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History, status and impact of genetically modified crops in India

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Abstract
The genetic engineering is one of the great marvels of 21st century human. It allowed for precise control over the genetic changes introduced into an organism. Today, we can incorporate new genes from one species into a completely unrelated species through genetic engineering, optimizing agricultural performance. India introduced Bt cotton seeds in 2002. It has greatly reduced the use of toxic pesticides. Bt cotton produces a common soil bacterium, *Bacillus thuringiensis* (Bt). It is a natural pest repelling bacteria that is toxic to many worms and pests that can harm the crop but is not hazardous to humans. Bt is widely sprayed on crops by organic farmers as a pesticide. As a result of the adoption of Bt cotton, India is now the largest cotton producer in the world. It reduces the use of pesticide and insecticide during farming that might be great moves for the betterment of the food supply. It can feed a rapidly increasing population because it shows dramatically increased yields. In India, GM plants like GM cotton, Bt brinjal and GM mustard are experimented, but the government refused to allow it to be commercialized. Recently, the government of India has examined a proposal on GM mustard seeds despite there being severe opposition to it among environmental activists.

Keywords: GM crops, History, India, Status

Introduction
There's a food crisis looming over India. Farmers in the country currently lose some Rs.50,000 crore ($5 billion) every year to pests and diseases. Droughts, coupled with a lack of irrigation facilities, are exacerbating the problem. The situation may only worsen as the United Nations estimates that the country's population, currently at 1.2 billion, will reach 1.8 billion by 2050 (GM basics, 2016) [8]. Given the high level of poverty, malnutrition and hunger and the low level of agricultural productivity in India, agricultural biotechnology has great potential. To feed a billion-plus population by relying on conventional methods of cultivation is next to impossible. India is rich in bio-resources and biotechnology offers opportunities for converting biological wealth into economic wealth, thereby creating new employment opportunities on an environmentally and socially sustainable basis.

Biotech crops have been cultivated globally for the past two decades with no negative impact on human beings, animals and the environment. The success of Bt cotton in India in the 2000s has set an excellent example of how genetically modified (GM) technology can turn around India's agriculture sector. Safety of GM crops being a serious issue, it is important to ensure that India has adequate regulatory instruments and infrastructures. At the same time, India has more serious food safety risks to worry about including unsanitary food processing, as well as food security concerns pertaining to the availability and affordability of food. Priority must go to more clearly demonstrated safety risks instead of hypothetical risks. Biotechnology reduces the farmer's dependency on pesticides and saves the equivalent of over 2, 36,000 kilos of pesticides in India each year (GM basics, 2016) [8].

India has the world's fifth largest cultivated area under genetically modified (GM) crops, at 11.4 million hectares (mh) in 2017. But unlike other big growers, its entire GM crop area is under a single crop, cotton incorporating genes from the *Bacillus thuringiensis* or Bt soil bacterium coding for resistance against *Heliothis* bollworm insect pests (AICCIP annual report, 2017) [1].

The country with the highest area under transgenic crops, at 75 mh, is the United States. According to the International Service for the Acquisition of Agri-Biotech Applications (ISAAA), the 75 mh GM acreage comprised 34.05 mh soybean, 33.84 mh maize (corn),

4.58 mh cotton, 1.22 mh alfalfa, 0.876 mh canola, 0.458 mh sugar-beet, 3,000 hectares potato and around 1,000 hectares each of apples, squash and papaya.

Similarly, Brazil's total 50.2 mh GM crop area included 33.7 mh soybean, 15.6 mh of maize and 0.94 mh of cotton. The corresponding acreage break-up for Argentina's 23.6 mh comprised 18.1 mh of soybean, 5.2 mh maize and 0.25 mh cotton, while it was 8.83 mh canola, 2.50 mh soybean, 1.78 mh maize, 15,000 hectares sugar-beet, and 3,000 hectares alfalfa in the case of Canada's total 13.1 mh. ISAAA's latest 'Global Status of Commercialized Biotech/ GM Crops in 2017' report (www.isaaa.org.) shows farmers across the world to have planted 189.8 mh under transgenic crops last year. This is as against 1.7 mh in 1996, the year when they were grown commercially for the first time. Total planted area grew particularly during the first decade of this century, while slowing down in the last five years.

The report by the global crop biotech advocacy organisation has estimated the highest share in the world's total 189.8 mh GM crop area for 2017 to be of soybean (94.1 mh), followed by maize (59.7 mh), cotton (24.1 mh), canola (10.2 mh), alfalfa (1.2 mh) and sugar-beet (0.50 mh). The GM traits in these crops through introduction of alien genes into host plants included both insect-resistance and tolerance for application of glyphosate herbicide (www.isaaa.org.).

