Biotech Cotton: Issues for Consideration

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1 Introduction

Cotton is an important fibre crop of global significance, which is, cultivated in tropical and sub-tropical regions of more than seventy countries the world over. The major producers of cotton are USA, China, India, Pakistan, Uzbekistan, Argentina, Australia, Greece, Brazil, Mexico, and Turkey. These countries contribute about 85% to the global cotton production. India has the largest acreage (9.4 m. ha) under cotton at global level and has the productivity of 560 kg Lint /ha and ranks second in production (5.334 m. MT 31.0 m. bales) after China during 2007/2008.

Cotton plays a key role in the National economy in terms of generation of direct and indirect employment in the Agricultural and Industrial sectors. Textiles and related exports of which cotton constitutes nearly 65% account for nearly 33% of the total foreign exchange earnings of our country which at present is around 17 billion dollars with a potential for a significant increase in the coming year.

2 Cotton and Textile Industry

The textile policy of 2000 aims at achieving the target of textile and apparel exports of US $ 50 billion by 2010 of which the share of garments will be US $ 25 billion. Consequently, the requirements of cotton are likely to increase perceptively in the coming decades in respect of internal consumption as well as to meet the targeted export demand, necessitating the need for concerted research, development, extension efforts to make Indian cotton compete effectively in terms of quantum, quality and competitiveness in the globalized trade scenario.

The elimination of quota restriction has opened the way for the most competitive developing countries to develop stronger clusters of textile expertise, enabling them to handle all stages of the production chain from growing natural fibres to producing finished clothing.

A Vision 2010 for textiles formulated by the government after intensive interaction with the industry and Export Promotion Councils to capitalize on the upbeat mood aims to increase India's share in world's textile trade from the current 4% to 8% by 2010 and to achieve export value of US $ 50 billion by 2010 Vision 2010 for textiles envisages growth in Indian textile economy from the current US $ 37 billion to $ 85 billion by 2010; creation of 12 million new jobs in the textile sector; and modernization and consolidation for creating a globally competitive textile industry.

3 Cotton Cultivation in India

Cotton is cultivated in three distinct agro-ecological regions (north, central and south) of the country. The northern zone is almost totally irrigated, while the percentage of irrigated area is much lower in the central and southern zones. The lowest being in the central zone which has nearly 60% of cotton area of our country (Table 1).

Table 1 Cotton Profile

Zones	Irrigated	Rainfed
North Zone	100 % *G. hirsutum, arboreum* *Intra hirsutum* hybrids & Diploid hybrids	-
Central Zone	23% *G. hirsutum* *Intra hirsutum* hybrids	77% *G. herbaceum, G. arboreum,* *G. hirsutum, Intra hirsutum* hybrids, Diploid hybrids
South Zone	*40%* *G. hirsutum* *G.barbedense* *Intra hirsutum* hybrids *Inter specific* hybrids (H×B)	*60%* *G. herbaceum* *G. arboreum* *Intra hirsutum* hybrids *Inter specific* hybrids (H×B) Diploid hybrids

Under the rain fed growing conditions rainfall ranges from <400 to > 900 mm coupled with aberrant precipitation patterns over the years leading to large scale fluctuations in production. In the irrigated tract canal and well irrigation are resorted to including the use of micro-irrigation system.

Northern zone comprising Punjab, Haryana and parts of Rajasthan and UP., where cotton is grown under irrigated conditions on alluvial and sandy soils. The region is known for growing hirsutum-arboreum type of cottons. After the introduction of Bt cotton , intra-hirsutum Bt cottons are being extensively cultivated. This zone has the highest productivity (558 kg lint per hectare). Cotton in this area is grown adopting farm mechanization. Presently short to long staple cotton is grown. Problems of salinity, alkalinity and rise in water table are often encountered. Cotton-wheat is the predominant cropping system. The north zone(Punjab), Haryana and Rajastan occupies only 16 % of the total cultivated area but contributes more than 18.5 % of the production.

