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Insect Resistance Transgenic Crops and their Current Status in India

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Abstract

As the world's population rises, so does the need for food, which current breeding methods can only partially provide. However, new biotechnological advancements like gene editing and transgenic crops enable plants to produce more and have higher nutritional value. The Indian government approved Bt cotton as the first transgenic crop to be produced commercially in March 2002. However, worries about possible human toxicity and allergenicity, potential environmental risks like gene flow, detrimental impacts on non-target organisms, and resistance development in weeds and insects hinder the widespread acceptance of transgenic crops harboring foreign genes. Moreover, before releasing of any GM or transgenic crop there is great need to conserve the germplasm of the crops in national and international germplasm repositories.

1. Introduction

Insect pests cause damage to crops through sucking of sap or their eating of plant parts such as fruits, leaves, stems, and roots. A previous study indicated that crop losses from diseases and insect pests might make up as much as 37% of global agricultural productivity, with insects alone responsible for 13% of losses. Crop losses as a result of several insect pests in various crops, *viz.*, soybeans (29%), wheat (28%), cotton (29%), maize (31%), rice (37%), and potatoes (40%) (Oerke, 2006). To tackle the pest problem, several insecticides were found. Due to continuous usage of insecticides problem of resurgence, secondary pest outbreak arises and nevertheless, research has shown that this type of crop protection is detrimental to both the environment and public health (Bakhsh et al., 2015). Therefore, transgenic plants can be used. Transgenic crops are agricultural plants whose genomes have been modified through genetic engineering in order to introduce new qualities or to improve existing traits that are not characteristic of the particular crop species (Kumar et al., 2020). The amount of food grains produced will not be able to feed the growing population as a result of climate change and population growth (Shukla et al., 2018). The future's needs for food and nutrition cannot be met by

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traditional technologies so biotechnology and molecular biology, provide several benefits. Since *Agrobacterium tumefaciens* can naturally insert Ti plasmid DNA (T-DNA) into host plant cell genomes, Ti plasmid serves as a vector to transfer foreign genes into plant cells. The first transgenic crops tobacco and petunia were developed which are antibiotic resistance. Plants resistant to insects have been produced using *Bacillus thuringiensis* (Bt) cry genes. Most Bt strains are detrimental to Lepidopteran insect pests, but some are also harmful to Coleoptera, Diptera and Hemiptera (Rajashekhar et al., 2018).

A vast number of farmers in 28 countries have planted genetically modified crops on 181.5 million hectares in 2014, an increase of 3.4 percent over the previous year. This is due to the development of genetically modified crops that express a variety of novel traits like insect resistance, disease resistance, herbicide tolerance, improved nutritional quality, etc. (Lucht 2015). The main producers and exporters of genetically modified crops and goods are the United States of America, Argentina, and Canada. The biggest producers of transgenic crops among developing nations are China and India. In India, more than 20 crops, including cotton, rice, wheat, maize, brinjal, potato, sorghum, mustard, groundnut, cauliflower, okra, chickpea, pigeon pea, castor, sugarcane, etc., are undergoing varying stages of research and field trials for genetic modification. These crops are being studied for traits like insect resistance, herbicide tolerance, drought tolerance, salinity tolerance, virus resistance, quantitative traits (yield increase), nutrition improvement.

2. Development of Transgenic Crops

Direct gene transfer via a gene gun or *Agrobacterium*-mediated transformation are the most common methods of introducing foreign genes into plant cells. The innate ability of *Agrobacterium* soil bacteria to operate as genetic engineers has been utilized. This *Agrobacterium* resulted in effective development of transgenic plants in all major cereal crops and a variety of other crops that were earlier transformable only by particle bombardment. Huge DNA fragments can be efficiently transmitted by "*Agrobacterium*" in field and horticultural crops.

3. Bt Cotton-Approval for Commercial Cultivation

In India the cotton production, productivity was reduced due to *Helicoverpa armigera*, commonly referred to as American Bollworm. In India, insecticides valued at close to Rs. 12 billion are utilized to manage the cotton bollworm complex alone. Bt cotton technology has been introduced into India by Mahyco (Maharashtra Hybrid Seed Company) in partnership with Monsanto. The Cry1Ac gene, which is expressed in Bt cotton and gives resistance to the bollworm complex, is derived from the common soil bacterium *Bacillus thuringiensis var. kurstaki*. Cultivation and production of Bt cotton has grown exponentially since then and India has become second largest producer of cotton and leading exporter in the world.