Genetically modified crops in India

India hasn't seen any new entrant in the sector of GM based crop varieties after Bt Cotton. Many GM varieties are believed to be under different stages of development, but yet to mark a formal release. GM Mustard is the new GM crop in the block that is doing the rounds of constant speculation and has been cleared by the Genetic Engineering Approval Committee (GEAC), the biotech regulator in India under the Ministry of environment and forests with no such bio safety or public health concerns. Many believe that food on the market derived from GM crops poses no greater risk to human health than conventional food. However, opponents have objected to GM crops on several grounds, including environmental concerns, safety of GM foods, the business interests behind GM crops, intellectual property laws etc.

Arguments in favour of GM Crops

The proponents, argue that the GM technologies have been around for about 15 years and they have been in use across the world including in countries such as Brazil and China. During a visit to India in March 2005, Norman Borlaug widely regarded as the father of the Green Revolution supported producing genetically modified (GM) food to eradicate hunger from the world. "It is better to die eating GM food instead of dying of hunger," said the Nobel laureate, who passed away in 2009.

Agriculture scientists from research institutions including IARI, ICAR and various Universities demanding "field trials" for GM crops, arguing that "confined field trials are essential for the evaluation of productivity performance as well as food and environmental safety assessment". A group of prominent scientists had met under 'father of green revolution' MS Swami Nathan at National Academy of Agricultural Sciences (NASA) and issued a 15-point resolution in favour of GM crops. "A brinjal crop normally requires up to 30 sprays of insecticides. This goes into the human consumption indirectly. If we grow and consume Bt brinjal, we will consume some of the genes that have been built into the seeds to make the crop pest- and herbicide-resistant. Ultimately, we have to see which of the two is less harmful for consumption" – S.S. Gosal, Director of Research, Punjab Agriculture University (James, 2017) [12].

Arguments against GM crops

Organisations such as Greenpeace argue that the GM crops don't yield better results, but push the farmers into de Bt. They lose their sovereign right over seeds as they are forced to buy GM seeds and technologies from multinational corporations. The increasing incidence of suicide by farmers cultivating Bt cotton is cited as an example of the perils of GM crops in a country such as India. Besides the suspect merits of GM crops, what the opponents also say is that once they are released into the environment, it's irreversible (GM-crops-in-India.pdf).

Impact of Bt cotton in India

The country has yet to approve commercial cultivation of a GM food crop. The only genetically modified cash crop under commercial cultivation in India is cotton. For the time being, the only genetically modified crop that is under cultivation in India is Bt cotton which is grown over 10.8 million hectares. Bt cotton was first used in India in 2002.

During the decade prior to 2002, cotton production and economy in India was in constant crisis due to insecticide resistant bollworms which were responsible for excessive use of insecticides at about 50% of the total insecticides used in the country coupled with constant low production and stagnant productivity of 15.0 to 17.7 M bales. Subsequent to 2002, after the introduction of Bt-cotton, the scenario has changed. It is beyond dou Bt that Bt cotton has been playing a major role in effectively protecting the crop from bollworms, especially the American Bollworm, *Helicoverpa armigera*, thus preventing yield losses. The biggest gain from the technology was in the form of reduced insecticide usage from 46% in 2001 to less than 26% after 2006 and 21% during the last two years 2009 and 2011. The reduction in insecticide usage in India from Rs 7180 M in 2004 for cotton *Lepidopteran* caterpillars to Rs 1100 M, with only Rs 230 M for the control of American bollworm in 2009, can be seen as a spectacular achievement of Bt cotton technology (Qaim, 2009) [15].

Over the past five years there has been a significant leap in the production. During 2004 and 2005 India produced about 24.0 M bales each year, 27 M bales in 2006 and 31.5 m bales during 2007-08. However, apart from the contribution of Bt cotton, the increase in yield may have also been due to other major changes in the past 8 years. Some perceptible changes include, implementation on IPM and IRM on a large scale by the Ministry of Agriculture and ICAR, the introduction of some excellent cotton hybrids, increase in cotton area in Gujarat from 1.5 M ha to 2.6 M ha, increase in check dams and drip irrigation systems, increase in hybrid cotton area from 40% to 90% and introduction of 6-7 new effective insecticide molecules for bollworm control and sucking pest management (Sadashivappa and Qaim, 2009) [15].

Though bollworm damage declined, the changes in pest management systems with reduction in pesticides and introduction of several new Bt hybrids, most of which were highly susceptible to insect pests and diseases, has resulted in increased damage of sucking pests such as jassids, white flies,

thrips mealy bugs and miridbugs. As a consequence of this, insecticide usage which had declined from Rs.10520 M in 2001 to Rs.5790 M in 2006, increased gradually to Rs.8804 M by 2010. It is interesting that the usage of fungicides and herbicides also increased significantly over the past 5 years. With the advent of herbicide resistant cotton such as RRFLex (Round-up ready Flex) that tolerates glyphosate and glufosinate resistant cotton, the use of post-emergence application herbicides is likely to increase further (Linton and Torsekar, 2010) [13].