Central zone comprises primarily rainfed tract of MP., Maharashtra and Gujarat. Predominant area is under black soil, which is subjected to runoff, erosion, soil and nutrient losses. Soils are poor in fertility. Cotton productivity is the lowest (510 kg lint per hectare) due to uncertainty and vagaries of monsoon, This area is known as' Central *hirsutum-arboreum-herbaceum* and hybrid zone. Moisture stress, salinity, soil degradation problems are often encountered. Farmers in this area are resource poor and therefore not in a position to invest more. Cultivation is done traditionally with bullock drawn implements and by manual labour. There are more weeds, pests and disease problems due to uncontrollable rain and soil problems. The area is more suitable for diploid cottons. Cotton is grown as a mono-crop or as an intercropping system. The central zone occupying more than 68% of the total area but contributes less than 60% to the total production and is characterized by proliferation of hybrids.

Southern zone comprising of Andhra Pradesh, Karnataka and Tamil Nadu is a zone for growing hirsutum-arboreum-herbaceum-barbadense and hybrid cottons. Soils of this zone are both black and red and poor in fertility. Cotton cultivation is done both under irrigated and rain fed conditions. This zone has the productivity of 599 kg lint per hectare. The area is well known for growing long and extra long staple H×B hybrid and *barbadense* cottons. Pest and disease problems are more. Due to type of climate available, cotton can be grown through out the year. Cotton is grown in south as sole crop or in intercropping system with onion, chili, cowpea, maize etc. Cotton-rice rotation is also followed in this area. The south zone is occupying 15.3% of area and contributing nearly 16.3% in national production.

Details of the area, production and productivity profile of the country (over the years) as well as in the three zones is presented in Figs 1 and Fig. 2.

The production trends as depicted in Fig.1 clearly indicate that there has been a significant enhancement in production from 2004/2005 onwards as compared to the earlier years (from 17.7 million bales in 2003/2004 to nearly 31.0 million bales in 2007/2008). Adoption of improved technologies IPM, IRM, new chemistry (including Bt cotton) coupled with favourable weather and low insect pest pressure in major cotton growing tracts has enabled this transformation in production and productivity. Punjab and Gujarat states recorded much higher productivity than national average and contributed to a large measure in enhancing productivity and production at the national level.

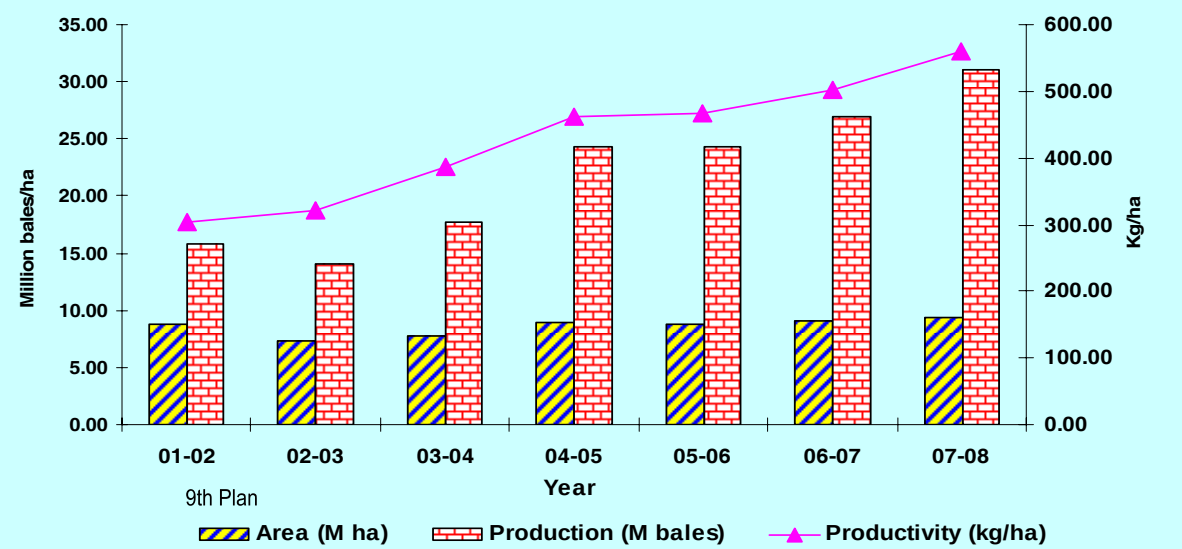


Fig.1 Trends in Cotton Area, Production and Productivity in India (2001/2002 to 2007/2008)

The average national productivity showed a remarkable spurt from nearly 303 kg lint/ha (2001/2002) to 560 kg lint/ha in 2007/2008. Amongst the three zones northern and southern recorded relatively higher productivity compared to the central zone. A trend of continuous improvement is quite clear from 2002/2003 onwards (Fig.2).

