CURRENT SCENARIO AND ITS IMPROVEMENT

CHALLENGES OF BT-COTTON IN INDIA

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ABSTRACT
Cotton (Gossypium spp) is the most important renewable natural fibre crop of global importance. Cotton production, processing and trade in cotton goods provide employment to about 60 million people in India. It provides fibre for textile industry. Stability analysis plays an important role in knowing the suitability of the genotypes to variable environments. The changing trends of clothing have always reflected the transformation and evolution of human civilization. Historically India has always played an important role in developments of cotton. India stands out as single largest country which has exploited heterosis in cotton to such a great extent. This unique feat is only possible in India because of intensive research on hybrid cotton, availability of labour for manual hybrid seed production etc., the increase in competition among crops for commercial value has always raised the expectation of productivity of cotton hybrid. Variability is one of the basic requirement for initiating a productive breeding programme for combining desirable genes from diverse sources either in hybrids or segregating generations intervarietal hybridization. The creation of genetic diversity through hybridization is the starting point of another cycle of crop improvement using different mating designs in a breeding programme. The challenges are many. Over the past 10 years between 2003 and 2014, the cost of cotton cultivation in India increased threefold, whereas the minimum support price only doubled. The cost on human labour increased four-fold during the decade, seed costs increased four-fold, fertilizer usage increased 2.5-fold and insecticide usage doubled over the past five years.

Keywords: Cotton, BT Cotton

INTRODUCTION
There are about 50 species of the genus Gossypium out of which only four species, viz. Gossypium arboreum, G. herbaceum, G. hirsutum and G. barbadense are cultivated and rest are wild. (Gossypium spp.) India is the world’s leading natural textile fibre crop and a significant contributor to oilseed. Cotton is one of the best gifts that nature best owed on mankind. India cultivates cotton in 12 to 13 million hectares which is the highest cotton acreage in the world with more than 37.5% of the global cotton area in 2014. The major cotton producing countries are China, USA, India, Pakistan, Uzbekistan, Egypt, Argentina, Australia, Greece, Brazil and Turkey. These countries contribute about 80% to the global production. In India, cotton crops is grown throughout the country. However, there are ten cotton producing states, viz. Punjab, Haryana, Rajasthan, Madhay Pradesh, Maharashatra, Gujarat, The estimated global cotton production in 2014 was 25.96 M tons (152.7 M bales of 170 kg/bale) from 34.14 M hectares. The global production of all fibres including cotton increased from 52.0 M tons in 2000 to 72.5 M tons in 2010. Cotton in India is grown in eleven states under 40% irrigated and 60% rainfed conditions. The three states of north India, Punjab, Haryana and Rajasthan cultivate cotton in about 1.4 million hectares under almost complete irrigated conditions. Maharashtra.
has the largest area of 4.0 to 4.2 million hectares of cotton area with more than 90% under rain-fed farms. Factors such as favorable weather conditions, extremely low bollworm infestation and good market price for the cotton have contributed to the phenomenal increase in area and production. Bt cotton which was introduced in 2002, contributed immensely towards stability in Indian cotton production over the past decade. The area under Bt cotton increased from 6.3 million ha in 2007-08 to over 11.6 million ha during 2014-15. The quality profile of Indian cotton changed significantly. Long staple cotton which constituted 20% in 2000, increased to more than 88% of the total cotton produced in 2014 because of the Bt cotton hybrids, most of which are of the long staple category. Indian cotton productivity levels over the past decade owing to several technological advances. Introduction of Bt cotton technology that efficiently protected the crop from bollworms and thus prevented yield losses of 15-50% each year. Increase in hybrid cotton area from 40% in 2000 to 98% in 2015 that ensured growth of the Indian seed industry with competition amongst them to invest on R&D for the development of new hybrids and production of quality seed significant improvement in the seed quality and hybrid traits.

**Improvement**

Global adoption of GM cotton has risen dramatically from 0.8mha 1996 to 15.5 mha in 2008 constituting 12.4% of total global hectarage under GM crops (James, 2008). Genetic modification of cotton has been carried out for insect resistance, herbicide tolerance and stacked insect resistance and herbicide tolerance. Bt cotton is the fourth dominant transgenic crop at the global level and is commercially cultivated in 15 countries.

