Pakistan J. Agric. Res. Vol 22 No1-2, 2009.

DEVELOPMENT, ADOPTION AND PERFORMANCE OF *Bt* COTTON IN PAKISTAN: A REVIEW

Raania Ahsan* and Zafar Altaf**

ABSTRACT: This article reviews development, adoption and performance of *Bt* cotton against the background of monopoly pricing of its seed in Pakistan. The area under illegal *Bt* cotton is 80 % with nearly 36 unapproved varieties. Most of these varieties are Cotton leaf curl virus susceptible, poor in fiber quality and high input demanding unapproved varieties. Almost all these varieties employed Monsanto *Cry1Acgene* (MON 531) as it was not patented in Pakistan. A positive development was approval of Monsanto plan to introduce advanced genetically modified (GM) crop technology in Pakistan by Government of Pakistan during 2009. In this regard Ministry of Food and Agriculture (MINFA) has been working on a two pronged strategy i.e. developing the technology through indigenous capabilities as well as inviting the multi-national companies (MNCs) to bring in the latest cotton production and protection in the country. *Bt* cotton can play a significant role to enhance agricultural productivity as the productivity of cotton in Pakistan 0.5 t ha^{-1}, as compared productivity of *Bt* cotton in China 9 t ha^{-1}, which implies a huge cotton productivity gap. This gap can be narrowed down by the adoption of *Bt* cotton in Pakistan which will have major impact on food security efforts in the country. The findings of literature review revealed that *Bt* technology significantly reduces pesticide application and increases yields; however, these advantages are curbed by the high prices charged for genetically modified illegal cotton seeds in the country. National Biosafety Guidelines of 2005, must be followed to approve all genetically modified crop varieties including cotton. This will encourage the introduction of this advanced technology through legal means with its complete package of benefits. After approval of *Bt* cotton cultivation by Government of Pakistan, R&D sector should be encouraged to transfer *Bt-Cry* genes into such genetic backgrounds which: (i) must have resistance against CLCuV, (ii) are suitable for a given ecology, (iii) meet the set fiber quality parameters (fiber length and strength, GOT% etc.) and (iv) other desirable features required for the release of a normal commercial variety.

Key Words: Bacillus thuringiensis; Cottons; Development; Adoption; Performance; Impact; Pakistan.

INTRODUCTION

Globally, cotton and other crop plants require an intensive use of pesticides to inhibit insect pests population (PARC, 2007). In Pakistan, over the past 30 years, pesticides are being used to protect cotton crop against sucking and chewing insects. Among the chewing, lepidopteran are the primary pests causing 20-30 % annual yield losses in the country. Different approaches have been used to develop inbuilt resistance against the bollworms and the only successful approach to engineering crops for insect tolerance/resistance is the use of addition of *Bt* toxin, a family of toxins originally derived from soil bacteria (PARC, 2007).

Major advances in biotechnology have made it possible to directly identify and isolate genes, know their functions, and transfer them from one organism to another which have many applications for increasing plant productivity, improving plant resistance to diseases and pests, and improving the quality of the output (Gandhi and Namboodiri, 2006). *Bt* cotton was

*Europe and America, Board of Investment, Government of Pakistan,G-5/1, Islamabad, Pakistan.
**Pakistan Agricultural Research Council, Islamabad, Pakistan.

among the first transgenic crops to be used in commercial agriculture. A gene from the soil bacterium

Bacillus thuringiensis (*Bt*) has been transferred to the cotton genome (Qaim et al., 2003). This gene codes for production of a protein that is toxic to the cotton bollworm, a severe insect pest in most cotton-growing regions of the world (Qaim and de Janvry, 2004). *Bt* is a gram-positive, aerobic, spore- forming bacteria that is found in soil, plant surfaces and in grain storage dust (Qaim et al., 2003). There are almost eighty different sterotypes of *Bt*, which are capable of producing many different toxins, including endotoxins, exotoxins and enterotoxins (PARC, 2007). Toxins produced by *Bt* are known as "*Bt* toxins". The Bt toxins consist of two main types, Cry (crystal) toxins (*cry* genes) and Cyt (Cytolytic) toxins. The Cry proteins are effective against different insect orders, being the most effective against lepidoptera (caterpillars), coleoptera (beetles) and diptera - small flies and mosquitoes (Qaim and Zilberman, 2003).

At the moment, Monsanto launched Bollgard II by combining Cry2Ab2 and Cry1Ac proteins in a single product provides an additional tool to delay the development of insect resistance to Cry proteins in cotton which provides increased control of cotton bollworm, as well as certain secondary insect pests of cotton, including armyworm (PARC, 2007).

Need to Grow *Bt* cotton in Pakistan

In 1960s, Pakistan's population was 96.32 million, which grew to 122.49 million in 1990s and 163.76 million in 2008-09 (Government of Pakistan, 2009). Due to a sharp decline in mortality since the 1650s without a corresponding reduction in fertility, the population growth rate has increased from 2 % in 1950s to 3 % in 1980s. With accelerated efforts of the national population planning programme and other socioeconomic changes, a decline in fertility and birth rate occurred during the 1990s, thereby reducing the population growth rate to 2.6 % during inter-census period of 1981-1998, and further to 1.87 % per annum by 2005 which is still amongst the highest in the region (Government of Pakistan, 2009). Given the existing trend, total population is estimated to reach 167 million by 2010 and 194 million by 2020 (NIPS, 2008). In the wake of growing population, the need for food security, provision of employment opportunities and housing are being burden on the economy and without population stabilization, addressing the critical issue such as global warming, biodiversity, the environment, energy, food supply, water supply, migration and security is extremely difficult (Government of Pakistan, 2009).

