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Review Article

Genetically Modified Crops- Need of the Hour: An Indian Perspective

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ABSTRACT

The sustainable growth in agriculture faces many challenges owing to the limited availability of land and water besides the biotic stresses (pests, insects) and abiotic stresses (drought, saline, heat, floods *etc.*). The unreliable rainfall in India and poor irrigation facilities further aggravate the problem of food crop production. Due to such climatic unpredictabilities, there is a dire need for the development of improved crop varieties. The goal of such an approach is to focus on the production of new varieties that can withstand the biotic and abiotic stresses and may add to the food productivity with better yields and nutritional enrichment. Advances in genetic engineering have contributed to the development of improved crops where scientists have been able to engineer desirable traits making them more beneficial. Although concerns have been raised in the past (vis-a-vis consumer acceptance, mandatory *vs* voluntary labeling of genetically modified (GM) products, approval of regulatory procedure), nevertheless GM crops have the potential to be the game changer in the Indian agriculture and will prove to be a boon to decrease the drudgery of the common Indian farmer and increase his prosperity in absolute terms. Several aspects need to be taken into account from sowing of seed, overcoming the stress of drought, salinity and frost at the outset to decreased dependence on chemical pesticides, herbicides, decreased use of insecticides, improving the nutrient profile of crops, prevention of spoilage, increasing the shelf life and higher profit gains and last but not least protecting the environment.GM crops offer tremendous scope for the farming community, society at large and the nation on the whole.

Keywords – GM Crops, regulatory bodies, Biotic stress, Bt. Cotton, Bt. Brinjal, India

INTRODUCTION

India is a large country with a present population of 1.39 billion which is likely to reach 1.8 billion by 2050. The annual rate of growth of population is about 1% and about 14 million individuals add up to the number every year. With a land mass of only 2.4 % India is supporting a mind-boggling 17.7% of the world population (https://www.worldometers.info/world-population/india-population/). The cultivable land in India is about 140 million hectares (Mha) which is on the decline as 0.03 Mha of agricultural land is lost every year due to shift to non-agricultural purposes e.g. roads, railways, housing etc.

Only about half of the cultivable land available, has irrigation facilities and Indian farmers have to heavily rely on the uneven, uncertain and erratic rainfall for irrigation. More than 86% of Indian farmers have a land holding of only 1.08 hectare (Figure 1). They are stricken by poverty and have suboptimal access to good quality seeds, NPK (Nitrogen, Phosphorus, Potassium) fertilizers, farm mechanization etc. The crops are also vulnerable to attacks by plant pathogens like bacteria, viruses, fungi and nematodes (James, 2008).