The first approval for commercial cultivation of Bt cotton in India was granted to three cottonbrids, MECH-12 Bt, MECH-162 Bt and MECH-184 developed by Mahyco (Maharashtra Hybrid Seed Co.) a leading seed company (Barwale,2002, Jayaraman, 2002). The insect resistance in these hybrids was into grossed from Bt gene cry1Ac containing Cocker-312 (event MON 531, Bollgard I) developed by Monsanto, USA into parental lines of Mahyco’s priority hybrids by using in an accelerated breeding programme and series of biotechnology tool. Mahyco developed stable hybrid with effective toxin expression. Pre-release biosafety and environmental safety testing on aspects of pollen flow, aggressiveness, gene stability, allergenicity, toxicity to small and large animals, protein expression, presence of toxin in by-products, influence on beneficial microorganisms and baseline susceptibility studied were carried out between 1997-2001 as per the guidance of regulatory authorities.

Nearly 500 field trials are carried out in different agroclimatic regions between 1998 to 2001 to assess the efficiency of MON 531 against bollwarms and the concomitant agromonic benefits. Simultaneously, the Council of Agricultural Research (ICAR). An apex national organization in agriculture research. Conducted 55 multi-location field trials through their network of All India Coordinated Cotton Improvement Project (AICCIP) for assessment of insecticidal efficacy and economic benefits of Bt cotton (AICCIP, 2002).

AICCIP trial cleared showed that the first generation Bt cotton hybrids provided effective control of boll warm, requiring no and fewer application of insecticides and also provided high economic benefits to the farmer. It was also found that cry gene incorporation into Indian cotton did not have any negative effects on fibre quality parameters. On the strength of comprehensive testing MECH-12, MECH-162 and MECH 184 were approved by GEAC in April 2002 for commercial cultivation in central and southern cotton-growing zones of India.

Relating the immense potential of the technology. Several Indian seed companies obtained licenses to incorporate the cry1Ac gene into their own hybrids. By 2008, the total number of commercially released hybrids reached hybrids reached 278 which also included three new events, Monsanto’s Bollgard II, GFM Cry A1 of the Chinese Academy of Science and Event1 of the Indian Institute of the Technology, S Khargapur. In addition, approval was granted to the first true breeding Bt-cotton variety Bt- Bikaner Nerma developed by University of Agricultural Science, Dharwad in collaboration with
During the initial years of Bt cotton cultivation some hybrids were reported to perform poorly under unirrigated conditions while other yielded inferior fibre quality (Arunachalam and Bala Ravi, 2003). These observation suggested that the genetic backgrounds in which the cry gene was initially introduced were not most desirable ones. This aspects has been addressed to a large extent during the past few years by the entry of several seed companies into Bt cotton development. The seed companies have used elite germplasm and adopted effective back crossing strategies to eliminate undesirable traits of the original Cocker and introduce desirable traits of yield, quality and adaptation. However there is still considerable scope of yield and quality improvement through the use of improved germplasm in view of the fact that cotton yield in India (567 kg/ha) is still far lower than of USA (902 kg/ha) 

### Genetic background

One of the apprehensions expressed about the adoption of GM technology is the likelihood of one or a few GM genotypes becoming the dominant cultivators thus leading to reduction of crop diversity in farmers fields. Reduction in traditionally crop diversity has in the past been associated with the large scale adoption of high yielding varieties during Green Revolution. However the history of Bt cotton adoption in India suggests that such fears may prove unfounded. Since 2002 when the first Bt hybrids were commercialized in India by one seed company, several others have transferred Bt genes in to many diverse germplasm lines from different sources. Zilberman et al (2007) suggested that the erosion of diversity due to adoption of GM technology would be insignificient once a multiple of GM varieties become available from seed sectors.