These population and resource facts, combined with a renewable commitment to fighting poverty, indicate that the main thrust of national policies aimed at solving issues of rural poverty and food insecurity must include broader agricultural and rural development objectives, such as significant increase in food production (Hayee, 2005). He further argued that to escape from poverty, rural population depends directly or indirectly on increased agricultural productivity and an innovation that increases productivity will have a major impact on food-security efforts. Bt cotton can play a significant role to enhance agricultural productivity as the productivity of cotton in Pakistan is 0.5 t ha^{-1} as compared productivity of *Bt* cotton in China is 9 t ha^{-1} which implies a huge cotton productivity gap. This gap can be narrowed down by the adoption of *Bt* cotton in Pakistan which will have major impact on food security efforts in the country.

METHODOLOGY

Development, adoption and performance of *Bt* cotton in Pakistan is assessed by reviewing the already work done in Pakistan and the world. A comprehensive literature on development, adoption and performance of *Bt* cotton in the world and Pakistan was reviewed. Historic perspective of development, adoption and performance of *Bt* cotton were analyzed and discussed.

RESULTS AND DISCUSSION

Background of *Bt* Cotton in the World

Bacillus thuringiensis, commonly known as *Bt* is a bacterium that occurs naturally in soil which has been used as a biological pesticide for more than 50 years (Qaim and Zilberman, 2003). It is a gram positive bacterium discovered by Japanese bacteriologist during 1901, from diseased silkworm (*Bombyx mori)* larvae, produces proteinaceous crystalline inclusion bodies upon sporulation. Berliner isolated from diseased larvae of *Ephetia kuhniella* and designated as *Bacillus thuringiensis* during 1915. Further research of *Bt* led to renewed interest in biopesticides and as a result more potent products such as Thuricide® and Dipel® were introduced (Barton et al., 1987). There are several subspecies of this bacterium which are effective against *Lepidopteran*, *Coleopteran* and *Dipteran* insects (Hoftey and Whitley, 1989). Formulations based on *Bt* occupy the key position accounting for 90% of the total biopesticides (Neale, 1997). The insecticidal proteins produce in the crystal form constitute two different families, *Cry* and *Cyt*, which have been further classified on the basis of amino acid identity into 300 *Cry* and 22 *Cyt* sub-groups (http://epunix.biolos. susx.ac .uk/home/Neil_Crickmore/Bt/ toxins.html).

The identification of *Bacillus thuringeinsis* var kurstaki strain provided a boost for the commercialization of *Bt* product in the market. The problems associated with the *Bt* formulation based biopesticides such as shelf life, potency and the presence of viable spores have been overcome by using modern tools in microbiology and genetic engineering (PARC, 2007). Genes encoding for the d- endotoxins have been cloned since 1980s (Schneph and Whitley, 1981) and the expression of introduced gene in tobacco and tomato provided the first examples of genetically modified plants with resistance to insects (Barton et al., 1987).

Development of *Bt* Cotton in Pakistan

Pakistan, unlike its neighbor India was slow to adopt *Bt* cotton and proper legislation (Biosafety rules, SOPs for GM crop release, Plant Breeders Rights and Seed Act 1976 amendments) was either delayed or not yet promulgated thus delaying the available technology to the farmers. Rao (2009) narrated the history of development of *Bt* cotton in Pakissan. Pakistan Atomic Energy Commission (PAEC) had sought special permission in 1997 from the Ministry of Environment under “Voluntary Code of Conduct for release of genetically modified organism (GMO) into the environment” prepared by NIBGE; and it conducted, checked and analyzed many safety tests on various cotton varieties which contain gene of GMO called *Bacillus thuringiensis* (*Bt*), a bacterium that is deadly to the “Sundies”.

Pakistan enacted the Biosafety Rules in April 2005 which provide legal requirements for import, export, transport, and handling of biological agents, genetic engineering organisms or vectors, seeds, crops and foods, besides setting conditions for the researchers; seeds developers and companies (Pakissan.com). In May 2005 PAEC provided 40,000.00 kg basic seed of *Bt* cotton (insect resistant) varieties “IR-FH-901”, “IR-NIBGE-2”, “IR-CIM-448” and “IR-CIM-443”.

Recently, National Biosafety Committee (NBC) of EPA of GoP approved six cases of *Bt* cotton (*Cry lAc*- event MON 531) based on previous history of its safe usage in other parts of the world. The MON 531 event is not patented in Pakistan and GoP is using flexibility of TRIPS regulation of Data Exclusivity (39A) allowing parties to use Biosafety data of others. At least six national seed companies have been given permission for field testing. It will take another year for commercial approval and officially approved *Bt* cotton (+MON531 event) will not be available till 2010-11 season. Meanwhile unapproved seed sale of *Bt* cotton will touch the mark of almost 100% during this season which will start in April-May this year. GoP also approved import of *Bt* cotton hybrid seed to Monsanto as well as to National seed company (Guard) from India. Another approval was given to import *Bt* cotton from China (Ali Akbar and Auriga) for evaluation (Pakissan.com).

