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PERSPECTIVE

INDIAN PERSPECTIVE: SUSTAINABILITY OF BT COTTON IS A MATTER OF CONCERN NOW!

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It must have been in 2004 or 2005 that a farmer named Narayan Bhawsar from a village in the Central India phoned to arrange for single-toxin Bt cotton seed (expressing *cry1Ac* gene isolated from the soil bacterium, *Bacillus thuringiensis*). Like Narayan Bhawsar, many farmers were clamoring for Bt cotton seed as it was in short supply and sold at premium rates far above the market retail price. The Government of India had approved Bt cotton in March 2002 for cultivation based on MON531 event (ISAAA website/GM Approval Database/event/EventID = 54) after Mahyco Monsanto Biotech Ltd. successfully demonstrated its efficacy against the cotton bollworm, *Helicoverpa armigera* in the agronomic trials and biosafety to the environment. A year earlier, farmers in the state of Gujarat had illegally cultivated single-toxin Bt cotton hybrid on a large scale. As Bt cotton was found quite effective against bollworms and increased yields significantly, news of its success spread like wildfire. The area under Bt cotton hybrids increased from 29,000 ha in 2002 to about 80% of the total cotton area (9.4 Mha) in the country in 2008, breaching by default 20% non-Bt cotton area to be kept as mandatory structured refuge. In the meantime, the Government of India also approved a dual-toxin Bt cotton (MON15985 event of Bollgard® II) (ISAAA website/GM Approval Database/event/EventID = 59) that produced Cry1Ac and Cry2Ab2 toxins to overcome evolution of resistance in bollworms and increase efficacy against lepidopterans. Eventually, the area under dual-toxin Bt cotton hybrids increased from 4% of the total Bt cotton area in 2006 to 27% in 2008, 57% in 2009, with an annual increment of 11% reaching 90% in 2012, and then stabilizing at about 95%.

Before the commercialization of Bt cotton in 2002, Indian farmers cultivated four species of cotton, *Gossypium barbadense*, *G. hirsutum*, *G. herbaceum* and *G. arboreum*, representing 3%, 69%, 11% and 17% of the total area, respectively. The latter two species are native short staple diploid cottons adapted to the Indian conditions. However, with the adoption Bt cotton, area under *G. hirsutum* that produces long-staple length lint increased to 90% of the total area, greatly reducing genetic diversity in the cotton industry.

With the adoption of Bt cotton, the cotton area increased from 7.87 Mha in 2002 to 12 Mha in 2011 stabilizing at about 11–12 Mha thereafter. Lint yield increased significantly from 307 $kg \cdot ha^{-1}$ in 2003 to 467 $kg \cdot ha^{-1}$ in 2007 and varied between 415 and 510 $kg \cdot ha^{-1}$ until 2019 except for years of drought or high infestation of pest insects at a local level. Cotton production ranged from 13.6 million bales (170 kg per bale) in 2002 to 40 million bales in 2014. India emerged as the world's largest cotton producer (about 34–36 million bales yr^{-1}) and a major exporter (4–7 million bales yr^{-1}) over the past decade. Adoption of Bt cotton helped to significantly increase gross profit margins ha^{-1} (after deducting increased seed cost and technology fee) from 83 USD in 2002 to 357 USD in 2007, which later declined to 287 USD in 2011 and to 112 USD in 2016 (Fig. 1). This also helped to increase farm income at a national level from 3.69 million USD in 2002 to 3 billion USD in 2011, which then declined to 1.45 billion USD in 2016. Like India, other countries in the Asia-Pacific region benefitted from growing Bt cotton[3].