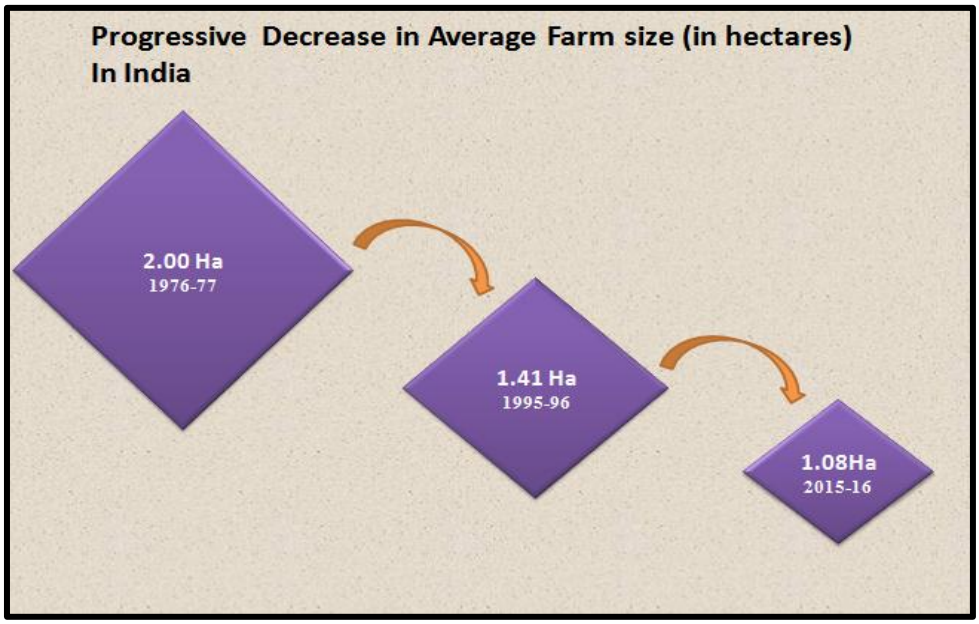

Figure 1: Progressive downfall in the average land holding per Indian farmer (in hectares) data source adapted from Mahapatra (2021).

The conventional methods of farming can hardly feed such a large and burgeoning population adequately because of the disproportionate rate of growth of population and rate of growth of agricultural productivity (Ahuja, 2018).

Biotechnology has an enormous potential to address most of the problems haunting Indian agriculture and increase food production besides protecting the fragile environment like a magical wand. Professor Norman Borlaug, a pioneer of Green revolution, advocates the cultivation of GM crops to eradicate hunger by saying, "it is better to die eating GM food instead of dying of hunger" (Borlaug, 2007).

NEED FOR GM CROPS

It has been observed that the commercialization of GM crops in the last 25 years has contributed immensely towards mitigating the problems of poverty, food insecurity, malnutrition, crop diseases, etc. The benefits accrued to the 17 million farmers in 29 countries (e.g. USA, Brazil, Argentina, Canada etc.) have prompted steady increase in the crop area to 190.4 million hectares (ISAAA Report, 2019). All over the world, scientists are working on developing new GM crops, as they have the benefit of transferring desirable traits, which are not found naturally and cannot be obtained by conventional agricultural practices and available plant breeding mechanisms. There is a tremendous scope for improving crops in terms of yield and productivity, nutritive value, disease, pest resistance, resistant to abiotic stresses like temperature, salinity, frost, water scarcity, maturing time *etc.* (Oliver, 2014; Gautam & Kushwaha, 2018). All these can be achieved by biotechnology and it is no wonder that the crops which can address most of these limiting factors would revolutionize the agriculture all over the world and the problems of malnutrition and hunger that affects the vast population globally can be taken care of. Getting encouragement from such benefits of biotech crops and to mitigate the sufferings of the cotton growing farmers of the country, ameliorating tough testing times for the ailing garment industry depending heavily upon yarn imports from China and Indonesia and loss of precious foreign exchange, a joint venture between Monsanto and MahyCo (Maharashtra Hybrid Seeds CO.) introduced Bt (*Bacillus thuriengenesis*) cotton, the first GM crops after due approval from Government of India (ISAAA report, 2019).

BACILLUS THURINGIENSIS (BT) COTTON--TRAILBLAZER GM CROP IN INDIA

Cotton is a very important cash crop since it not only provides fibers to the textile industry but livelihoods to millions of people in India. One of the indigenous 'desi varieties '*Gossypium arboreum'* ruled the state until the 20th century. In the 1980s and 90s, most of the cotton crop was lost due to infestation by local pests (Pink bollworm) and the sucking pests. The farmer got himself entangled more and more into the clutches of local money lenders and banks and had no option left but to take his own life. Thus the suicide rate of farmers jumped many folds (Gruere & Sengupta, 2011).

Taking cognizance of this along with the various other factors vis. a vis. international competition and to project India as a nation welcoming the advancements in biotechnology along with IPR (Intellectual Property Rights) regime and new seed policy, the Government of India allowed the cultivation of GM cotton crops in 2002 (Bansal & Arora, 2015). Though the first generation Bt. Cotton (Bollgard1-BG-1) expressing *Cry1Ac* (crystal protein) genes from bacterium *Bacillus thuringienesis*, producing a toxic protein in the gut of the pest was commercialized and released in 2002, it was the Bollgard II (the second generation Bt Cotton) expressing *Cry1Ac* and *Cry 2 Ab 2* genes approved in 2006 that pyramided the growth of Bt cotton and currently occupies 95% of the total growing area in India (Choudhary & Gaur, 2010).