A positive development was approval of Monsanto plan to introduce advanced GM crop technology in Pakistan by Government of Pakistan during 2009. In this regard Ministry of Food and Agriculture (MINFA) has been working on a two pronged strategy i.e. developing the technology through indigenous capabilities as well as inviting the multi-national companies (MNCs) to bring in the latest cotton production and protection in the country (Government of Pakistan, 2009). In this respect letter of intent and memorandum of understanding has been signed with Monsanto Company for introduction of latest technology (bollgard-II) in the country to maximize cotton production. National Biosafety Committee (NBC) of Ministry of Environment has also authorized biosafety clearance to eight cotton varieties with bollard-I in the country (Government of Pakistan, 2009). It is expected that if followed in letter and spirit this will pave the way for establishment of viable seed industry in Pakistan (Pakissan.com).

Cotton is cultivated on large area in Pakistan-3.2 million ha and thus a lucrative seed market for MNC, Chinese seed companies as well as for national seed sector. It is essential that GoP should move faster to formulate efficient and effective laws to build viable seed sector in the country. Technology is available, though at a cost. Almost 100 percent *Bt* cotton in India is by foreign technology (not by their public sector) Asking price is also declining rapidly. Even genuine investor needs return of his investment. To achieve target of 20 million bales in 2015 we have to make best use of available technologies from USA, China and even from India. A level playing flied is needed for public as well as for private (national/MNC) sector (Pakissan.com) .

Global Adoption of *Bt* Cotton

Bt cotton was among the first transgenic crops to be used in commercial agriculture (Qaim et al., 2003). Commercial cultivation of *Bt* cotton has taken in US, Australia and Mexico in 1996, and by China and South Africa after a lag of one year. Countries such as India, Indonesia and Colombia have taken up its commercial cultivation much later, since 2002. Over half of the world cotton production is from Biotech cotton (not only *Bt* but herbicide tolerant also). More than 15 cotton producing countries officially approved cultivation of Biotech cotton. Among the top cotton producing countries, Pakistan is a major exception.

Bt was developed by the US company Monsanto as one of the first GM crop technologies which became commercially available in the mid-1990s (Gandhi and Namboodiri, 2006). Since the introduction transgenic crops in 1996, there has been a substantial increase in their area (Chaturvedi, 2002). *Bt* is currently grown in a large number of countries, including United States (95%), China (95%), Australia (89%), South Africa (80%), India (70%), Argentina (40%), Indonesia and Pakistan (Gandhi and Namboodiri, 2006 and PARC, 2007).

In the USA and China, *Bt* cotton covers about 30–40% of the cotton area in both countries (Qaim and de Janvry, 2005). Recent studies show that USA and Chinese *Bt* adopters realize significant pesticide and cost savings in most cotton-producing regions (Carpenter et al., 2002; Pray et al., 2002; Huang et al., 2002a). Preliminary benefits of *Bt* cotton have also been reported for South Africa (Thirtle et al., 2003 and Isma¨el et al., 2002) and Mexico (Traxler et al., 2001). Nonetheless, relatively little is known about *Bt*–insecticide interactions and productivity effects under different agroecological conditions (GRAIN, 2001). The broader impacts of GM crops in general, and *Bt* cotton in particular, are still a matter of controversy, especially with respect to long-term environmental implications and sustainability (Batie and Ervin, 2001; Benbrook, 2001 and UK Soil Association, 2002). This holds true both in developed and developing countries.

USA, China and Australia have reported positive experiences with *Bt* cotton. *Bt* cotton has spread very rapidly in China. There is good demand for it from the farmers since it reduces the cost of pesticide applications as well as the exposure to pesticides (Gandhi and Namboodiri, 2006). In China the government has played a major role in providing GM technology to the farmers (Pray et al., 2002).

In Argentina, *Bt* cotton was patented by Monsanto and released in 1998 by Genética Mandiyú, a joint venture between Monsanto, Delta and Pine Land (D&PL), and the local company Ciagro (Qaim and de Janvry, 2004). Unlike other countries, however, in Argentina the diffusion of *Bt* cotton has been rather slow. According to official statistics, four years after its introduction, *Bt* technology only covered about 5% of the national cotton area in Argentina as compared to GM soybeans which were adopted almost completely in the country within a similar time frame (Qaim and de Janvry, 2004). However, their introduction in India has been relatively late and controversial and they still have considerable ground to cover in the country (Gandhi and Namboodiri, 2006).

Adoption of *Bt* Cotton in Pakistan

Pakistan, unlike its neighbor India was slow to adopt *Bt* cotton. Proper legislation (Biosafety rules, SOPs for GM crop release, Plant Breeders Rights and Seed Act 1976 amendments) was either delayed or not yet promulgated thus delaying the available technology to the farmers (PARC, 2007). *Bt* cotton (insect resistant) varieties “IR-FH-901”, “IR-NIBGE-2”, “IR-CIM-448” and “IR-CIM-443” were grown over 8,000 acres of land during 2005-06. Large quantities of illegal Bt seed are in use. PARC (2007) revealed that area under illegal Bt cotton is 80 % with nearly 36 unapproved varieties. Most of these varieties are Cotton leaf curl virus susceptible, poor in fiber quality and high input demanding unapproved varieties. Almost all these varieties employed Monsanto Cry1Acgene (MON 531) as it was not patented in Pakistan.

Impact of Bt Cotton in the World

Qaim and de Janvry (2003) analyzed the adoption and impacts of Bt cotton in Argentina against the background of monopoly pricing. Based on survey data, it is shown that the technology significantly reduces insecticide applications and increases yields; however, these advantages are curbed by the high price charged for GM seeds. Using the contingent evaluation method, it is shown that farmers’ average willingness to pay is less than half the actual technology price. A lower price would not only increase benefits for growers, but could also multiply company profits, thus, resulting in a Pareto improvement.