Bt cotton cultivation reduced the volume of insecticide active

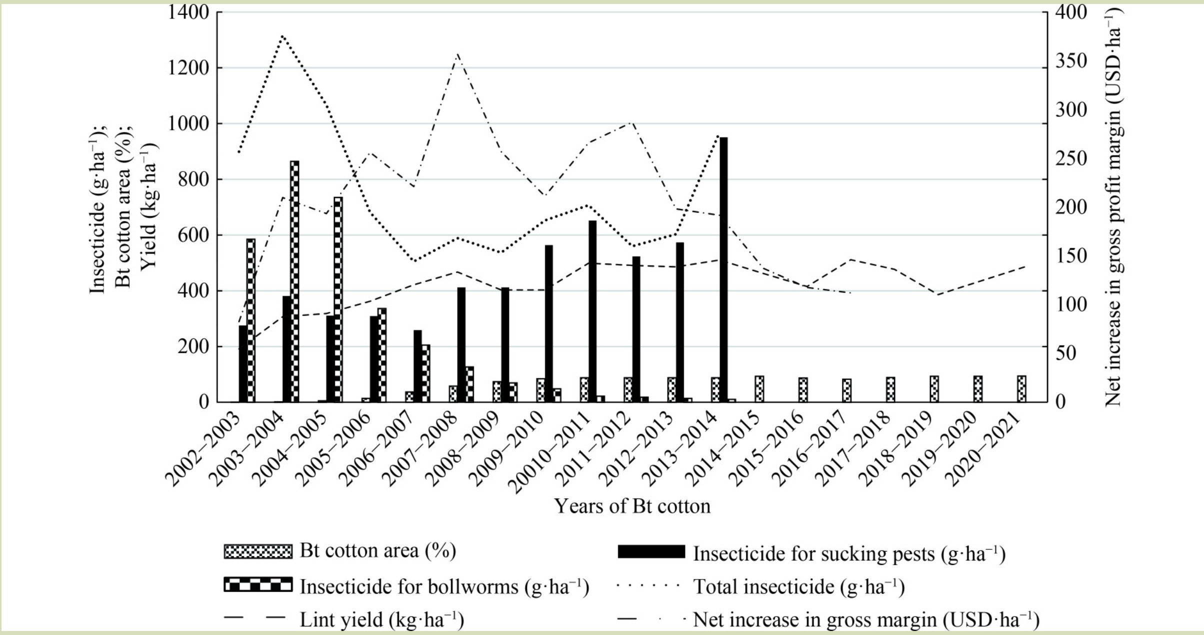

Fig. 1 Trends in insecticide use for bollworms, sucking pests and total; cotton area, yield and profit based upon data from Choudhary and Gaur[1], Kranthi[2] and Brookes[3].

ingredients (a.i.) applied per hectare from about 1.3 kg in 2003 to 969 g in 2013. Insecticides (a.i.) applied to control bollworm decreased from 864 $g{\cdot}ha^{-1}$ in 2003 to 10 $g{\cdot}ha^{-1}$ in 2013 and non-specific insecticides from 70 $g{\cdot}ha^{-1}$ in 2003 to 9 $g{\cdot}ha^{-1}$ in 2013. However, per hectare active ingredients of insecticide use for sucking pest control increased from 381 g in 2003 to 950 g in 2013[1]. Insecticide use remains high even now. Many studies during the 2010s reported the major benefits of Bt cotton in terms of reduction in insecticide use and its cost, improvement in environmental quality and increase in socioeconomic status of cotton farmers[1,4,5].

SUSTAINABILITY OF BT COTTON IS AT CROSSROAD!

In the early 2010s, farmers started reporting stagnating or poor yields of Bt cotton unlike in the initial years of its adoption. Over the years, this became the major concern of cotton farmers. As the area sown to Bt cotton increased, it provided more congenial agroecological conditions for pest complex to multiply. Sucking pests, such as whitefly, leafhopper (jassid), thrip, mealybug, aphid and mirid bug, became the major pests of Bt cotton. Also, plant diseases, such as wilt, parawilt, cotton leaf curl virus, bacterial blight and boll rot, took their toll on cotton yields. An outbreak of whitefly in the northern state of Punjab in 2015 severely impacted cotton production by more than 65% resulting in loss of 1.1 million bales of lint costing 433 million USD and incurring an additional expenditure of 8 million USD on increased insecticide use in comparison to the base year 2013. In some areas, insecticide use increased to those of the pre-Bt cotton period. Also, use of both fungicides and herbicides has increased in Bt cotton over the years. In a study surveying farmers in three major cotton producing districts of Punjab, there was no significant difference in insecticide applications, its use in quantity and expenses between Bt and non-Bt cotton in 2016, which meant that Bt cotton no longer offered additional benefits. The comparison of insecticide usage in Bt cotton between 2004 and 2016 revealed that mean insecticide applications increased by 66%. However, insecticide use (a.i.) per hectare declined by about 26%, proportion of insecticide costs to the total cost of cultivation increased by about 1.4% and mean seed cotton declined by about 13%[6]. The number of marginal (< 1 ha) and small (1–2 ha) farmers increased relative to large farmers (> 10 ha), constraining the ability to bear the increasing cultivation costs. This study showed a significant decline in the cotton area and shift toward rice cultivation casting doubts on the sustainability of Bt cotton cultivation in Punjab[6]. Another study at the national level showed high operational cost, especially for human labor and agronomic inputs, yield stagnation and volatile cotton prices that reduced net profit from 2011 onwards and even becoming negative from 2014[7]. Export earnings from cotton have declined from the highest of about 9 billion USD in 2013 to 800 million USD in 2020.

