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Aspects of Bt-cotton Hybrids can Prove Problematic

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Abstract
Before the introduction of Bt-cotton in 2002, India's cotton productivity and area under cultivation were both decreased by recurrent bollworm infestation. Area and production then both rose. The cultivation of a huge number of inappropriate hybrids is one of the factors contributing to India's output stagnation at 454–50 kg lint/ha during the previous 16 years, from 2005 to 2021. It is not possible to blame Bt cotton technology alone for declining yields. Indian cotton producers rely on Bt-hybrids, which have many issues over open-pollinated Bt-cotton varieties, in contrast to other cotton-growing nations where open-pollinated Bt-cotton varieties are grown.

Keywords: Bt technology, Bt-cotton hybrids, and cotton productivity.

Cotton is one of the most important fiber and a cash crop of India and plays a dominant role in the industrial and agricultural economy of the country. Worldwide area under cotton for the year 2020-21 was31.66 million hectares and production and productivity accounted for 113.11 million bales and 778 kg/hectare respectively. In India during 2020-21 (provisional), production of Cotton was 371.00lakh bales cultivated under an area of 129.57lakh hectares with a productivity of 487 kg per hectare (Cotton Corporation of India).Three bollworm species, including the American bollworm (Helicoverpa armigera), the Pink bollworm (Pectinophora gossypiella), and the Spotted bollworms, can damage cotton, a crop that takes a long time to mature (Earias vittella and Earias insulana). These big bugs pose a substantial danger to cotton production and will likely reduce yields significantly. An increase in area and productivity of cotton was reported after the introduction of Bt cotton technology in India, acquiring 1st rank in the world in the cotton area at about 125.86 lakh-ha *i.e.* about 37% of the world area of 336.3 lakh/ha. However, this increase was not solely due to the use of BT cotton but other factors like the use of IPM/IRM strategies, new insecticides and conversion of new land under cotton cultivation too were responsible. Still, India's productivity is very low as compared to the USA (955 kg/ha) and China (1764 Kg/ha). Yield stagnation in India at 454±50 kg lint/ha from 2005 to 2019 is attributed mainly to the vast number of unsuitable hybrids, rainfed conditions, the incidence of new pests and diseases, the uncertainty of Monsoon, climate changes, and evolving resistance against Bt cotton by bollworm, etc. These factors are considered as the main constraints to obtain sustainable and expected cotton production, not the Bt cotton technology. In 2002, Bollgourd-I (BG-I) with *Cry1Ac* gene (Firstgeneration) derived from *B. thuringiensis* was introduced for commercial cultivation. It successfully controlled lepidopteran pests, especially bollworms which are the main constraint in cotton productivity. However in 2009, the bollworm species begins to develop resistance and as a result, India adapted Bollgard II with two genes *Cry1Ac+Cry2Ab* (Second-generation) for commercial cultivation, which have a different mechanism and mode

of action to protect against bollworms. Deployment of two dissimilar genes mutually assisted in delaying resistance, it could not be deferred indefinitely and by 2014 these hybrids became susceptible to bollworm species. The Bt-cotton available in other cotton-growing countries are open-pollinated verities and not susceptible to the bollworm pest.

Fig.1 Bt- Cotton Cultivation

India grows all four species of cultivated cotton *Gossypium hirsutum* (American Upland cotton), *G. herbaceum* (Asian cotton), *G. barbadense* (Egyptian cotton) and *G.arboreum*. *Gossypium hirsutum* contributes 88% of the hybrid cotton production and all the current Bt cotton hybrids belong to the species *G. Hirsutuim* in India. Owing to the high input intensive nature of hybrids, they are unsuitable to rainfed conditions. Nearly 62% of cotton is cultivated in rainfed areas and 38% in irrigated areas in India.