Qaim et al. (2003) assessed the agronomics and sustainability of transgenic cotton in Argentina. Study results revealed that Transgenic *Bt* cotton can half pesticide application rates in Argentina while significantly increasing yields. Yield effects are bigger than in other countries, due to the current low levels of insecticide use. Although smallholder farmers are not currently using the technology, gross benefits are predicted to be highest for them. Biological model simulations showed that rapid resistance buildup in pest populations appears to be unlikely if minimum non-*Bt* refuge areas are maintained.

Qaim and de Janvry (2004) carried out adoption and impacts of *Bt* cotton in Argentina against the background of monopoly pricing. Survey data revealed that the technology significantly reduces insecticide applications and increases yields; however, these advantages are curbed by the high price charged for GM seeds. Studies showed that farmers’ average willingness to pay is less than half the actual technology price. A lower price would not only increase benefits for growers, but could also multiply company profits.

Purcell and Perlak (2004) assessed the global impact of insect-resistant (*Bt*) cotton. Study results revealed that insect-resistant (*Bt*) cotton has been rapidly adopted since its introduction in 1996. Farmers around the world both large and small holders benefit from this technology through increased productivity, convenience, and time savings. The vast majority of farmers using *Bt* cotton globally are smallholder farmers. The economic, environmental, and social benefits derived from adoption of this important tool have very positive implications for the farmers.

Qaim and de Janvry (2005) analyzed the effects of insect-resistant *Bt* cotton on pesticide use and agricultural productivity in Argentina. Farm survey data revealed that the technology reduces application rates of toxic chemicals by 50%, while significantly increasing yields. Using a damage control framework, the effectiveness of *Bt* versus chemical pesticides was estimated, and technological impacts are predicted for different farm types. Gross benefits could be highest for smallholder farmers, who are not currently using the technology. The durability of the advantages is analyzed by using biological models to simulate resistance development in pest populations. Rapid resistance buildup and associated pest outbreaks appear to be unlikely if minimum non-*Bt* refuge areas are maintained. Thus, promoting a more widespread diffusion of *Bt* cotton could amplify the efficiency, equity, and environmental gains. Conclusive statements about the technology's sustainability, however, require longer-term monitoring of possible secondary effects and farmers' behavior in maintaining refuges.

Hofs et al. (2006) assessed the impact of *Bt* cotton adoption on pesticide use by smallholders: a two year survey in Makhatini Flats, South Africa. The survey explored insecticide use in fields cropped with conventional or *Bt* cotton varieties in a smallholder farming area. The study was carried out during 2002-2003 and 2003-2004 growing seasons as part of a broader survey based on daily monitoring of a sample of smallholdings. The adoption of *Bt* cotton led to a decrease in pyrethroid use, but the level of insect resistance of this cultivar was not sufficient to completely drop this pesticide from the spraying programme. On the other hand, organophosphates were still being applied in substantial amounts, thus raising questions as to the impact of *Bt* cotton adoption on farmers' health. The overall economic results obtained with *Bt* cotton were slightly positive despite the low cotton yields obtained in the Flats during our survey. *Bt* cotton adoption did lead to labour savings, but the extent of this gain was not as high as expected. In conclusion, cropping *Bt* cotton in Makhathini Flats did not generate sufficient income to expect a tangible and sustainable socioeconomic improvement due to the way the crop is currently managed. Adoption of an innovation like *Bt* cotton seems to pay only in an agro-system with a sufficient level of intensification.

Gandhi and Namboodiri (2006) analyzed the adoption and economics of *Bt* cotton in India. Survey findings revealed that biotech crops, which made their appearance in the world about a decade ago, have gained substantial popularity and acceptance in many parts of the world including US, China, Australia, Mexico, Argentina and South Africa. However, their introduction in India has been relatively late and controversial and they still have considerable ground to cover in the country. Data from the survey, which covered the important cotton states of Gujarat, Maharashtra, Andhra Pradesh and Tamil Nadu, and 694 farmers, indicates that *Bt* cotton offers good resistance to bollworms as well as several other pests. The incidence of these pests is reported to be considerably lower in *Bt* cotton as compared to Non-*Bt* cotton. The yields of *Bt* cotton are higher and the yield increase/difference statistically significant in all the states under both irrigated and rainfed conditions. As a result, given the good market acceptance of the product, the value of output per hectare is higher in all the states and conditions. The question of higher cost of cultivation exists, and is confirmed, mainly because of high seed cost and not commensurate reduction in pesticide cost. However, the profit is found to be higher in all the states to the estimated extent of about 80-90 % on an average when the effects of associated inputs are included. The returns are highest in Maharashtra followed by Gujarat and then Andhra Pradesh. Subjective assessment indicates that farmers see advantage in *Bt* cotton in pest incidence, pesticide cost, cotton quality, yield and profit. Almost all farmers indicate that they plan to plant *Bt* cotton in the future. To increase the benefits from the technology, the farmers strongly urge reduction in the seed cost, greater field extension and demonstration work on the correct practices, and more Bt cotton varieties to suit the diverse agro-ecological settings of India.

Frisvold and Reeves (2007) analyzed the economy, using global trade analysis project model. Productivity gain estimates are based on 2005 adoption rates for *Bt* cotton in seven countries. Global economic benefits are nearly $1.4 billion, while US benefits are over $200 million. Increased production from *Bt* cotton adoption leads to a 3% reduction in the world cotton price. Employment and trade balances in the textile and apparel sectors increase for China and India, but generally decline elsewhere. Individual countries obtain greater economic welfare gains if they adopt *Bt* cotton than if they do not adopt. Non-adopting regions lose cotton market share to adopting regions.