BENEFITS OF Bt COTTON

There has been a steady and significant increase in the production of Bt cotton and per hectare yield has almost doubled since it was first introduced. As of now, Bt cotton occupies fifth position in terms of area under GM crops all across the world (Kalamkar, 2013). The increase in cotton production has resulted in India becoming the second-largest exporter of cotton, while only a few years back it had to depend on huge imports. The rise has been dramatic; from a paltry 8.6 million bales in the year 2001-02 to 36 million bales in 2020 (AICCIP,2007; Sudha et al., 2020).

The introduction of Bt cotton has resulted in farmers raking in impressive economic benefits and there has been a quantum jump in their earnings ranging between 3 - 8 times. Higher cotton yield has generated more employment for agricultural labourers

and boosted rural transport and trading business (Choudhary & Gaur, 2014). The net increase in disposable income has created more demand for food and non-food items, FMCG (fast moving consumer goods) thus giving impetus to the rural economy. Bt cotton has provided more employment opportunities to rural women folk as harvesting is done primarily by the females only. This has brought about a positive impact on child nutrition, health and welfare, contributing to overall prosperity of rural households. Pest control measures which generally employed males, are no longer required and the saved labour can be effectively utilized in alternative agricultural or non-agricultural vocations making the rural household richer than ever before. Health hazards to the labourers handling insecticides and pesticides have also come down drastically, improving individual health (Egorova et al., 2015).

Bt Cotton has undergone all the necessary regulatory processes and has been tested for allergenicity and toxicity. Trials were conducted on small- and large- scale fields for each hybrid and strict quality control protocols were observed for the presence of gene and other insecticidal proteins. No untoward risk has been observed on the health of the farmers after its introduction in the fields. In fact, the reduced use of pesticides sprays has, in turn reduced the health hazards caused to labourers and farmers (Shukla et al., 2018). Since Bt Cotton is specific to kill target insects therefore its cultivation is safe for other non-target insects. Lesser pesticide use and irrigation have resulted in decreased runoff causing less water pollution and drastic fall in biological amplification, decrease in pesticide residues in food crops, vegetables and fruits. This will go a long way in contributing positively to our physical and mental health (Sudha et al., 2020).

The Bt crops have made farming less labour intensive because it involves less tilling, irrigation, pesticide spray, supervision thereby cutting cost enormously and at the same time increasing yields from the same crop lands thus increasing absolute household incomes. In the past, Indian farmers could not sell their agricultural produce in the international markets because of a strong mismatch between the cost inputs and the prevailing international prices. Cost cutting of inputs through Bt cotton has resulted in farmers earning precious foreign exchange and India is now the second largest exporter of cotton in the world (ISAAA, 2019).

The profits of the farmers have soared up to 50% after the introduction of Bt Cotton. This is because the cost of inputs is completely offset by the overwhelming positive yield changes compared to the conventional crops, where the margin of profits had either remained stagnant or steadily declined previously. The increase in profits can contribute to a great extent towards the government target of doubling farming returns by 2022 (Qaim, 2009).

STATUS OF OTHER GM CROPS IN INDIA

GM (Bt) Brinjal – Recalcitrant Ordeal

Bt brinjal was the second GM crop that sought introduction but had to face stiff opposition from the leading brinjal producing states on account of lack of consensus on Bt technology in the scientific community, absence of independent biosafety studies, public mistrust *etc.* Therefore, in view of these resistances, the central government in 2010 imposed a moratorium on its cultivation which has now been withdrawn by the Union Government in May, 2020. GEAC (Genetic engineering advisory Committee; now called Appraisal Committee) of MoEF (Ministry of Environment and Forest) has allowed field testing of Bt. brinjal developed by ICAR till 2023, taking the first step towards commercial marketing of India's second GM crop after Bt Cotton (https://pib.gov.in/PressReleasePage.aspx?PRID=1654492).