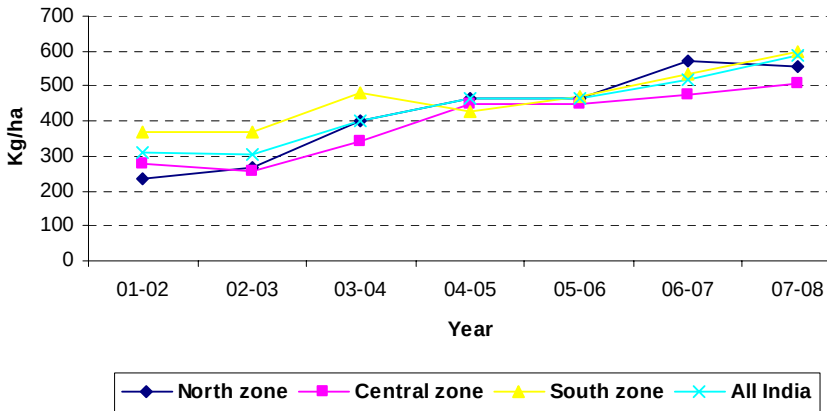


Fig.2 All India Cotton Productivity Trends during 2001/2002 to 2007/2008

4 Silver Lining in Cotton Production

The country was the third largest importer of cotton in the World in 2002/2003. In 2005/2006 the country the second largest exporter of Cotton in the World. The cotton growers in Gujarat achieved cotton

Yields of 743 kg/Ha., during 2007/2008 which was on par with the World Average of 770 kg/Ha. To harvest record crops in succession for four consecutive years is a record in itself in as much as never before the country had ever harvested successive good crops. During current year the country is the second largest producer of cotton in the world after China.

5 Cotton Consumption on the Rise

The consumption of cotton in the country has been rising year after year and there is a boost in cotton consumption subsequent to the abolition of Quota Regime from 1st January 2005. The VISION STATEMENT prepared by the Confederation of Indian Textile Industry places the requirement of cotton by the Textile Industry by 2010 at 35.0 million bales. The rising trend in cotton consumption during the last decade would be evident from the following:

Table 2 Cotton Consumption Trend (million bales)

Crop Year	Cotton Consumption
1996/1997	15.830
1997/1998	14.978
1998/1999	15.177
1999/2000	15.897
2000/2001	16.033
2001/2002	15.870
2002/2003	15.405
2003/2004	16.339
2004/2005	18.001
2005/2006	20.000
2006/2007	22.000

6 Bollworms the Major Cotton Pests

In cotton bollworms cause significant yield losses. Three types of bollworms, viz. American bollworm (*Helicoverpa armigera*), pink bollworm (*Pectinophora gossypiella*) and spotted bollworms (*Earias vitella*) attack cotton crop. We do not have sources of resistance to the bollworms in the germplasm of cotton the world over. Moreover, about 10% of insecticides on global basis and 45% in India are used for control of insects in cotton crop alone. Insecticides have adverse effects on (i) natural predators and parasites of bollworms, (ii) beneficial insects, (iii) human health and (iv) microorganisms such as earthworm, blue green algae, and nitrogen fixing bacteria. Use of insecticides also leads to environmental pollution (soil and water), increase in cost of cultivation and sometimes development of resistance in insects against insecticides. Hence, there is need to develop bollworm resistant cotton to control yield losses due to bollworms.

In India around 45 percent of crop pesticide used is on cotton. In spite of usage of huge amount of pesticides the control of insects on cotton has become Psycho-Socio Economic tension in farmers of India. When the newer pesticides like synthetic pyrethroids were introduced in India during 1980s their utilization was pre-whelming and unscientific also. Indiscriminate use of such pesticides has resulted into development of resistance in bollworms and resurgence of white flies. Since we are in need of safe and sustainable agriculture, it is imperative to deploy effective and eco-friendly strategies to manage insects. Genetic engineering provides us with valuable tools to develop transgenic crops carrying resistance to insect pests.