Wang et al. (2008) assessed the impact of *Bt* cotton on the farmer's livelihood system in China. A sample of 169 farmers and extension personnel in the main cotton production areas in Hebei province in 2002 and 2003 was taken. The results showed that the application of *Bt* cotton increased the cotton growing area as well as farmers' income due to higher productivity of *Bt* cotton. For 67% of the farmers interviewed, cotton area has been continuously increasing since 1997. The income from cotton played a significant role in the investment to education, leisure and health care. The socio-economic impacts of cotton production are nevertheless not yet optimal because there were still many factors limiting them. Lack of labor and land were the main limiting factors. Productivity is restrained by the high price of *Bt* cotton seeds which pushed farmers to keep seeds from their own cotton production (42% of the farmers in 2002 and 2003). Farmers are still lacking technical command in using *Bt*-cotton: 78% of the farmers admitted that while more than 94% of the farmers complained not getting information from local extension and technical services. More success in using *Bt*-cotton calls upon going beyond providing seeds and asks for continuous assistance from research and extension department, notably to achieve a full knowledge of the *Bt*-cotton characteristic so as to optimally integrate it into the farmers' system.

Performance of *Bt* Cotton in Pakistan

Hayee (2005) study revealed that illegal import and multiplication of Bt cotton seed in Sindh and Punjab provinces of Pakistan created havoc at farmers' fields. Absence of biosafety guidelines at government level and awareness at farms level further complicated the issue in the country. Those were the civil society organizations that brought the problem at national as well as government level and attempted to protect the national biodiversity and farmers' interests. To mitigate the issue in future, the author made following recommendations:

- There is a need to create awareness at public as well as private level regarding safe use of biotechnology, its allied issues and their impact on various elements of our ecosystems.
- Capacity building in the areas of biosafety conservation, regulations and their effective implementation is proposed. Establishment of National Biosafety Implementation and Monitoring Committee, comprising biological scientists, social, political and legal personnel for effective implementation of the biosafety guidelines at national level are also proposed.
- Intellectual property rights (IPR), biosafety and ethics needs to be addressed at public and private level and must be openly debated by all the stakeholders.

- Scientific research may be conducted on long-term effects of biotechnology along with ethical and safety principle.
- Considering the potential risks involved in development, release and use of transgenic organisms in the open environment, safety of users and the environment must be ensured.
- There is need to develop and adopt safety protocols during laboratory experiments as well as during eventual use of GMOs and products derived thereof.
- Pharma crops using HIV-1, AIDS virus should be banned from the open fields, as they will contaminate our food supply with dangerous consequences, not only for human beings also for the other organisms in the food chain.

Rao (2009) assessed the performance of IR-FH-901, IR-NIBGE-2, IR-CIM-448 and IR-CIM-443 Bt varieties planted on 8000 acres of land in 2005-06. Findings revealed that adopters of *Bt* cotton varieties in Bahawalpur, Multan, Muzaffargarh and Karor Pakka observed and evaluated independently its resistance and susceptibility to different pests including factors like abiotic stress and yield then compared it with non *Bt* cotton varieties grown in the same locations. A large number of farmers have visited these fields, and become aware of the benefits of the locally developed *Bt* cotton.

Although germination of these *Bt* cotton seed varieties varied from 65% to 85% but mixing or impurities were less than 2%. In the beginning overall attack of "Lashkari Sundi", "American Sundi" and other bollworms remained low as compared to previous years but attack of sucking pests like jassid, whitefly, thrips and other aphid were high in both *Bt* and non *Bt* cotton crops. No serious incidence of cotton leaf curl virus disease was reported in Bt cotton varieties. Heat stress in cotton crop was also recorded in different region, however no stress was observed in *Bt* cotton varieties.

Bt cotton varieties yielded significantly more per acre as compared to non *Bt* cotton varieties-- an average 98.84 kg ha^{-1} versus 45 kg ha^{-1} to traditional cotton varieties. This translates into more than 30 % increase in yield. It is noteworthy that in *Bt* cotton crops average number of cotton bolls per plant are 120 while average boll weight is app. 1.75g including seeds and number of plants per acre are as recommended by the department of agriculture. The economical gain by using *Bt* cotton per acre is more than Pak Rs. 3,000 at the market sale price of Rs. 1100 per maund. In Pakistan average cotton grower has 10 acres of land; increase in such small income per acre would improve his quality of life. It is expected that cotton growers should have Bt seeds of the above varieties for at least 75,000 acres of land in 2006-07.

PARC (2007) assessed the status of cotton harboring *Bt* gene in Pakistan. A survey was conducted in the cotton growing areas of Sindh and Punjab provinces during July -August, 2007. The major objective was to investigate the presence/ absence of *Cry* toxin in *Bt* transformed cotton. In Sindh province, ten districts (Hyderabad, Nawabshah, Sanghar, Mirpur Khas, Dera Allah Yar, Umer Kot, Matiari, Khairpur, Sukkur, and Nowshero Feroze) were surveyed and samples of cotton were collected from 42 different locations. It was observed that almost 80 % of cotton growing area in Sindh has become under *Bt* cotton. Study results revealed that an exotic source of *Bt* cotton named as Australian *Bt* was also found in the field. A very high incidence (60-100%) of CLCuV infection was observed in Aus-*B*t cotton. Similarly, eleven districts (Multan, Khanewal, Lodhran, Bhawalpur, Rahim Yar Khan, Vehari, Bhawalnagar, Pakpattan, Sahiwal, Jhang and Faisalabad) were surveyed in the Punjab province and samples were collected from 84 different locations. Almost 50% area has been occupied by *Bt* cotton in these districts. In Punjab, *Bt* cotton is grown with different names, however, *Bt*-121 has occupied major area. A range of segregation (10-20%) was observed in some of the fields of *Bt* cotton.