GM Mustard - Unending Travails

It is worth mentioning here that, Dhara Mustard Hybrid 11 or DMH11, a herbicide-tolerant modified variety of mustard has been developed by Professor Deepak Pental and his team at South Campus, Delhi University by using barnase/barstar gene system transgenic technology (Grover & Pental, 2003). The GM mustard has also been shelved *sine die* because there is a growing concern as DMH 11's commercial *i.e.* it can harm rich biodiversity of mustard via cross-pollination with wild populations. Mustard plants are basically pollinated by wind and insects and are therefore extremely susceptible to outcrossing and this may have deleterious effects on India's rich mustard germplasm which is contributed primarily by wild varieties and domesticated landraces. Once the approval is given by the Centre Government, it will be the third GM crop after Bt Cotton and Bt brinjal (Grover & Pental, 2003).

Many proposals for GM rice, wheat, and maize have also been put up for sanction but are put in abeyance due to a lack of relevant scientific data. None of the state Governments in India have approved the field trials for 21 GM vegetables and cereals crops for commercial cultivation owing to lack of authentic scientific information.

CONCERNS AGAINST GM CROPS

Evolution of Superweeds

The GM crops can act as a mediator for transferring genes to wild plants which may create more weeds, resistant to the prevalent weedicide resulting in the evolution of super-weeds. To control this, scientists will have to develop new biocides which may prove toxic for the various animals feeding on these GM crops. Uptake of these biocides can have ominous consequences for aquatic ecosystems (Gilbert, 2013; Sudha et al., 2020).

Long-term Health Effects on Humans

GM crops may have genes that can make crops resistant to antibiotics and could also affect people's ability to defend against illness and hence can contribute to the evolution of superbugs (Bawa & Anilakumar, 2013).

There is a possibility of the genes getting transferred to cells in the body and bacteria in the GIT of human beings that may prove carcinogenic. GM crops may cause allergic reactions because of their altered gene structure that can trigger allergies (Chandler & Dunwell, 2008). Artificial insertion of genes into the plant could destabilize the gene pool by activating or deactivating other genes and encouraging gene mutations that could be detrimental to humans, the environment, or both (Venkat, 2016; Giraldo et al., 2019).

Interference with Wild Species

Large-scale production of GM crops could cross-pollinate a non- GM crop thereby leading to the creation of new hybrid varieties and artificial strains that could endanger biodiversity through competition. They may also prove dangerous to the beneficial insects important for pollination such as moths and butterflies thereby disturbing the ecosystem (Venkat, 2016).

Potential Impact on NTOS (Non-Target Organisms)

GM crops can be dangerous to unintended targets particularly those involved in pollination of crops like butterflies, honey bees, and birds and microbes in soil and water which are beneficial to the crops (Kramkowska et al., 2013; Choudhary & Gaur, 2014).

Monopolistic Practice by Multi-National Companies (MNCs)

Another very important concern is related to the monopoly of the big multinational companies on GM seeds, which dictate terms to the government and the farmers, setting up unreasonable pre-conditions before releasing these seeds (Choudhary & Gaur, 2014). These MNCs make use of GURT (genetic use restriction technology) or termination technology (suicide seeds)that restrict the use of GM crops by activating or deactivating some genes in response to certain stimuli resulting in the second generation seeds to be infertile, thereby making the farmers totally dependent upon these companies for growing the next crop (Zhang et al., 2016).

Global Scenario of GM Crops

As per International Service for the Acquisition of Agri-Biotech Application (ISAAA briefs -2018) report, more than 70 countries have adopted Biotech crops. Twenty-six countries (21 developing and five industrialized countries) raised Biotech crops on 191.7 million hectares in toto. It is also revealed that malnutrition and hunger keep on rising with around 108 million individuals in 48 countries being at the risk of severe food security and hunger, therefore it becomes undeniably necessary to adopt the cultivation of biotech crops with improved traits over the conventional methods. Though the USA, Brazil, Argentina, Canada, etc. have shown the adoption rates of many major crops to be as high as 100%, yet the global challenge needs to be addressed aggressively (Aldemita et al.,2015).