India uses Bt technology only in hybrids. Hybrids are crosses resulting from two crop varieties of species through sexual reproduction that shows heterosis. The agreement to license BG-I and BGII to Indian seed companies was restricted to the use of Bt to hybrids only. Hybrids are economically very attractive to seed companies owing to their "value capture mechanism". Indian farmers can sell or save the seeds under intellectual property laws but in other countries, the selling and saving of seeds are prohibited. Indian seed companies prefer hybrids because hybrids segregated into a 3:1 ratio and lose their genetic stability when their seeds are sown in the next generation. This forces farmers to repurchase cotton seeds every growing season, protecting corporate revenue. Monsanto has a monopoly on Bt cotton seeds in India that has been the major concern for activists. Seed companies cannot develop varieties with BG-II due to patent issues, but they can with BG-I, since the agreement of the licensed period is over in India. Hybrids are liable in terms of resistance development The majority of the Bt hybrids available in markets are of 180 to 200 days duration and bushier and bigger so farmers cultivate them at low densities (11,000 to 16,000 plants/ha) in India. Whereas, countries like Brazil and U.S. plant at high densities (80,000 to 100,000 plants/ha) because open-pollinated verities are less vigorous. To get maximum yield with low densities, Indian farmers grow them longer as ratoon crops (160 and 300 days) so that they produce sufficient cotton. The longer duration of crops due to hybrid, volunteer, and ratoon has grown cotton crop, allows a pest to increase in number, this may enforce extra selection pressure on bollworm species for the resistance development against Bt-cry proteins produced by Bt cotton. Other cotton growing countries strictly removed the crop from the field before 160 days. Cotton crop is required to be removed or destroyed by root cutting, plowing, or by spraying herbicide immediately after harvest so that they cannot continue to act as hosts for bollworm species. Incidence of bollworms was observed sometimes from a few fields across the country due to fact that bolls on F1 hybrid crop have 25% non-Bt seeds (25:75 ratio) allowing the existence of bollworm larvae which feed mostly on the developing seeds. In India, large numbers of different hybrids were grown under three seasons, so their flowering and boll formation period is different ensuring the continuous supply of food for bollworm infestation leading to the development of resistance by Bollworm species against cry protein. Secondary pest infestation is also increased due to the cultivation of inappropriate long-duration hybrids and specificity of the Bt gene to bollworm and avoidance of refuge strategy by farmers. Therefore pesticide use is increasing with the emergence of secondary pests. Bt-cotton Hybrids are unsuitable for rainfed conditions Hybrids are responsive to a high level of inputs and are always advantageous to high input-intensive systems, which are not suited to rainfed agriculture with

marginal soils. Such area contributes around half of the area in the country.

Bt cotton is suitable in both rainfed and irrigated conditions but unsuitability is associated with hybrids. The majority of the Bt hybrids available in markets are of 180 to 200 days duration that suffers from moisture stress. Seeds of hybrid cotton are expensive and usually sown late, subsequent to ensuring enough soil moisture to circumvent the economic load of re-sowing. Late sown hybrids undergo severe moisture stress at the critical period of boll formation that occurs much later after the rains recede. The moisture stress is increased in rainfed regions in marginal, shallow soils, which cannot hold enough water to maintain boll formation, resulting in low yields. Supplemental and protective irrigation is not possible in the 97% rainfed area of Vidarbha. In general, Bt hybrids are more suitable to irrigated regions because of longer duration with a large number of bolls/plants, having a longer fruiting window.

Fig-2. Hybrid of Bt-cotton

The boll retention percentage is more in hybrids so, only irrigated regions can continuously supply nutrients and soil moisture during the peak boll formation stage for high yields. In long-duration hybrids, boll formation starts in October and reaches a peak in November, but rainfall begins in June and recedes in September. It badly affects boll formation and retention due to moisture stress particularly in shallow, marginal soils, consequently, the performance of hybrid cotton is unsatisfactory. Farmers often mistakenly attribute such deprived performance to Bt cotton technology.