7 Global Adoption of Bt Cotton

Global adoption of Bt cotton has risen dramatically from 800,000 hectares in 1996 to 5.7 million hectares (alone and stacked with herbicide-tolerant cotton) in 2003. In 2002, Bt cotton was grown

commercially in the United States, Mexico, Argentina, South Africa, China, India, Australia, and Indonesia, and precommercial plantings were grown in Colombia. Bt cotton is a global product, with plantings in North America (United States), Australia, three countries in Latin America, one country in Africa, and three countries in Asia. Large-acreage farmers in industrialized countries (such as the United States and Australia) derive significant value from Bt cotton, but the vast majority of growers are in developing countries. Over six million Bt cotton farmers are in developing countries; the vast majority of these are resource-poor farmers in China, South Africa and India. A number of studies have examined the significant economic, environmental, and social benefits derived from growing Bt cotton.

Bt cotton has been one of the widely adopted and effective transgenic crops grown worldwide. Bt cotton (known as Bollgard) was first introduced in the US on 730,000 hectares in 1996 (James and Krattiger 1996) with additional small hectarage in Mexico and Australia for a global total of approximately 0.8 million hectares. In 1997, for the first time, China adopted Bt cotton while the stacked genes of Bt and herbicide tolerance were introduced in the US (James 1997); by 2003 the stacked gene product accounted for 46 % of all the global commercial cotton containing the Bt gene, compared with 54% of the single Bt gene. By 1998 the hectarage of Bt cotton had doubled to 1.5 million hectares and Bt cotton was grown in a total of six countries. The global adoption of Bt cotton increased more than seven fold from 0.8 million hectare in 1996, to 5.7 million hectares in 2003. Assuming a global average of 34 million hectares of cotton, the percentage of global adoption of Bt cotton has increased from 2% in 1996 to 21% in 2003. 2002 -05 were significant years in terms of Bt cotton adoption worldwide.

China increased its Bt cotton area for the fifth consecutive year from 2.1 million hectares in 2002 to 2.8 million hectares in 2003, equivalent to 58% of the total cotton area of 4.8 million hectares.

8 Bt Cotton Adoption in India

In India, after extensive testing of Bt cotton hybrids (with Cry1 Ac gene) in All India Coordinated Cotton Improvement Project (AICCIP) and farmers field, Government of India has approved commercial cultivation of Bt cotton hybrid with effect from 2002 crop season. In the first year of its (Bt cotton hybrid) release it occupied 38,038 ha. (2002). The area under Bt cotton hybrids has gradually increased from 38,038 ha. in 2002/2003 to 0.5 million ha. by 2004/2005 and showed a steep increase to 1.30 million ha. in 2005/2006 followed by a phenomenal enhancement to 3.721 million ha. in 2006/2007 and 6.200 million ha in 2007/2008 (Fig.3**)**.

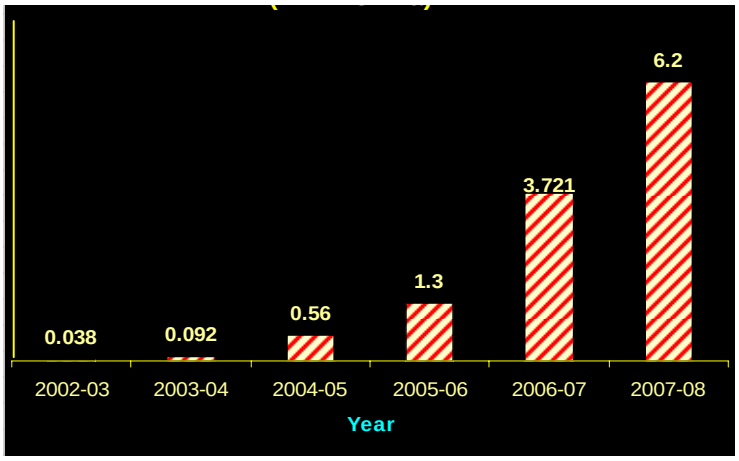


Fig.3 Spread of Bt Cotton in India(million ha)

Thus within a span of five years nearly 42% of the cotton area in India come under Bt hybrid umbrella. It is envisaged that with availability of more Bt hybrids coupled with reduction in seed cost from 2006 onwards, the area under Bt cotton is likely to show a perceptible increase during 2007-08 as

well. Among the cotton growing states Maharashtra leads the others with 2.0 m ha. under Bt cotton followed by Andhara Pradesh and Gujarat with 0.67 and 0.33 m ha. respectively. Among the northern states the area was maximum in Punjab with 0.28 m ha. followed by Harayana 0.042 m ha. Thus, it can be seen that the cultivation of Bt cotton hybrids has picked up momentum in the last two years and it is being cultivated in all the three cotton growing zones of the country (Table 3).