The ISAAA report (2018) highlighted many key findings, *viz.* (1) 91% of the global Biotech crop area was occupied by five countries *i.e.* USA, Brazil, Argentina, Canada and India, and 19.13 million hectares of land was planted with Biotech crops in nine countries in Asia and the Pacific; (2) Biotech maize is continuously being cultivated by Spain and Portugal to control the European corn borer (ISAAA Briefs (2017); (3) In our neighborhood, Bangladesh has successfully adopted Bt brinjal provided to them by

India based Mahyco (Maharashtra Hybrid Seeds Co) and BARI (Bangladesh Agriculture Research Institute) and 17% of farmers have reported increase in net yields and decrease in growing cost leading to overall prosperity; (4) Many other Biotech crops such as potatoes with non-bruising, non-browning and reduced acrylamide as well as late blight resistant traits, insect resistant and drought tolerant sugarcane, non-browning apples, high oleic acid canola and safflower, Golden rice, Bt rice, herbicide tolerant cotton, low gossypol cotton , herbicide tolerant soybean, low lignin alfalfa,omega-3 canola are some of the biotech crops which are in the process of getting approval and being adopted by several countries (ISAAA, 2019); (5) Soybean (69.2 million ha), maize (41.7 million ha),cotton (16.1 million ha) and canola (6.4 million ha)are the biotech crops that have gained substantial acreage since their initial cultivation.; (6) USA (USD 23.4 billion), Argentina (USD 9.2 billion), China (USD 7.6 billion), India (USD 5.1 billion), Brazil (USD 2.8 billion), Canada (USD 2.1 billion) and other countries have gained the most by growing these Biotech crops during their first 13 years of commercialization from 1996 to 2013 (James, 2015).

FUTURE PROSPECTS

India is one of the largest importers of oilseeds in the world spending around 12 billion dollars per year (Sudha et al., 2020). There is a great potential in increasing the production of oilseeds with the adoption of safflower, soybean, and canola as the experience with these crops, by the farmers have been impressive worldwide and they have been growing these crops in their respective countries replacing their conventional counterparts. The government should also lift the ban on GM mustard after requisite regulations since it holds great promise in producing high yields by up to 30% than their conventional mustard variety. In the same way, Bt brinjal which has been on hold for certain objections should be released without delay since eggplant has worldwide acceptance as a preferred food crop (Venkat, 2016; Raman, 2017; Kumar et al., 2020).

The second-generation GM crops will have higher nutritional value through biofortification like golden rice which is rich in vitamin A and iron (Smyth, 2020). Since rice is a staple diet in Southern and Eastern India, vitamin A deficiency presenting with night blindness, dry eye, etc. is endemic because rice is deficient in carotene, which is a precursor for vitamin A. Golden rice can drastically reduce public health burden of

Vitamin A deficiency at an affordable low cost. Higher yields of GM food crops can effectively bring down prices making them more easily available and affordable and resulting in better health of the individual and the society (Kumar et al., 2020).

In view of the utopian environment created by Bt Cotton, almost 95% of farmers have adopted it in 11.9 Mha of cropland (Table 1). Therefore, it becomes imperative for the government to allow other GM crops that will bring about prosperity to the farming community and the nation as a whole after addressing the concerns raised by various stakeholders (Chaturvedi et al., 2019). Figure 2 shows that GM Maize occupies a large chunk of cultivated land globally after GM soybean. Taking cue from this, India should also start growing Biotech maize on a larger scale as it is a nutritive food crop. Besides these, other crops like apple, pineapple, alfalfa, squash, potatoes, sugar cane, etc. are being grown by developed and developing nations. The time has come where the Biotechnology Regulatory Authority of India, as an independent regulatory body should take the charge to allow the induction of some GM food crops and release the moratorium laid on a few others.