A range of field studies assessing economic performance of Bt cotton in India revealed that farmers have benefited from adopting Bt cotton technology through increased yields and reduced pesticide costs. Although Bt technology does not target increased yield, substantial yield increases are attributed to decreased pest damages. In spite of higher costs of Bt cotton seed, reduced pesticide use, and reduced costs associated with pesticide use, offsets increased expenditures on seed. Additional spill-over benefits include improved quality of life due to increased income and better health due to less pesticide exposure (ASSOCHAM Survey, 2007) [3].

Examining effects of Bt cotton production on world and Indian cotton prices at 2005 adoption levels, they estimated a global increase in total factor productivity (TFP) at around 3.3%, with 0.9% and 0.7% increases in textile and apparel production, respectively. They concluded that while Bt adoption in India led to a more than US$ 200 billion gain in India, increased worldwide production led to a 3% decline in world cotton prices. Anderson, Valenzuela and Jackson (2008) [2] estimated that widespread adoption of Bt cotton in India and other South Asian countries will result in additional regional welfare gains on the order of $1 billion per year.

Bt Brinjal- India's First Vegetable Biotech Crop

Fruit and shoot borer (FSB) resistant brinjal or Bt brinjal was developed using a transformation process similar to the one used in the development of Bt cotton. Bt brinjal incorporates the *cry1Ac* gene expressing insecticidal protein to confer resistance against FSB. The *cry1Ac* gene is sourced from the soil bacterium *Bacillus thuringiensis* (Bt). When ingested by the FSB larvae, the Bt protein is activated in the insect's alkaline gut and binds to the gut wall, which breaks down, allowing the Bt spores to invade the insect's body cavity. The FSB larvae die a few days later.

Bt Brinjal was developed by the Maharashtra Hybrid Seeds Company (Mahyco). The company used a DNA construct containing the *cry1Ac* gene, a CaMV 35S promoter and the selectable marker genes *nptII* and *aad*, to transform young cotyledons of brinjal plants. A single copy elite event, named EE-1, was selected and introduced into hybrid brinjal in Mahyco's breeding program. Mahyco also generously donated the Bt brinjal technology to the Tamil Nadu Agricultural University (TNAU), Coimbatore and University of Agricultural Sciences (UAS), Dharwad. The event EE-1 was backcrossed into open-pollinated brinjal varieties. Mahyco also donated the technology to public research institutions in the Philippines and Bangladesh.

Several other research institutions, both public and private have also been developing Bt brinjal using different genes. The National Center on Plant Biotechnology (NRCPB) has developed Bt brinjal varieties expressing the cryFa1 gene. The technology was subsequently transferred to companies including Bejo Sheetal, Vibha Seeds, Nath Seeds and Krishidhan Seeds. The Indian Institute of Horticultural Research (IIHR) is also developing Bt brinjal using the cry1Ab gene. Scientists are also looking for ways to develop Bt brinjal in conjunction with other multiple and beneficial traits (www.thehansindia.com).

However, since Brinjal was a food crop, the furore over permission to field trials was overwhelming. Despite of the claims of the company that it has done all Biosafety tests, there were concerns over potential health hazards and problem of terminator seed in Brinjal (which would compel farmers to by seeds from Monsanto). The matter reached to Supreme Court and an expert committee, appointed by Supreme Court recommended a 10-year moratorium on field trials of all genetically modified (GM) food crops and a complete ban on field trials of transgenics in crops which originate in India. The result was that the government imposed a moratorium on field trials of Bt Brinjal in 2010 (www. isaaa.org).

GM-Mustard

Dhara Mustard Hybrid-11 or DMH-11 is a genetically modified variety of mustard developed by the Delhi University's Centre for Genetic Manipulation of Crop Plants. The researchers at Delhi University have created hybridised mustard DMH-11 using "barnase / barstar" technology for genetic modification. It is Herbicide Tolerant (HT) crop. If approved by the Centre, this will be the second GM crop, after Bt Cotton, and the first transgenic food crop to be allowed for cultivation in the country. There has been strong opposition from various organisations and also from within government to the approval given to GM mustard(www. isaaa.org).

