only 7% for bollworms in this state where almost all the farmers are BT growers). Furthermore, Stone (2010) also revealed the reduction of 54.7% in spraying with BT cotton cultivation. On average, BT adopters use 50% less insecticides on their crop than conventionally cultivated cotton (Qaim and Janvry, 2005). Insecticide application is dependent on the socioeconomic factors of the growers and more importantly on the insect pest population or pressure on the crop. Different studies demonstrated that insecticides selection bias is a problem, as the educational level and prosperity have their influence on utilization of insecticides (Dasgupta, Meisner, & Huq, 2007; Qaim, 2003). Explanation of the statement indicates that most educated financially sound farmers hold maximum interest for their crops so they take steps according to the recommendations and with the consultation of experts. Some contradiction was also revealed when studies of (Pemsl et al., 2005; Yang et al., 2005) indicated that BT adopters didn’t decrease their spray application as much as they could despite of the BT cultivation. The explanation of these studies findings reveal that these farmers were not having enough educational level and these growers were doing applications at their own without any consultation just for maximum production purpose. On the other hand they were unaware that they were increasing their cost of production. Moreover, insecticide applier also remained unaware that it can be problematic as Widawsky et al. (1998) revealed that insecticides could be problematic if these are applied as a response to high pest pressure. Substituting BT for wide-ranging pesticides could possibly lead to a higher incidence of non-BT target pests. In fact, a few technology adopters depicted more problems with plant bugs and sucking pests. In this regard Qaim and Janvry, (2005) suggested longer term monitoring to analyze whether application will entail a decline in BT-induced pesticide reduction over a period of time. Utilization of insecticides excessive or lesser than the requirement or recommendation shows hilarious impacts. Low amounts of insecticides on high pest pressure will increase the resistance of insects’ pests rather than kill them and this is one of the major reasons of yield reduction in different countries. In China and USA, for example, yield attained was smaller than 10% on average (Carpenter et al., 2002; Pray et al., 2002; Huang et al., 2002a). In Argentina, yield reduction noted was more than the China and USA because of excessive insecticides application on BT (Qaim and Janvry, 2005) although pesticides are often heavily over used in China (Huang et al., 2002a) the major producer of Cotton at current. In above mentioned countries yield losses in conventional cotton were low and BT was mainly pesticide reducing at constant output levels. Here it can be said that BT yield effects will be greater in situation where damage of crop is not effectively controlled through chemical pesticides (Qaim and Zilbermans, 2003). Similar statement was presented by Thirtle et al. (2003) for South Africa and by Qaim (2003) for India. In Pakistan, study of Ali et al. (2010) reported lesser application of insecticides on BT cotton by BT adopters.

Impact on Environment

Any variety either its transgenic or conventional is considered most viable when it has lesser negative impacts on environment and this is also the bio-safety criteria to approve the varieties or strains for commercial purpose. BT varieties were approved globally in countries such as USA, China, South Africa and India after strict screening. The major question that arises here is how the BT is environment friendly. Various studies evaluated the impact of BT on environment. Bennett et al. (2004b); Morse et al. (2006) narrated that reduction in the number of bollworm sprays had tendency to create beneficial environment. However, excessive application of non-bollworm pesticides also hold tendency to nullify the benefits. Keeping in mind this complex situation Batie and Ervin (2001); Benbrook (2001) commented that versatile impacts of genetically modified crops particularly BT cotton, are still controversial especially in respect to long term environmental implications and sustainability. The findings of Pemsl (2006) and Wang et al. (2006) demonstrated a considerably greater usage of chemical insecticides/pesticides by the BT cotton Adopters which was not viable for environment. Pest resistance against BT-Toxin might be able to be the possible explanation of excessive insecticides application.

“Practical outlook indicates that growers utilize more or less quantity of insecticides than recommendation to control the pest pressure which not only kills the pests but increase the pests’ resistance. Next time this resistance of pests compels farmers to utilize more and more insecticides”.