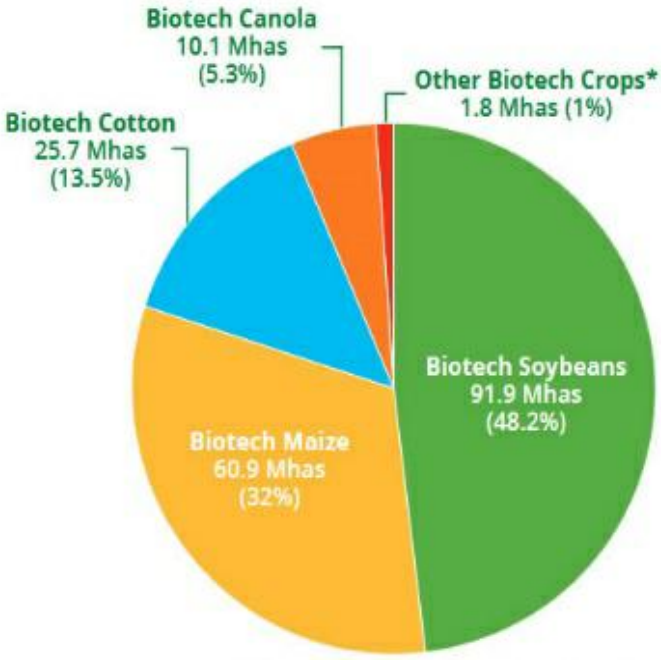

Figure 2: Biotech crops in 2019 (Area and Adoption rate) Source: ISAAA, 2019 (https://www.isaaa.org/resources/publications/briefs/55/executivesummary/default.asp; License: CC-BY-NC-ND)

Table 1: Global area of Biotech crops in 2019: by Country (Million Hectares) Source: ISAAA, 2019 (https://www.isaaa.org/resources/publications/briefs/55/executivesummary/default.asp; License: CC-BY-NC-ND)

Rank	Country	Area (million hectares)	Biotech Crops
1	***USA****	**71.5**	Maize, soybeans, cotton, alfalfa, canola, sugar beets, potatoes, papaya, squash, apples
2	**Brazil***	**52.8**	Soybeans, maize, cotton, sugarcane
3	**Argentina***	**24.0**	Soybean, maize, cotton, alfalfa
4	***Canada****	**12.5**	Canola, soybeans, maize sugar beets, alfalfa, potatoes
5	**India***	**11.9**	Cotton
6	**Paraguay***	**4.1**	Soybeans, maize, cotton
7	**China***	**3.2**	Cotton, papaya
8	**South Africa***	**2.7**	Maize, soybeans, cotton
9	**Pakistan***	**2.5**	Cotton
10	**Bolivia***	**1.4**	Soybeans,
11	**Uruguay***	**1.2**	Soybeans, maize
12	**Philippines***	**0.9**	Maize
13	***Australia****	**0.6**	Cotton, canola, safflower
14	**Myanmar***	**0.3**	Cotton
15	**Sudan***	**0.2**	Cotton
16	**Mexico***	**0.2**	Cotton
17	***Spain****	**0.1**	Maize
18	**Colombia***	**0.1**	Maize, cotton
19	**Vietnam***	**0.1**	Maize
20	**Honduras**	**<0.1**	Maize
21	**Chile**	**<0.1**	Maize, canola
22	**Malawi**	**<0.1**	Cotton
23	***Portugal***	**<0.1**	Maize
24	**Indonesia**	**<0.1**	Sugarcane
25	**Bangladesh**	**<0.1**	Brinjal/Eggplant
26	**Nigeria**	**<0.1**	Cotton
27	**Eswatini**	**<0.1**	Cotton
28	**Ethiopia**	**<0.1**	Cotton
29	**Costa Rica**	**<0.1**	Cotton, pineapple
	Total	**190.4**	

*Biotech mega countries which grew more than 50,000 hectares or more

CONCLUSION

From the foregoing, it is abundantly clear that GM crops are the crops of the future and all the efforts should be made to remove any doubts in the minds of farmers and the general public about their side effects and risks. The experience of the last two decades has clearly shown that the potential risks attributed to GM crops are not significant as compared to the benefits which far outstrip the deleterious effects attributed to them. Nevertheless, whatever arguments are there against them should be tackled with the available scientific evidence so that there is no iota of doubt left in the minds of the consumers about their misconceived deleterious side effects. In conclusion, it can be said that GM crops can change the face of Indian agriculture by providing a healthy and nutritious diet to one and all, with a single goal of providing food security and bringing prosperity to the farming community, society and nation as a whole.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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