Five samples were randomly collected

from each location. Of these five, two were further subjected to Immuno Strip analysis for the detection of *Bt-Cry* protein. The results of Immuno Strip analysis revealed that 81 % (34/42) and 90 % (76/84) samples from Sindh and Punjab provinces, respectively, were positive for *Bt* protein. The level of *Bt* gene expression varied from low (+) to high (+++) indicating that source of seed is different. All positive samples harbored *CryIAb/Ac* gene, whereas, none of the sample was found to have *Cry2Ab* and *CryIF* genes. A part of the samples within a location giving negative response indicates the possibility of seed mixing/segregation for *Bt* gene. The samples showing negative reaction in the Immuno Strip analysis were further analyzed to confirm their transgenic nature by ELISA for *npt-II* (Kanamycin) marker gene encoded protein. Overall, *Bt* transgenic cotton is widely grown in the cotton growing areas of Sindh (80%) and Punjab (50%).

Productivity of *Bt* Cotton in China and Pakistan

Huang et al. (2001) measured the effect of the impact that genetically modified cotton varieties have had on the production efficiency of smallholders in farming communities in China. They observed that the adoption of *Bt* cotton varieties leads to a significant decrease in the use of pesticides. Hence, *Bt* cotton appears to be an agricultural technology that improves both production efficiency and the environment. In terms of policies, the findings suggest that the government should investigate whether or not they should make additional investments to spread *Bt* to other cotton regions and to other crops.

Pemsl et al. (2003) analyzed *Bt* cotton productivity considerations from India and China. The approval of commercial planting of *Bt* cotton in China and India was implemented in 1997 and 2002 respectively. Upto 2003 *Bt* varieties have reached over 50% of the total cotton area in China. The study results revealed that the benefits derived from *Bt* cotton were significantly higher than non *Bt* cotton which are based on higher productivity of *Bt* cotton in China.

Thirtle et al. (2003) assessed the impact of *Bt* cotton in Makhathini Flats, KwaZulu-Natal, South Africa. Study result revealed that *Bt* cotton adopters in 1999–2000 benefited according to all the measures used. Higher yields and lower chemical costs outweighed higher seed costs, giving higher gross margins. These measures showed negative benefits in 1998–99, which conflicts with continued adoption, but stochastic efficiency frontier estimation, which takes account of the labor saved, showed that adopters averaged 88% efficiency, as compared with 66 % for the non-adopters. In 1999–2000, when late rains lowered yields, the gap widened to 74% for adopters and 48 % for non-adopters.

Barwale (2004) studied the prospects for *Bt* cotton technology in India. The findings of the study revealed that process of introduction of *Bt* cotton took six years of experimentation, during which time agronomic, environmental, and biosafety data was generated and reported. The trials conducted prior to commercialization clearly established the superior performance of *Bt* cotton, as demonstrated by increased yields and reduction in application of pesticides. Transgenic technology is suitable for the Indian farmer despite small farm holdings. The area under *Bt* cotton is projected to increase rapidly in the coming years.

Bt cotton can play a significant role to enhance agricultural productivity in Pakistan as the current productivity of cotton in Pakistan is 0.71 tha^{-1} (Government of Pakistan, 2009) as compared productivity of *Bt* cotton in China is 9 tha^{-1} (Altaf, 2009) which implies a huge cotton productivity gap. This gap can be narrowed down by the rapid adoption of *Bt* cotton in Pakistan which will have major impact on food security efforts in the country.

Entrepreneurship for Cotton Sector in Pakistan

Gilani (2008) during his address to

launching ceremony of The Indus Entrepreneurs (TiE) Islamabad Chapter emphasized on promotion of entrepreneurship in Pakistan. According to him, the TiE needs to give equal attention to traditional sector such as textiles, and the emerging ones, such as Information Technology (IT), Bio-Informatics or Organic Farming. Pakistan have young people with exceptional talent, who are creating softwares that are being used by the World's IT giants. These young people are fully capable of creating marvels in other fields as well. He was glad that the TiE is endeavoring to develop an Entrepreneurial Echo System in the country—a system that put all ingredients of entrepreneurship in place. This system has been paying the nations across the world. Although the country is late starter, but still it can catch up which requires implementation of all these ingredients with sincerity of purpose. While giving due importance to mentoring and networking on a sustainable basis, Pakistan needs to focus on education, training and exposure of existing entrepreneurs.

In this connection, Gilani suggested that teams of qualified academicians from Internationally reputed institutions like MIT, Harvard and others, should be engaged to impart market based skills, especially to start ups. It is satisfying that the TiE intends to involve universities and colleges in its programs; these institutions are, indeed, a proper ground to hunt talent for entrepreneurship. However, involving the people already in business would result in building up the relevant industry, as these enterprises are in a position to accept and deliver business orders.

Gilani further stated that Angel Investment and Venture Capital are the most important part of the Echo System; angel investment is not a new experience, this is deeply rooted in Islamic polity; and is still in vogue among various Muslim communities. This mode of investment provides an additional funding opportunity to new entrepreneurs. Pakistan, therefore, must endeavor to harness this source of funding; focused efforts need to be made on creating a pool of Angel Investors and establish Venture Capitalists within and outside the country. He believes that TiE will accord special attention to this aspect of the Entrepreneurial Echo System in Pakistan. Finally he proposed that mentoring, networking and business plan competitions, if organized at the International level, will harness foreign investment in the country.