Table 3 State-wise Adoption of Bt cotton in India (1000 hectares)

State	2004	2005	2006	2007
Maharashtra	200	607	1,840	2,880
Andhra Pradesh	75	208	830	1,190
Gujarat	122	150	470	818
Madhya Pradesh	80	146	310	500
Northern Zone*	- -	60	215	592
Karnataka	18	30	85	145
Tamil Nadu	5	27	45	70
Other	-	-	5	5
Total	500	1,300	3,800	6,200

* Punjab, Haryana, Rajasthan

Source: ISAAA, 2007.

Three hybrids viz. MECH 12, MECH 162 and MECH 184 of Mahyco Monsanto were recommended in 2002 for cultivation in central and south cotton growing zones. In 2004 one more Bt hybrid i.e. RCH-2 was recommended for commercial cultivation, while in 2005, 16 hybrids were recommended for commercial cultivation. During 2006, 42, in 2007 more than 150 and in 2008 about 250 hybrids have been recommended for commercial cultivation. All these hybrids were developed by private seed companies utilizing different genes (Table 4) .

Table 4 Genes Utilized for the Development of Transgenic Cotton Hybrids in India

Company's Name	Gene utilised
Mahyco -	Cry1Ac
Monsanto	Cry1Ac+2Ab
Nath seeds	Cry1Ab+Ac fusion (China)
JK seeds	Cry1Ac modified (IIT Khargpur)
Syngenta	Vip3A+cry1Ab
Dow Agri. Science	cry1Ac+Cry1F,
Metahelix	cry1C
ICAR	Cry1Aa3
	Cry1F
	Cry1Ia5
	Cry1Ab
	Cry1Ac
NBRI	Cry1Ec

The transgenic hybrids released in the country can be categorized in different ways on the basis of transgene involved. They can be categorized in two groups viz., (i) Bollgard (single gene) (ii) Bollgard II (double gene) and based of species involved they can again be classified into two distinct types (i) Intra-*hirsutum* (ii) Inter-specific hybrids (*hirsutum*×*barbadence*) .

9 Development of Bt Cotton Varieties

Indian Council of Agriculture Research and Department of Biotechnology have entrusted the responsibility of developing transgenic cotton varieties to CICR, Nagpur, NRCPB, New Delhi, NBRI,

Lucknow, ICGEB, New Delhi and UAS, Dharwad. The available genes cry1Ac, cry1Aa3 and cry IF were used through *Agrobacterium* mediated transfer and Cry I A(c) gene was transferred as per the protocol standardized by UAS, Dharwad and CICR, Nagpur in *G. hirsutum* and *G. arboreum* cultivars respectively.

In 2008 Bikaneri Nerma conferring Cry1 Ac developed by UAS, Dharwad, CICR Nagpur and NRCPB, New Delhi has been approved for commercial cultivation after bio safety tests.

9.1 Development of Bt kits

Central Institute for Cotton Research, Nagpur has developed diagnostic kits viz., Bt Express, Bt Detect, Bt-Zygosity, Bt Quant for the detection of Bt toxin and these kits have been effectively deployed all over the country to verify the purity of Bt seed and ensure the supply of quality Bt hybrids seed to the farming community.