For Bt crops, insect resistance management (IRM) is a mandatory requirement in order to sustain this transgenic technology. However, in view of non-compliance of IRM, there are as many as 19 cases of field-evolved resistance worldwide[8]. In India, field-evolved resistance to single-toxin Bt cotton in the pink bollworm was first reported in the larvae collected from Bt cotton in Amreli (Gujarat) in 2008[9]. Later, Monsanto reported in a press release (dated 6 March 2010) an unusually high survival of pink bollworm in Gujarat during its field monitoring of 2009 cotton crop. Unfortunately, these results were ignored to favor the single-toxin Bt cotton events, such as Event-1 of JK AgriGenetics, GFM of Nath Seeds, BNLA 601 of CICR Nagpur-UAS Dharwad and MLS 9124 of Metahelix, being developed by Indian companies. As both single- and dual-toxin Bt cottons were cultivated until Bollgard® II became dominant, this mosaic of Bt toxins with differential expression and toxicities to the larvae of pink bollworm, as well as lack of IRM implementation, provided much better ecosystem to evolve resistance to both Cry1Ac and Cry2Ab2 toxins. The Bt-resistant pink bollworm has reduced cotton yields in some years in many localities. In the state of Gujarat alone, using 2013 as the base year, we estimated loss of 0.67 million bales in 2014 and 1.41 million bales of cotton in 2015 valued at 817 million USD largely due to resistant pink bollworm. IRM for Bt cotton was a missed opportunity in view of impracticality of refuge implementation and lack of stewardship of both transgenic and agronomic technologies coupled with seed quality and trait expression issues[2,10].

Crop biotechnology is often promoted for its benefits, but it needs to be regulated to prevent any unintended effects on environment including human health. Dominance of the corporate sector, especially of the developed countries creates suspicion of exploitation of natural resources as well as of regulatory system in the developing countries. Lack of respect for intellectual property rights has affected development of the Bt technology in many developing countries. For technology developers, hybrids are the only way to protect biotechnological innovations in developing countries, unlike Bt crop cultivars available to farmers in most developed countries. This also deprives farmers of the advantages of cultivating Bt cotton cultivars. As a result of more than a decade of policy paralysis with respect to the transgenic technology, farmers in some developing countries are increasingly resorting to the use of illegal transgenic products. India is no exception. Herbicide-tolerant Bt cotton technology was developed during the late 2000s and early 2010s in India, but did not reach the approval stage due to differences in policy perception between stakeholders. Hence, illegal transgenic technology has been used in the country for many years with reportedly as much as 1.5 Mha under HT-Bt cotton in 2021.

In view of problems of Bt cotton, some farmers are growing local non-Bt cotton cultivars to reduce production costs. However, the non-Bt cotton area remains low. Bt cotton is still preferred due to its agronomic performance. But, its widespread adoption has taken a heavy toll on natural resources, as good agricultural practices are ignored and more sustainable alternative technologies are not implemented to address the problems.

Green initiatives in crop protection are aimed at reducing pollution and ensuring sustainability. In hindsight, what can be more green than the time tested safe and effective Bt technology? As India completes two decades of Bt cotton, cotton farmers are yearning for crop protection technologies like those of sterile insect releases, mating disruption and agronomically suited Bt transgenic upgrades like Bollgard® 3 to be used in harmony with others under integrated crop management to ensuring Bt cotton sustainability.

REFERENCES

1. Choudhary B, Gaur K. Biotech Cotton in India, 2002 to 2014. ISAAA Series of Biotech Crop Profiles, Ithaca: *ISAAA*, 2015
2. Kranthi K R. Cotton in India—Long term trends and way forward. *ICAC Recorder*, 2020: 3–40
3. Brookes G. The economic and environmental impact of genetically modified crops in the Asia Pacific Region. In: Gujar G T, Trisyono Y A, Chen M, eds. Genetically Modified Crops in Asia Pacific. Melbourne: *CSIRO Publishing*, 2021, 9–18
4. Krishna V V, Qaim M. Bt cotton and sustainability of pesticide reductions in India. *Agricultural Systems*, 2012, **107**: 47–55
5. Ranganathan T, Gaurav S, Haldar I S. Pesticide usage by cotton farmers in India-Changes associated over a decade. *Economic and Political Weekly*, 2018, **53**(19): 43–51
6. Peshin R, Hansra B S, Singh K, Nanda R, Sharma R, Yangsdon S, Kumar R. Long-term impact of Bt cotton: an empirical evidence from North India. *Journal of Cleaner Production*, 2021, **312**: 127575
7. Reddy A R, Blaise D, Anuradha N. Cost escalation in cotton

cultivation: an analysis. *Economic Affairs*, 2018, **63**(4): 833–838

8. Tabashnik B E, Carrière Y. Global patterns of resistance to Bt crops highlighting pink bollworm in the United States, China, and India. *Journal of Economic Entomology*, 2019, **112**(6): 2513–2523
9. Dhurua S, Gujar G T. Field-evolved resistance to Bt toxin Cry1Ac in the pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), from India. *Pest Management Science*, 2011, **67**(8): 898–903
10. Mohan K S, Kalia V, Gujar G T. Resistance management in Bt cotton in India. In: Gujar G T, Trisyono Y A, Chen M, eds. Genetically Modified Crops in Asia Pacific. Melbourne: *CSIRO Publishing*, 2021, 31–52