### Refuge crop

One of the condition for the environmental release of Bt cotton is that each such fields is to be surrounded by blet on non-Bt cotton of the same variety to serve as refuge for Bollwarms. The size of the refuge belt should be either five rows of non-bt cotton or 20% of total sown area whichever is more (Ghosh 2001). The refuge strategy is designated to ensure that Bt-susceptible insects will be available to mate with Bt-resistant insect, should they arise. The available genetic data indicate that susceptibility is dominanent over resistance (Tuli er al 2000). The off springs of these mating would most likely be Bt susceptible thus the mitigating the spread of resistance in the population. It has been widely reported that these normes are not followed in practice, which could lead to rapid build up of Bt- toxin resistance in bollwarms

### High density planting (HDPs)

In current cotton scenario spreading type of plants technically called as “Bushy Plant Type” required more spacing and ultimately per acre population will be less because of wider spacing applied and yield level not increase as such level while arrival of Bt technology from 2000 from that time yield of
cotton directly increase than of traditionally use Non Bt hybrids, but in present situation it need to develop such type of plant type fit for high density planting.

In this concept farmer can need to change its traditionally applicable agronomic practices. If cotton scientist develop such type of genotypes and use in hybrid development programme and its multi locational testing per acre yield will be double than previously use techniques. In this concepts per acre seed rate will be double and to increase per acre population with less spacing i.e 120x15 cm in rainfed zones of India and 120x30 or 45 cm in irrigated zones of India and according to its soil type (i.e heavy, medium & light).

In future fr rainfed zones in India Mechanical Cotton Picking machin technology also under trial it can reduce cost against labour fr cotton picking. In China, USA already adopted this techniques, but this technology only applicable to high density planting concepts and also in one time cotton brusting, 3 fit cotton height is more successful in above conditions. Factors such as favorable weather conditions, extremely low bollworm infestation and good market price for the cotton have contributed to the phenomenal increase in area and production. Bt cotton which was introduced in 2002, contributed immensely towards stability in India cotton production over the past decade. The area under Bt cotton increased from 6.3 million ha in 2007-08 to over 11.6 million ha during 2014-15. The quality profile of Indian cotton changed significantly. Long staple cotton which constituted 20% in 2000, increased to more than 88% of the total cotton produced in 2014 because of the Bt cotton hybrids, most of which are of the long staple category. There has been a significant increase in the Indian cotton productivity levels over the past decade owing to several technological advances.

**Main factors for yield enhancement**

1. Introduction of Bt cotton technology that efficiently protected the crop from bollworms and thus prevented yield losses of 15-50% each year, but its time to gradually pink bollwarm resistance to Bt-Cotton because of not planting Non-Bt cotton surrounding to Bt- Cotton as sapera ket packet provide.

2. Increase in hybrid cotton area from 40% in 2000 to 98% in 2015 that ensured growth of the Indian seed industry with competition amongst them to invest on R&D for the development of new hybrids and production of quality seed. As an onward breeding team focus on to develop early maturiting hybrids so as to excape pink boll warm attack start form December onward.

3. Significant improvement in the seed quality and hybrid traits due to high commercial competition between the 46 ‘Bt cotton sub-licensee’ seed companies

4. Increase in irrigated area under cotton after 2000 as Bt Cotton introduce, as study in 2014-2015-2016 long duration maturity hybrids avoids for planting because of Pink boll warm infestation in BGII, so prefered early maturing hybrids.

5. Implementation of water saving technologies such as drip and sprinklers along with fertigation.

6. Regulation of seed quality based on CICR technologies through regulatory agencies.

7. Fertilizer use on cotton in India constantly increased over the past 10 years from 96 kg/ha in 2002 to 222 kg/ha in 2011 (Source http://eands.dacnet.nic.in). The increasing trend is continuing

8. For increasing cotton productivity adoption of High Density Planting in Rainfed zones and preferred early maturing hybrids with erect plant type only sympodial growth habit.