9.2 Quantitative expression of Cry1Ac in Bt-cotton

Quantification of Cry1Ac expression in various plant parts of eight Bt-cotton hybrids was done using ELISA and bioassays throughout the cropping season during 2001－2003. Cry1Ac expression ranged at 0.01 to 19 μg/g in various parts of the plant. The highest expression was in leaves at 75 days after sowing (DAS). A decline in expression of toxin levels was observed in all the eight hybrids. The earliest decrease was in MECH-162, with toxin levels falling off to 1~2 μg/g by 85 DAS. Expression in some hybrids such as RCH-144 and MECH-184 declined only after the 120th day after sowing. The expression levels were highly variable in different plant parts. Though younger leaves expressed highest levels of the toxin, there was a lot of variability in expression. The boll rind, buds and flowers had low expression at 0.01 to 2 μg/g. On an average the Cry1Ac expression in the eight Bt-cotton hybrids was found to be adequate for bollworm protection at least until the first 100~120 days after sowing. However, some plant parts such as the boll rind, square bracts, buds and flowers which express low levels of Cry1Ac, may sustain a small proportion of larvae that feed on them. Survival of 5%~10% larvae on Bt-cotton plant parts in *semi-invivo* bioassays is not uncommon. Though 2~3 fold differences in Cry1Ac levels were common between the hybrids during early phase of the crop growth, variability up to 7-fold was also observed at times. The current study showed that increasing levels of *H. armigera* survival were correlated with the toxin levels decreasing below 1.8 μg/g of the plant parts. Hence, despite the variability in toxin expression, the pest control properties are unlikely to be affected significantly at least until the crop becomes 100~115 days old, after which, the toxin levels may decline below 1.8 μg/g in some plant parts. The efficacy to a large extent was dependent on the host into which Cry1Ac was introgressed. An overall analysis revealed that the Bt-cotton technology had a capability of reducing insect pest infestations by 60%~90% under field conditions.

9.3 Emerging pests on Bt cotton in India

Due to large scale cultivation of Bt cottons since 2002 in India changes in insect pest complex are evident. Mealy bugs and mirid bugs are emerging as potential threat.

First report of mealy bugs was in 1997 on *desi* and hybrid varieties of cotton in Wagad area of Kutchh district. But with the cultivation of Bt cotton it has became havoc in cotton since 2006. During 2007-08, the pest caused serious damage in Punjab with an approximate yield loss upto 0.2 million bales worth Rs 1.59 billion. Similar situation was noticed in Hariyana also. Other affected states with this pest includes Rajasthan, Sourashtra (Gujarat), Maharashtra, Andhra Pradesh etc. Unfortunately farmers are forced to rely on heavy use of insecticides once again in cotton to control mealy bugs. *Phenacoccus solenopsis* (Tinsely) (Pseudococcidae: Homoptera)

is largely appearing species throughout India which has been confirmed both by conventional taxonomy and molecular analyses. *Phenacoccus solani* and *Maconellicoccus hirsutus* (Pseudococcidae: Homoptera) are also found to appear in isolated patches.

When mirid bugs are considered, a green mirid, *Creontiades biseratense* (Distant) (Miridae: Hemeptera) is appearing since 2005 in Karnataka and causing considerable damage to Bt cotton. The

severity is found in Haveri district of Karnataka last year. This is also seen in Tamilnadu , AndhraPradesh and Maharastra. Apart from this *Campylomma livida* (Reuter) has also been reported from Maharastra. The mirid pests cause heavy shedding squares and small sized bolls.

Apart from these two pests *Spodoptera litura* (Noctuidae: Lepidoptera) has been considered as potential threat to BG-I cottons. However no outbreak reports are seen so far leading to considerable crop loss.

9.4 Management of resistance

Large scale cultivation of Bt cotton hybrids may lead to the development of resistance to Bt toxins. To avoid the development of resistance, the concept of refuge (use of non-Bt crop) has been recommended.