Altaf (2008) presents an overview of the economics and political economy of the entire cotton value chain, including growing raw cotton, ginning into lint, spinning into yarn, weaving into fabric, producing cotton "made-ups," such as towels and other nonapparel goods, producing apparel, and marketing. These combined sectors contributed 11 % to Pakistan's gross national product in 2004–2005, nearly 50 % of manufacturing output, and more than 60% of the country's foreign exchange earnings. His analysis has an optimistic theme. He addresses the successes of Pakistan's industries in terms of its rapid growth of yarn and textile production levels and highlights cases of highly competitive and successful entrepreneurs. But, he is also critical of the industry overall for failing to have sufficient entrepreneurial spirit, which he argues is necessary in the globalized fibers-to-apparel economy that has emerged. He lays the roots of weakness in the protected market environment in which Pakistan's industry developed—not just the multilateral quotas of the MFA but also its own protected market, including its historically captive market in Bangladesh when that country was East Pakistan. His assessment recounts incidents of the distortions this protected market created. He raises many challenges to the industry; chief among these are the upgrade of the work force, the development of modern entrepreneurs, and greater attention to product differentiation and value, which requires marketing expertise and initiatives.

CONCLUSIONS AND SUGGESTIONS

Bt transgenic cotton is widely grown in the cotton growing areas of Sindh and

Punjab. The level of *Bt* gene expression varied from low to high indicating that source of seed is different. Immnuno Strip analysis revealed that only *CryIAb/Ac* gene is present in exotic as well as in the local germplasm. None of the sample harbor *Cry2Ab* and *CryIF* genes in the cotton area surveyed. A part of the samples within a location giving negative response indicates the possibility of seed mixing/segregation for *Bt* gene. All the *Bt* transformed germplasm is susceptible to CLCuV. The exotic germplasm was comparatively more susceptible to CLCuV than the local. Incidence of CLCuV was higher than previous years (farmer saying). Mealy Bug presence was clearly noticed in majority of the fields. Irrespective of intensity/incidence, CLCuV was present in the cotton area surveyed. *Bt-Cry* genes have worldwide proven performance to increase cotton production by providing protection against boll worm. To fully utilize its potential in Pakistan, government and all key stakeholders will have to integrate.

Bt cotton can play a significant role to enhance agricultural productivity as the productivity of cotton in Pakistan is 0.5 tha^{-1} as compared productivity of *Bt* cotton in China is 9 tha^{-1} which implies a huge cotton productivity gap. This gap can be narrowed down by the adoption of *Bt* cotton in Pakistan which will have major impact on food security efforts in the country.

National Biosafety Guidelines of 2005 must be followed to approve all genetically modified crop varieties including cotton. This will encourage the introduction of this advanced technology through legal means with its complete package of benefits. After approval of *Bt* cotton cultivation by Government of Pakistan, R&D sector should be encouraged to transfer *Bt-Cry* genes into such genetic backgrounds which: (i) must have resistance against CLCuV (ii) are suitable for a given ecology and (iii) meet the set fiber quality parameters (fiber length and strength, GOT% etc.) and other desirable features required for the release of a normal commercial variety. Diversity of *Bt-Cry* genes has to be maintained under a timeframe for durable resistance and to enhance the life of *Bt* transformed cotton varieties. Repeated use of only one *Bt* gene may result in the development of cross resistance in insect pests over a period of time.

Effective, stringent, and transparent enforcement of quarantine measures must be observed on the import of exotic plant materials. The uncontrolled import of genetically engineered varieties might irreversibly damage our cotton crop, just like Banana Bunchy Top Virus from untested and non approved Australian variety of banana has done in Sindh. The introduction of Aus-*Bt* cotton in Sindh province, which is highly susceptible to CLCuV, will increase the inoculum pressure. This will play a role in the evolution of new virus strain as it has happened in “Burewala virus” resulting in huge losses to cotton crop in the country.

Expression of *Bt-Cry* genes in the approved cotton varieties need to be continuously monitored during the crop growing season and over the years according to standards described in this report. A threshold level of *Bt* toxin “*Cry*-protein” is very crucial as extremely low level of toxin may lead to the development of cross resistance. There is a need to develop awareness among the farmers regarding the appropriate management practices for fully utilizing the *Bt* potential taking into account the ineffectiveness of *Bt* against sucking insects pests which require conventional pest management measures.

LITERATURE CITED

Altaf, Z. 2008. Challenges in the Pakistan Cotton, Yarn, Textile, and Apparel Sectors. In: Corora ton C.B. Salam A. Altaf, Z. and David, O. (eds.) Cotton-Textile-Apparel Sectors of Pakistan: Situations and Challenges Faced. IFPRI Discussion Paper 00800.

Barton, K. Whitley, H. and Yang, N.S. 1987. *Bacillus thuringiensis* - endotoxins in transgenic *Nicotiana tabaccum* provides resistance to lepidopteran pests. Plant

Physiol. 85: 1103-1109.

Barwale, R.B. Gadwal, V.R. Zehr, U. and Zehr, B. 2004. Prospect of *Bt* cotton technology in India. AgBioForum, The Journal of Agrobiotechnology, Management and Economics, 7:(1&2). 23-26.

Batie, S.S. and Ervin, D.E. 2001. Transgenic crops and the environment: missing markets and public roles. Environment and Development Economics, 6:435–457.