In 1993, Bt cotton was authorized for field trials in the US, and in 1995, it was authorized for commercial usage. It was first introduced to India in 2002 (BG-I) and 2006 (BG-II) through a joint venture between Monsanto and Mahyco. The Genetic Engineering Appraisal Committee (GEAC), in its 32nd meeting, held on March 26, 2002, made the landmark decision of approving cultivation of Bt cotton in India; three hybrids (MECH 162 Bt, MECH 184 Bt, and MECH 12 Bt) were approved for cultivation. India is the leading producer as of 2014. In India, it is currently commercially cultivated as a GM crop.

3.1. Benefits of Bt cotton in India

• In comparison to conventional cotton, Bt-cotton has boosted profit and yield by 50% and 24%, to Rs. 1877 per acre (US$38) and 126 kg/acre of cropland, respectively.

• The use of Bt cotton has also led to a 22-fold growth in India's agri-biotech sector, as plantings have increased by an astounding 212 times between 2002 and 2011.

• Consequently, Bt cotton has brought economic prosperity to Bt-cotton growers, in fact, the years 2002–2011 are frequently referred to as the "white gold" years for India's GM cotton industry.

4. Bt Brinjal

The GM brinjal is a group of transgenic brinjal plants made by introducing the crystal protein gene (Cry1Ac) of the soil bacteria *Bacillus thuringiensis* into the genomes of different cultivars of brinjal. It was developed against brinjal shoot and fruit borer as the pest became resistant to many of the insecticides. To lessen the damage that pests cause to brinjal and to save the environment from the harmful effects of pesticides trials were started to develop Bt brinjal by Mahcyo, Tamil Nadu Agricultural University in Coimbatore, University of Agriculture

in Dharwad (Karnataka) and two Indian Councils of Agricultural Research (ICAR) institutions.

Acute oral toxicity trials were conducted on rats, in 2004, multi-location field trials on five Bt brinjal hybrids (MHB-4, 9, 10, 80 and 99) and effects on non-target were studied. In order to evaluate the agronomic effectiveness and environmental impact of Bt brinjal hybrids, the Indian Institute of Vegetable Research conducted a significant amount of field testing between 2007 and 2009. The effectiveness of the Bt gene in controlling the fruit and shoot borer has also been tested. It has shown successful in controlling the target pest, indicating that the shoot and fruit borer may be killed by the expression of Cry1Ac protein. Biosafety investigations revealed no noticeable differences between Bt and non-Bt brinjal (Kumar et al., 2011).

4.1. Controversies for the release of bt brinjal

• In Indian medical systems such as ayurveda, sidha, homoeopathy, and unani, brinjal is utilized as a medicinal element for treating respiratory disorders. The brinjal plant itself is used in both raw and cooked form. There is concern that Bt brinjal will eliminate these medicinal characteristics due to synergy loss, variations in alkaloids, and other active principle modifications. A few people of India are strongly against the Bt brinjal's release and the utilizing the Bt gene was the primary factor behind this dispute.

• People think that using the Bt gene could be dangerous because scientists have not provided complete evidence of its safety.

• Some scientists feel that Bt brinjal requires more time to review.

• In response to the controversy surrounding Bt Brinjal, the Genetic Engineering Appraisal group (GEAC) formed an expert committee in 2006.

• On October 14, 2009, GEAC determined that the Bt brinjal plants were safe and recommended for commercial use, and it imposed a moratorium on commercial release of Bt Brinjal.

• In response to concerns highlighted by scientists, farmers, and anti-GMO activists, the Indian government formally declared on February 9, 2010, that it required additional time before distributing Bt brinjal. Indian Environment Minister Jairam Ramesh stated that there is no urgent need to introduce Bt brinjal in India.

• Jairam Ramesh confirmed on February 17, 2010, that the center had simply placed a temporary stop on the distribution of transgenic brinjal hybrids, not an outright prohibition, adding that "this moratorium will remain until we arrive at a political, scientific, and societal consensus."

5. Bt Mustard

DMH-11, often referred to as Dhara Mustard Hybrid-11, is a hybrid cultivar of *Brassica juncea* that has undergone genetic modification. It was developed by Professor Deepak Pental from the University of Delhi, to reduce the imports of edible oil. By mainly utilizing the Bar, Barnase, and Barstar gene systems, transgenic technology was used to develop DMH - 11. The Early Hira mutant (EH -2) and Varuna are the two parental strains used to develop DMH -11.

5.1. Safety evaluation

The mustard hybrid was subjected to biosafety field evaluation under the Indian Council of Agricultural Research (ICAR). This trial was carried out during 2014-15. The following biosafety studies were done for DMH-11: molecular characterization, food safety, environmental safety and detection protocols.