9.5 Resistance monitoring

Ninety four field populations of *H. armigera* from 44 sites of north, central and south India were bioassayed with Cry1Ac during 1998 to 2006. The log dose probit response indicated that Cry1Ac was highly toxic to the bollworm larvae collected from all the sites in India. Strains from south India were found to be more tolerant to Cry 1Ac compared to all other strains from rest of the country. The range of LC_{50} was 0.01 to 0.88 µg/mL of diet (88-fold tolerance) in field populations of *H. armigera* collected from various parts of the country over the five-year bioassay period. Strains from south India periodically showed tolerance levels that were higher (> 0.16 µg/mL) than the composite average (0.10 µg/mL) published baseline value. However, the tolerance observed throughout the assay period was found to be within the acceptable limits of the baseline, and did not indicate any shift in tolerance of *H. armigera* to Cry1Ac. The LC_{50} and IC_{50} values of Cry1Ac, in our studies are similar to those reported previously for *H. armigera* strains from India, Australia and China. However, the baseline LC_{50} susceptibility values of *H. armigera* to Cry1Ac in China were found to be very variable with a range from 0.091 to 9.073 µg/ml diet. The baseline LC_{50} values of 0.01 to 0.67 µg/ml reported by CICR previously, and 0.11 to 0.71 µg/ml reported recently for Indian strains indicate that the Chinese *H. armigera* strains are inherently more tolerant to Cry1Ac than the Indian strains. The baseline range of EC_{50} values at 0.003 to 0.008 and EC_{90} 0.009 to 0.076 µg/ml diet, published by Jalali et al. (2004), our previous EC_{50} data of 0.014 and EC90, 0.084 µg/ml diet, and the current values of the Bt-seed based bioassays at $IC_{50,}$ 0.012 to 0.013 and $IC_{90,}$ 0.091 to 0.109 µg/ml diet, showed that the results of the bioassays on Indian H. armigera population were comparable even when performed independently in laboratories across the country.

9.6 Resistance management strategies –new insights for the Indian conditions

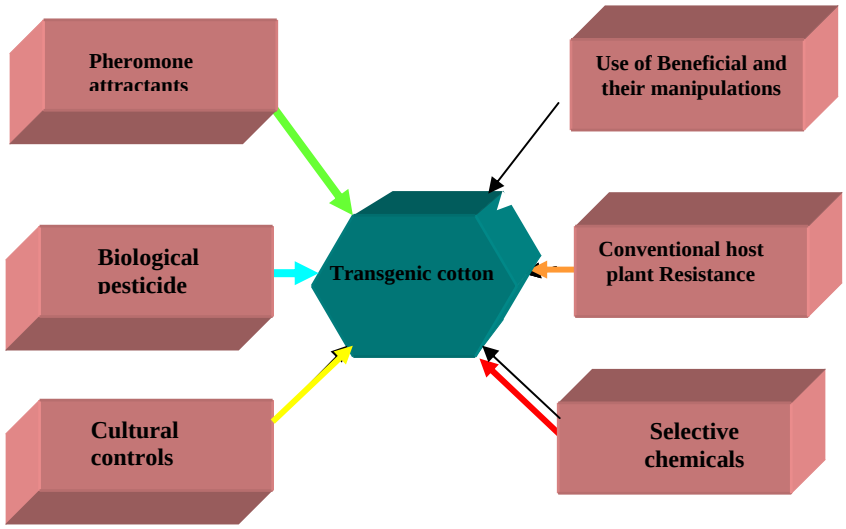
In India 5 border rows of non-Bt cotton surrounding Bt-Cotton per acre has been recommended. The area accounts for 20% refugia. However, , modeling studies showed that maintenance of a 20% refugia may not confer significant advantage in delaying resistance development. This is mainly due to the natural availability of an non structured refugia in the form of alternate host crops in the cotton eco-system.

The stochastic model 'Bt-Adapt' developed at CICR, Nagpur to understand and predict the rate of resistance development of *H. armigera* to Cry1Ac based Bt cotton showed that with 40% Bt cotton area in India, it would take at least 11 years for *H. armigera* Cry1Ac resistant allele frequency to reach 0.5, which would cause difficulties in pest control with Bt cotton. It would be an understatement to suggest that one of the most important strategies in Bt resistance management would be to reduce the Bt cotton surviving population of *H. armigera* through any pest management practices. The extent of reduction in the surviving population, which represents resistant genotypes, would determine the longevity of the technology utilization. Therefore the strategies that would enable extending the usefulness of Bt technology would be 1. Use alternate genes that do not share common resistance mechanisms as that of Cry1Ac, in transgenic plants either in rotation or alternation or mixtures. 2. Use eco-friendly methods such as cultural control or handpicking of surviving bollworms in Bt cotton fields. Biopesticides that are

neem based or HaNPV would be useful to manage younger larvae on 60-90 days old crop. Alternatively, conventional insecticides such as endosulfan, thiodicarb, quinalphos and chlorpyriphos, or new molecules such as spinosad, emamectin benzoate, novaluron or Indoxacarb can be used on 90 and 120 days old crop to reduce populations of resistant genotypes. 3. Identify and use attractive synchronous alternate host crops for *H. armigera* which could be used as intercrop or trap crop refuges. 4. Avoid use of Bt based biopesticides that may contribute to selection of a broad-spectrum resistance to several useful Bt genes of interest.