Benbrook, C. 2001. Do GM crops mean less pesticide use? Pesticide Outlook, 12:204–207.

Carpenter, J. Felsot, A. Goode, T. Hammig, M. Onstad, D. and Sankula, S. 2002. Comparative environmental impacts of biotechnology-derived and traditional soybean, corn, and cotton crops. Council for Agricultural Science and Technology.

Chaturvedi, S. 2002. Agricultural biotechnology and new trends in IPR regime: Challenges before developing countries, Economic and Political Weekly, 37: 13, March 30.

Frisvold, G.B. and Reeves, J.M. 2007. Economy-wide impacts of *Bt* cotton. Proc. of the Beltwide Cotton Conference, January 2007.

Gandhi, V.P. and Namboodiri, N.V. 2006. The adoption and economics of Bt cotton in India: Preliminary results from a study at Indian Institute of Management, Ahmedabad, India.

Gilani, S.Y.R. 2008. Address at The Launch of 'The Indus Entrepreneurs' (TiE) Islamabad Chapter Rawalpindi June, 2008.

Government of Pakistan. 2009. Economic survey of Pakistan, Economic Advisor's Wing, Finance Division, Government of Pakistan, Islamabad.

GRAIN. 2001. 'Bt cotton through the back door', Seedling 18, Barcelona: Genetic Resources Action International.

Hayee, A. 2005. Cultivation of Bt cotton Pakistan's experience. Actionaid, Islamabad, Pakistan.

Hofs, J.L. Fok, M. and Vaissayre, M. 2006. Impact of Bt cotton adoption on pesticide use by smallholders: A 2-year survey in Makhatini Flats (South Africa). Crop Protection, 25: 984-988.

Hoftey, H. and Whitley, H.R. 1989. Insecticidal crystal proteins of *Bacillus thuringiensis*. Microbiol. Rev. 53: 242-255.

Huang, J. Hu Ruifa, Rozelle, S. Qiao, F. and Pray C.E. 2001. Small holders, transgenic varieties, and production efficiency: The case of cotton farmers in China. California Agricultural Experiment Station, Giannini Foundation for Agricultural Economics, Department of Agricultural and Resource Economics, University of California Davis, USA

Huang, J. Rozelle, S. Pray, C. and Wang, Q. 2002a. Plant biotechnology in China., Science 295: 674–677.

Isma¨el,Y. Bennett, R. and Morse, S. 2002. Benefits from Bt cotton use by smallholder farmers in South Africa, AgBio Forum, 5 (1): 1–5.

Neale, M.C. 1997. Bio-pesticides hormonisation of registration requirements within EU directive 91-414. An industry view. Bull. European and Mediterranean Plant Protection Organization, 27: 89-93.

NIPS, 2008. Population Trend. National Institute of Population study in Islamabad

PARC. 2007. Status of cotton harboring Bt gene in Pakistan. Plant Biotechnology Program, Institute of Agri-Biotechnology and Genetic Resources, National Agricultural Research Centre, Islamabad.

Pemsl, D.E. Orphal, J. and Waibel, H. 2003. Bt-cotton productivity considerations from India and China. Paper presented in Conference on International Agricultural Research for Development, Gotingen, October 8-10.

Pray, C.E. Huang, J. Hu, R. and Rozelle, S. 2002. Five years of Bt cotton in China – the benefits continue, The Plant Journal, 31: 423–430.

Purcell, J.P. and Perlak, F.J. 2004. Global impact of insect-resistant (Bt) cotton. AgBioForum, 7(1&2): 27-30.

Qaim, M. and Zilberman, D. 2003. Yield effects of genetically modified crops in developing countries. Science, 299: 900-

902.

Qaim, M. Cap, E.J. and de Janvry, A. 2003. Agronomics and sustainability of transgenic cotton in Argentina. AgBioForum, 6(1&2): 41-47.

Qaim, M. and de Janvry, A. 2003. Genetically modified crops, corporate pricing strategies, and farmers' adoption: The case of Bt cotton in Argentina. Am. J. Agric. Econ. 85(4): 814-828.

Qaim, M. and de Janvry, A. 2004. Cheaper GM seeds could boost adoption, farm benefits and company profits: The case of Bt cotton in Argentina. Crop Biotech Brief, 4(1): 2004.

Qaim, M. and de Janvry, A. 2005. Bt cotton and pesticide use in Argentina: Economic and environmental effects. Environment and Development Economics, 10: 179-200.

Rao, I.A. 2009. First Bt cotton grown in Pakistan. Pakissan.com

Schnepf, H.E. and Whitley, H.R. 1981. Cloning and expression of *Bacillus thuringiensis* crystal protein gene in *E. coli.* Proc. Natl. Acad. Sci. USA, 78: 2893-2897.

Thirtle, C. Beyers, L. Ismael, Y. and Piese, J. 2003. Can GM-technologies help the poor? The impact of Bt cotton in Makhathini Flats, KwaZulu-Natal, South Africa. World Development, 31 (4): 717-731.

Traxler, G. Godoy-Avila, S. Falck-Zepeda, J. and Espinoza-Arellan, J. 2001. Transgenic cotton in Mexico: Economic and Environmental Impacts, Auburn: Auburn University.

UK Soil Association. 2002. Seeds of doubt: North American Farmers Experience of GM Crops, Bristol: UK Soil Association.

Wang, G. Wu, Y. Gao, W. Fok, M. and Liang, W. 2008. Impact of Bt cotton on the farmer's livelihood system in China. ISSCRI International Conference on Rationales and Evolutions of Cotton Policies", Montpellier, May 13-17.