5.2. Controversies regarding Bt- Mustard

***5.2.1. Ecological effects*:** Due of DMH - 11's tolerance to glufosinate, farmers may have been encouraged to apply the herbicide freely once it was commercialized. This puts artificial pressure on weeds to undergo selection, which may lead to the establishment of weed species resistant to glufosinate.

***5.2.2. Health effects*:** Farmers' ongoing usage of herbicides may have a lot of detrimental impacts on human health because to DMK-11's tolerance to glufosinate.

6. How are Genetically Modified Crops (GMC) Regulated in India?

In India, all the regulation activities related to GMCs are regulated by the Union Ministry of Environment, Forest and Climate Change (MoEF&CC) under the provisions of the Environment (Protection) Act, 1986. The Genetic Engineering Appraisal Committee (GEAC) under (MoEF& CC) has the authority to examine, oversee, and approve all GMO-related operations, including their manufacture, usage, import, export, and sale. The Food Safety and Standards Act, 2006, subjects GM foods to rules administered by the Food Safety and Standards Authority of India (FSSAI). Committees do several

safety evaluations before approving them for additional testing on open fields. These fields are under the control of the Indian Council for Agricultural Research (ICAR) or are situated at agricultural universities. These field trials take place over multiple crop seasons and different types of geographical conditions to assess its suitability across different States. A transgenic plant can be approved for commercial distribution if it excels over equivalent non-GM variants on stated parameters and without causing ecological harm to other species.

7. Current Status in India

Now, the only genetically modified crop that is commercially grown in India is cotton. Transgenic trials are being tested for additional crops, such as tomato, brinjal, maize, and chickpea. The GEAC in October 2022 gave its approval for the GM mustard hybrid DMH-11 to be released into the environment, advancing it towards full commercial production. A proposal to test a novel type of transgenic cotton seed that carries the gene Cry2Ai resistant to the common insect known as pink bollworm was recommended by GEAC to conduct preliminary trials in farmers field of Gujarat, Maharashtra, and Telangana, Haryana. But Only Haryana gave permission to conduct the field trials.

8. Negative Impacts of Transgenic Crops

The impact on the environment and ethical considerations are two of the main obstacles to GM crop research and deregulation worldwide, including in India. Concerns about risks and ethics have led to a disturbance in society about the introduction of transgenic crops into the traditional food production system. Regarding genetically modified crops, five ethical concerns have been raised: the technology's "unnaturalness," potential harm to human health, potential environmental impact, negative influence on traditional agricultural practices, and excessive corporate control. There is some foreign DNA in a transgenic plant that is not present in the plant naturally. These DNA fragments are often produced from cis (wholly distinct species) such as bacteria and viruses, or trans (similar species, like plants). A growing number of people are concerned about things like whether eating "alien" DNA could harm animal or human systems (Bawa and Anilakumar, 2013).

8.1. Negative environmental impact of GM crops

• The monarch butterfly: There are some reports that monarch butterfly larvae and other non-target organisms were killed after swallowing transgenic maize pollens, because it contains bacterial poison.

• Crop-to-weed gene transfer: Genes transfer from crops to weeds through a process of gene flow, where pollen from genetically modified crops carrying herbicide resistance genes can be transferred to nearby weeds, this makes the weeds more difficult to control with herbicides.

• GM protein leakage into soil: Genetically modified protein leakage into soil occurs through various pathways such as root exudation, root decay or microbial decomposition of GM plant residues. This leakage has potential impacts on soil microorganisms, and overall soil health.

9. Future Prospects

• Transgenic plants may provide advantages for the environment when used in bioremediation, a method that cleans contaminated soils and water (Kovalchuk et al., 2001).

• The potential use of genetically modified crops to produce biodegradable polymers, such as poly (betahydroxyvalerate) and poly hydroxybutyrate (PHB)

• Reduced post-harvest losses due to improved shelf life, marketing flexibility (tomato) and to storage pest resistance.

• Increased nutritional quality (oil in canola)

• More effective hybrid seed production.

• Decreased losses due to the damage of viruses and insect pests, and pesticide use.

10. Conclusion

Transgenic crops that are resistant to insect pests have been shown to provide higher yields with less chemical input besides improving farmer and consumer health. The impact of transgenic crops on ecosystems should be regularly researched to allay any fears about possible risk. These can be employed for future generations as a means of meeting food demand of growing population, as traditional methods of producing food are no longer sufficient.

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