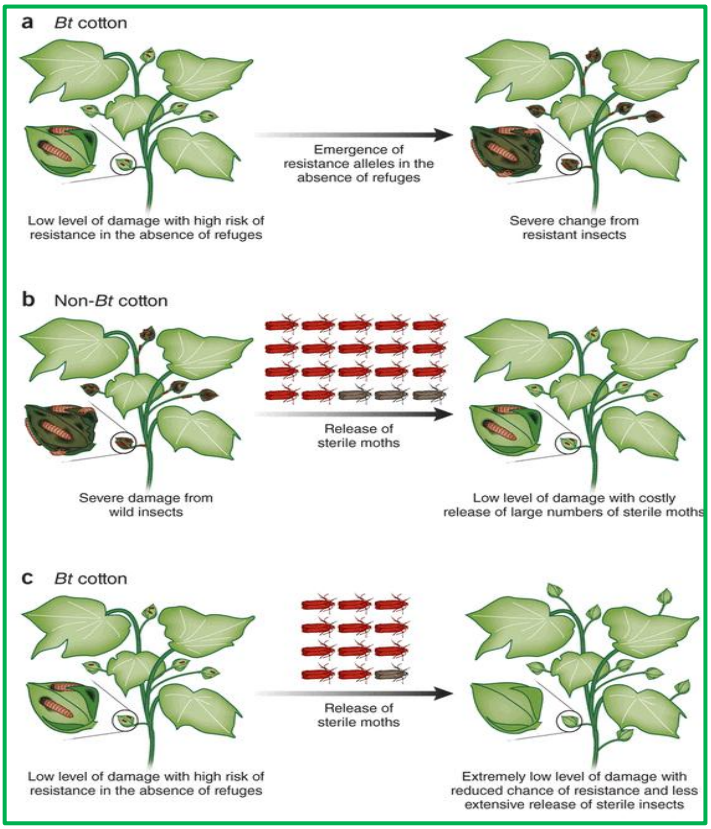

Fig. 3 Development of BT-cotton

Other problems with hybrids

The seeds of Bt cotton hybrids are more costly than native varieties. Indian farmers can sell or save the seeds under intellectual property laws but in other countries restrict selling and saving of seeds is enforced. Indian seed companies prefer hybrids because, in contrast to varieties, hybrids segregat into 3:1 ratio and lose their genetic stability when their seeds are sown in the next generation. These force farmers to repurchase cotton seeds every growing season. Innumerable Bt-cotton hybrids are available in the market, thus creating confusion amongst farmers and seed testing organizations are facing difficulty to monitor the quality of seed. Some farmers take trials of new hybrids on their own field to test its

performance. Therefore, the quality of seeds has become the main issue. It leads to the sale of unauthentic seed to farmers who are forced to try new hybrids every season because of seed scarcity of popular hybrids. Furthermore, several hybrids are vulnerable to leaf curl virus, leaf reddening and sapsucking insects, contributing to more input costs. Earlier ICAR approved Bt hybrids after three years of multiplication trials but GEAC approves within a year. Therefore more stringent hybrids are not coming to market. However several hybrids were recommended for one zone but are being cultivated in different zones. How to exploit the maximum potential of Bt technology To exploit the full potential of Bt technology, particularly for rainfed regions of shallow-marginal soils, use of low input-intensive, early planting, short-duration Bt-hybrids or Bt-varieties which are resistant to sapsucking pest, dwarf stature, suitable for rained regions, zero monopodial, which are comfortable for high-density planting populations (>100,000 per acre) is the best option. The major benefit with varieties is that farmers can reuse seed and have the liberty of early dry sowing, sometimes before the onset of the monsoon, with no need to worry about poor germination risks and re-sowing. The transgenes encoding cry toxins will be present in the homozygous condition in varieties, while in hybrids transgenes present in the hemizygous condition. Homozygous condition of transgenes in varieties expressed higher levels of cry toxin in comparison to the hemizygous hybrids. Therefore better protection is provided by varieties against bollworm. The cry toxins encoding gene in the Bt-variety cannot segregate into seeds of the bolls whereas in the case of F1 Bt-hybrids, the boll seeds would segregate into 25% non- Bt seeds and 75% for Bt seeds, consequently, bolls are vulnerable to bollworm feeding.

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