9. Day by day increasing labour picking problem so new technology introduce Machine Sowing and Machin Picking so adoption of this cocept fully successful in rainfed zones for per acre productivity increases with low inputs.
Challenges

Cotton is a commercial crop that provides livelihood security to farm families in India and several countries. Cotton production influences the lives of millions of persons. The textile industry provides livelihood to an estimated 40 million persons in India and 150 million across the globe. Cotton economy is influenced by a wide variety of factors. Farmer livelihood depends on yields, production costs and market price that determine the net profitability. The value-chain industry depends on raw cotton at an affordable price to enable them produce yarn, fabric and apparel in a global-competitive environment. The technology and input providers exercise enormous influence on inputs, generally orienting market demands that ensure reasonable profits. Consumers expect good quality products at affordable prices. All the stakeholders eventually get benefitted if the production costs are lowered and yields get enhanced. Some of the main challenges are listed below:

1. Genetic erosion and narrowing of genetic diversity in cultivated varieties/hybrids
2. Non-availability of public sector GM cotton varieties mainly Bt cotton
3. Indian cotton productivity levels are 30-50% below world average of the leading countries.
4. Insect Resistance development to Bt cotton and insecticides
5. Spurious inputs such as GM seeds and pesticides.
6. Significant decrease in fertilizer factor productivity of Indian soils from 20 kg grains/kg fertilizer in 1980 to 8 kg grains/kg fertilizer in 2010.
7. Low soil organic carbon content.
8. Fertilizer usage doubled to 28 million tons in 2014 over the past 20 years.
9. Imbalanced fertilizer usage and micro-nutrient deficiencies in soils are resulting in increased insect pests, insect resistance to insecticides and concomitantly increased insecticide usage.
10. Ever increasing cost of inputs such as seeds, fertilizers and pesticides and non commensurate market price of cotton is lowering down profitability over time.
11. Cotton seeds costs increased constantly over the past 10 years from ` 1058/ha in 2002 to ` 3594/ha (Source: http://eands.dacnet.nic.in)
12. Despite the introduction of Bt cotton, which was expected to reduce the need for insecticide use, the expenditure on insecticides on cotton increased constantly over the 10 year period from ` 1385/ha in the year 2002 to ` 2429/ha in 2011 (Source: http://eands.dacnet.nic.in)
13. Lack of irrigation facilities in more than 60% of cotton area.
14. Non-availability of small scale low cost machines for sowing and picking.
15. Labour shortages and enhanced wages, which doubled over the past 7 years are resulting in delayed crop operations and diminishing profits.
16. Erratic monsoon, droughts and extreme temperatures
17. Chemical influenced soil degradation, water pollution and poor microbial diversity
18. Reducing ground water levels by 2-4 mbg within one decade in North and Western regions of India

Climate change

Climate change and global warming are serious challenges to agriculture. The atmospheric changes can result in fragile unpredictable ecosystems that extend vulnerability to many cropping systems. The Intergovernmental Panel on Climate Change

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(IPCC) projections estimate that atmospheric CO2 concentration would rise to 450-500 ppm by 2050 and 575 ppm by 2080’s along with increase in the mean temperature by more than 2°C. Cotton crop is generally resilient to several abiotic stress factors, but needs support systems to enable them mitigate the additional stress imposed by climate change. It is important to breed for climate resilient varieties and ensure conservation of natural resources to improve the resilience. Nevertheless, cotton crop can be affected by the unpredictable environmental stress inducing variables depending on the critical window, which affects production. However, cotton cultivation and processing also contribute to greenhouse gas emissions, albeit to a lesser extent. The entire process of cotton crop production, fibre processing and maintenance of clothes contributes to less than 1.0% of the total greenhouse gas emission. Much of the CO2 and NO2 emissions are actually from irrigated cotton in developing countries. It is estimated that chemical inputs in cotton cultivation cause an emission of about 1200 kg/ha of CO2 and 1800 kg/ha of NO2. Irrigation pump sets were found to contribute to 642 kg CO2 per hectare. Over the past few years there is wide spread awareness on the need to reduce chemical dependence that in turn can minimize the climate change impact. While elevated temperatures and CO2 induced more feeding in insect pests such as the leaf eating caterpillar, *Spodoptera litura*, the cotton sap-sucking pests whiteflies, thrips, aphids, mealybugs etc. were found benefit by enhanced survival and reproduction. The whitefly, *B. tabaci* B biotype causes huge economic yield losses to cotton, apart from

**Gaps in research**

**Characterization of genetic resources**

- Need for Rain-out shelters & Phenotypic platforms to characterize genetic sources for resistance to biotic & abiotic stresses.