10 Pest Management in Bt Cotton

With its intrinsic resistance capability to bollworms damage, Bt cotton can become an ideal component for implementing integrated pest management (IPM) quite effectively. The expression of Cry1 Ac protein is not uniform through out the growing period and usually by 110-120 days of crop age the expression level comes down considerably making the crop relatively susceptible to bollworms. The problem of sucking pest has increased considerably in most of the Bt hybrids. The adoption of the IPM system with all its biological, cultural and other components will be immensely beneficial for economic, effective and eco-friendly management of insect pests in Bt cotton.



Sustainable IPM based on transgenic cotton

11 Impact of Bt Cotton in India

The consistent and perceptible increase in cotton production and productivity during last 3 years is partially attributed to higher rate of adoption of Bt cotton in the country.

After the introduction of Bt-cotton in 2002, the insecticide use patter on cotton in India has undergone a complete change. The conventional groups of insecticides were replaced by the new chemistries for their enhanced efficacy. The pattern of insecticide use in cotton in India is similar to rest of the cotton growing countries across the world. Over the last 4 years, more than 40% of India's cotton area was covered by Bt-cotton, which resulted in low insecticide use against bollworms. The recommended insecticides for bollworm control were spinosad, indoxacarb and emamectin benzoate amongst other ecologically acceptable groups of insecticides. The recently recommended cotton pest management strategies in India are based on use of a rational and sensible sequence of insecticides that are effective on the target species, cause less disturbance to beneficial fauna and minimize selection

pressure and rotation of insecticide group based on unrelated resistance mechanisms. Thus, cotton pest management in India is now almost free of the conventional chemistries and ranks amongst the few countries, which use eco-friendly pesticides mostly and also less pesticides for bollworm control.

12 Benefits of Bt Cotton

Bt cotton has several advantages over Non-Bt cotton. Important advantages of Bt cotton include increase in yield, protection from bollworms, reduction in pesticide use, reduction in cost of cultivation, reduction in environmental pollution, genetic resistance, eco-friendly, no adverse effect on parasites, predators and beneficial insects and no health hazards. It also induces earliness. These points are briefly discussed below:（1） Bt cotton does not contain yield enhancing gene. However, it leads to increased yield due to effective control of three types of bollworms viz. American, Spotted and Pink bollworms.（2）The Bt gene is very much effective in controlling insects related to lepidoptera order. Cotton bollworms belong to the order lepidoptera and therefore are sensitive to Bt Cry I, Cry 2 and Cry V proteins which are specific to these insects.（3）The cultivation of Bt cotton leads to significant reduction in the use of pesticides. The Bt insecticidal proteins are very effective in controlling bollworms. As a result, there is hardly need of spraying insecticide in Bt cotton.（4）In Bt cotton, there is drastic reduction in the number of insecticidal sprays. There is reduction in the insecticide sprays to the tune of 75%~80%, which in turn leads to reduction in the cost of cultivation.（5）In Bt cotton, the insecticides are less used. This helps in reduction of environmental pollution**.**（6）Bt Cotton has inbuilt or genetic resistance which protects the crop from the attack of bollworms. This is a permanent type of resistance that is not affected by environmental factors such as rainfall, temperature, humidity etc. If there is a rainfall after the spray of insecticide, the effect of insecticide is washed away. This is not the case with Bt Cotton.（7）Bt cotton is ecofriendly. It does not have adverse effect on parasites, predators, beneficial insects like honey bee, silkworm, lac worm etc. and microorganisms such as earthworm, blue green algae, nitrogen fixing bacteria etc.（8）Bt cotton promotes multiplication of natural enemies of the insects, pests such as *Chrysoperla, Trichogramma, Vasps* etc. These insects help in controlling the bollworms by feeding on their larvae and eggs.（9）Use of insecticide has adverse effect on the human health particularly who is engaged in spraying of such insecticides. Bt cotton does not have any such adverse effect on the human health.（10）It has been observed that the Bt cottons are early in maturity as compared to their non-Bt counterparts. The earliness ranges from 20~30 days in different cotton hybrids tested in India.