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To address this issue, strategy “Refuges” is recommended in the US and other countries. Farmers are encouraged to plant a certain portion of their cotton area with conventional varieties. In these non-BT refuges, BT-susceptible insects remain undamaged, so they can mate with the resistant insects that survive on the nearby BT plot and produce non-resistant insects. In this way, a rapid increase in the frequency of resistance may be avoided (Qaim and de Janvry, 2005). In Argentina and China, it has been shown that the presence of a refuge area can control the rapid resistance buildup and associated pest outbreaks (Qaim and de Janvry, 2005; Wang et al., 2006). This practice may result in maintaining the technological advantages for a longer time period. Furthermore, control on excessive usage of insecticides and pesticides can be a suitable and economical strategy for instance; USA reduced insecticide use by 1, 870, 000 pounds of active ingredient (AI) per year in 2001 (Gianessi et al., 2002) followed by the China insecticide applications were reduced by an average of 67% and the kilogram of active ingredient by 80% (Huang et al., 2002) while South African growers reduced sprays by 66% (Ismael et al., 2002a). In Australia, 90% reduction in pesticide application was noticed because of Bollgard® (Murray, 2005). BT cotton as an alternate to conventional cotton variety could be a most suitable source preserving the beneficial organism populations (Head et al., 2001) and is compatible with Integrated Pest Management Initiatives where biological control is major purpose (Benedict & Altman, 2001). In addition, secondary positive environmental impacts also can be generated through BT adoption such as conservation of materials needed to prepare chemicals/insecticides, conserving fuel required for manufacturing and reducing the need to disposal of insecticides tanks or bottles (Leonard & Smith, 2001).

Benefits to Small Farmers

BT adoption hold tendency that can provide several benefits to the small farmers who are totally dependent on the earning from farm. First of all, increased productivity of BT reduced the agricultural risks and kept the production sustainable. Control of insect pests with lesser application of chemicals can positively impact the farmers and their families’ quality of life by increasing productivity and reducing the cost of production (Ismael et al., 2002; Pray et al., 2002). BT cotton had greater yields than the non-Bt varieties and also generates greater net profit (Ismael et al., 2002). Furthermore, in India and South Africa, the small farmers adopting BT cotton varieties were likely to be prosperous and established as they had access to fertile land and credit and had ability to afford the costs of GM cotton seed (Glover, 2003). Costs of seed of BT cotton were double than non-BT, although chemicals costs were lower, resultantly, gross margins of BT adopters were higher than the other varieties (Ismael et al., 2002). Same results were identified by Pray et al. (2000, 2001). Lesser application of chemicals reduced the harmful impacts of pesticides not only on the environment but also on the human health. Other hand several cases of human poisonings due to pesticides had been reported in numerous studies (Betz et al., 2000; Rother, 2000; Wilkinset al., 2000; Yousefi, 2000). Along with mentioned benefits, several other benefits exist on part of BT adoption such as Traxler et al. (2001) in Mexico indicated that BT cotton could make a momentous contribution to the livelihoods of smallholder farmers in many different locations such as reduction in labor costs as a result of lesser spray application. Labour reduction benefits were also demonstrated by (James, 2002).

SUMMARY

BT cotton appeared as a significantly important BT cotton is an increasingly important component for cotton growers residing around the globe. Small farmers need more attention and revenue; so, not only large or medium scale farmers but small acreage holder farmers can enjoy the productivity potential of BT cotton. Adoption of BT cotton revealed positive impacts globally as discussed in review cited but case for the Pakistan is found different where BT is commercially adopted late. In this regard Pakistan research need special attention and consideration to explore the BT cotton in much better way. In this regard Pakistan research should work with the collaboration of Developed countries research that is having adoption of BT from many years. In Pakistan majority of the farmers are small farmers so BT could be a road map for their development after little consideration of public sector.
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