Controversies and Moratoriums associated with GM Crops in India – Timeline

- 2002 – Bt cotton introduced in India.
- 2006 – Activists filed a PIL against GM crops in the Supreme Court.
- 2010 – The then environmental minister Jairam Ramesh blocked the release of Bt Brinjal until further notice owing to a lack of consensus among scientists and opposition from brinjal-growing states. No objection certificates from states were made mandatory for field trials.
- 2012 – Parliamentary standing committee on agriculture, in its 37th report asked for an end to all GM field trials in the country.
- 2013 July – New crop trials have been effectively on hold since late 2012, after a supreme court-appointed expert panel recommended suspension for 10 years until regulatory and monitoring systems could be strengthened. Though the SC panel suggested moratorium on GM trails, there was no official verdict from the Supreme Court on this issue.
- 2013 July – Environment minister Jayanthi Natarajan put on hold all trials following SC panel suggestions.
- 2014 – Her successor, Veerappa Moili cleared the way for trails. (NB: Two of Manmohan Singh's own environment ministers had stalled GM trials earlier, but Veerappa Moily took an opposite stand and the process of approving the one-acre field trials restarted.)
- 2014 March – GEAC (UPA government) approved field trials for 11 crops, including maize, rice, sorghum, wheat, groundnut and cotton.

- 2014 July – 21 new varieties of genetically modified (GM) crops such as rice, wheat, maize and cotton have been approved for field trials by the NDA government in July 2014. The Genetic Engineering Appraisal Committee (GEAC) — consisting mostly of bio-technology supporters — rejected just one out of the 28 proposals up for consideration. Six proposals were rejected for want of more information.
- 2016: GEAC gave green signal to GM Mustard for field trial, but SC stayed the order and sought public opinion on the same.
- There are as many as 20 GM crops already undergoing trails at various stages.

Conclusion

Field trials for 21 GM food crops, including GM vegetables and cereals have been approved by the government though commercial cultivation of GM food has not been permitted by any State government in India till now (Vidya Venkat, 2016) [17]. It is significant to note that 109 Nobel laureates recently signed a letter urging the well-known environmental NGO, Greenpeace, to end its opposition to genetically modified organisms (GMOs) and called upon governments across the world to reject the NGOs campaign that opposed biotechnological opposition in agriculture. This appeal is indeed important for a country like India, where over 60 percent of the population is engaged in agriculture and there is an imperative need to increase production and productivity. The letter clearly stated: "Scientific and regulatory agencies around the world have repeatedly and consistently found crops and foods improved through biotechnology to be as safe as, if not safer, than those derived from any other method of production." Richard J Roberts, who is currently chief scientific officer of the New England Biolabs, in a recent interview to The Washington Post, stated that Greenpeace and some of their allies deliberately "went out of their way to scare people. It was a way for them to raise money".

In tune with the above opinion, a technical body of the Central Government of GM mustard stated that it is safe for human and animal health and doesn't pose any threat to biodiversity. The Environment Ministry recently made this report public, wherein it clearly stated: "From the toxicity and allergenicity studies, it is concluded that GE mustard, the parental lines and Dhara Mustard Hybrid-II (DMH-II) doesn't raise any public health and safety concern."

GM crops have been a contentious issue, at least in India. While one section is of the opinion that it could address hunger issues and brings down prices of food and commodities, the other group argues it was dangerous for environment and the health of its citizens. Now with the global scientists consent on such crops, the government should move a step forward. One cannot deny the fact that food security is vital for the country, having only 2.3 percent of the world's land area but cannot ensure food security for 17.5 percent of the world's population.

Keeping this in view, time has possibly come to allow GM crops in the country. Multiple studies have shown that benefits include there are no human or ecological ill-effects, yield increases and there is resistance to pests. Perhaps the most wide-ranging of these is a 2014 meta-analysis, by Wilhelm Klumper and Matin Qaim of University of Gottingen, Germany, of 147 studies on farm surveys and field trials of GM crops carried out across the world. Their results: use of GM technology increased crop yields by 22%, reduced chemical pesticides by 37 percent and increased farmer profits by 68 percent, with better results in developing countries than in developed ones.

The constitution of the Biotechnology Regulatory Authority of India (BRAI) as an independent regulatory body is thus critical to the country's progress in biotechnology. The BRAI bill has been hanging fire for several years now because of hostile public view propagated by a section on GM crops. It is time the government took a bold stand and laid the ground for a measured and tested introduction of GM crops. Bt brinjal and Bt. mustard could be seriously considered for induction in the country. Apart from passing the BRAI bill, IPR issues have to be resolved that have again come up with the Andhra Pradesh government seeking compulsory licensing or revocation of the Bt cotton technology patent in its struggle with Monsanto. It is also necessary, to organise a conference of experts to clear misgivings.

International experts connected with the matter may also be invited to give their views to aid the government to take a judicious decision. Keeping in view the issue of food security that is of great concern for a populous country like India, the induction of GM crops may eventually be of help.

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