**Biotechnology – critical gaps**

- IPR protected indigenous genes and promoters
- IPR protected genetic transformation constructs and genetic engineering technologies
- Novel technologies of RNAi and site directed gene integration
- Platforms for Bioinformatics and Molecular software application
- Indigenous gene data banks, molecular and microbial resources

**Crop improvement – critical gaps**

- Genetic enhancement with reference to climate change
- Breeding for Multi-Adversity-Resistant hybrids/varieties
- Consolidation of genetic sources of resistance to cotton leaf curl virus (CLCuV) disease and bacterial blight
- Intensification of research on heterotic pools and development of hybrids with high harvest index and boll development synchrony
- Markers for major economically important traits
- Marker Assisted Breeding initiatives for pest & disease resistance
- Exploring the possibility of harnessing stable epigenetic variations across generations to improve adaptability of cotton to changing environments, hybrid vigour and productivity
- Developing epigenetically engineered cotton by chemical treatments and/or spontaneous/environmentally induced epimutations for higher productivity
• Early maturing hybrids for rainfed regions
• Robust genetic sources for abiotic resistance (salinity, drought and heat tolerance)

**Crop production – critical gaps**

• Conservation Agriculture Technologies and soil moisture conservation
• Intensive research to identify cropping systems of cotton with Nitrogen fixing crops (fodder and pulses) and microbial biofertilizers (*Azolla*, *Anabaena*, *Azotobacter*, Phosphorus solubilising microorganisms (PSM), Arbuscular Mycorrhiza (AM) etc.) also to ensure self sustaining IPM ecology and Integrated farming systems with animal husbandry
• Biological Weed Management Technologies
• Combined effective water-nutrition management
• Mechanization of operations to substitute labour drudgery
• Studies on the possible impact of technologies on labour displacement
• Real-time analysis of micro nutrient disorders and crop-specific formulations
• Standard package of practices for organic production
• Pollination ecology in enhancing productivity
• Research to mitigate the impact of climate change on crop productivity
• Secondary Agriculture and waste utilization

**Plant protection - critical gaps**

• Robust research on components of IPM & IRM Integrated Pest Management (IPM) and Insect Resistance Management (IRM)
• Research on host plant resistance to whiteflies and CLCuD
• Addressing the challenge of insect pests and diseases that are common to many crops such as- Borers, viral diseases, virus vectors –whiteflies and thrips that have impact on cotton pest management
• Documentation of molecular diversity of cotton insect pests, parasitoids, predators, pathogens and economically important microbial populations in the cotton cropping systems
• Bio-security & planning for invasive pests such as whitefly B-biotype and Mealybugs
• Rapid diagnostic tools especially for cryptic insects and diseases

**Seed science & technology – critical gaps**

• Package of practices exclusively for cotton seed processing production
• Simple cost effective nurseries for hybrids
• Diagnostics – Critical for seed borne diseases
• Simple and cost effective genetic purity testing method for commercial hybrids (other than that for the transgene)
• Research on pollination for seed production and quality

**Social sciences – critical gaps**

• Research on Market Intelligence methodologies for yield and
price forecast

Research on integrating novel ICT tools for precision farming

Research methodology in extension, e-extension, crop specific portals, field guides and expert systems

Research on welfare schemes such as MNREGA (Mahatma Gandhi National Rural Employment Guarantee Act), MSP (Minimum Support Price), input subsidies, and their impact on agrarian welfare and cotton production

Partial factor productivity and Total factor productivity

Co-ordination of projects – critical gaps

Overhauling evaluation systems for technology validation, varietal suitability and release for specific agro-eco zones

Removal of redundancy and over-lap in experiments

REFERENCES


