



## GENETICALLY MODIFIED ORGANISMS: AS A SUBSTITUTE FOR PESTICIDES

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### ABSTRACT

Pests are the major threat to agricultural crops. According to a recent survey up to 40% of the agricultural crops in the world are lost to pests every year. There are many different groups that can affect crops, including weeds, diseases, and insects. These pests can cause damage to crops through feeding, reproduction, and other activities, which can reduce crop yields and quality. Pest management strategies are used to control or eliminate pests in order to protect crops and maintain optimum level of productivity. These strategies can include the use of chemicals, such as pesticides, as well as cultural, biological, and physical methods. Plant protection techniques can either cease or significantly reduce crop losses caused by these destructive organisms. Synthetic pesticides can be effective in controlling pest populations, but can persist in soil and water, and have the potential to accumulate in the food chain system for long which can be toxic to non-target organisms, including pollinators and other beneficial insects. In recent years, there has been an increased focus on the development and use of more sustainable pest management practices, such as integrated pest management (IPM) and organic pest control methods to reduce the use of pesticides to a level that is economically and environmentally acceptable. One of the key tools in IPM is the use of genetically modified organisms (GMOs) or transgenic plants, which have been genetically engineered to be resistant to pests. In order to work toward a more sustainable and environment friendly approach to agriculture, this article aims to increase our understanding of GMOs as a potential tool for pest management.

**KEY WORDS:** Synthetic pesticides, GMOs, Transgenic plants, Genetic engineering

### INTRODUCTION

Agriculture and its associated sectors shape the bedrock of Indian economy as it engages more than 42% of the workforce and accounts for 17% of the country's GDP (DES, 2014). Green revolution has increased yield in India (Eliazer *et al.*, 2019). Synthetic fertilisers, herbicides, and high yield crop types were used to improve crop productivity (Dalrymple, 1985; Pingali, 2012). Its early successes had addressed the food issue in the country (Conway, 1997). Eventually it resulted in sociological, financial, and environmental issues of the nation (Evenson, 2000). To produce a luxuriant harvest, the high yield types need a lot of synthetic fertilisers and insecticides (Cooper *et al.*, 2007). The use of synthetic fertilizers and pesticides has been linked to environmental pollution and negative impacts on human health (Yadav *et al.*, 2015). Most agrochemicals have been found to affect soil biochemical and microbiological activities (Lo, 2010; Pelosi *et al.*, 2014). Additionally, the reliance on a few high-yield crop varieties

has led to a decrease in biodiversity, which can have negative consequences for the sustainability of agriculture in the long term. Some of the ways that India is addressing these issues include the promotion of sustainable agriculture practices, such as the use of organic fertilizers and pest management techniques, as well as the development of new crop varieties that are better adapted to local conditions and more resilient to pests and diseases. Since the advent of genetic engineering technology, transgenic plants with insecticidal properties have emerged as novel, highly targeted pest control strategies (Davies *et al.*, 2003; Oliver, 2014). But least information is available on the biotechnological approaches towards the development of plants with insecticidal properties helpful in sustainable crop management.

### CONCERN FOR AGRICULTURE: PEST AND ITS CONTROL (CHEMICAL PESTICIDES)

Pest infestations have always been a top issue for

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farmers in the agribusiness (Oerke, 2006). Weeds, plant pathogens (specific fungus, bacteria, and viruses), rodents, mites, and nematodes are some of these pests (Savary, 2019). Because they occasionally spread harmful viruses, they reduce crop yields in agricultural and horticultural crops both directly and indirectly. Farmers should therefore take great care of these pests (Oliveira, 2014). They apply a wide range of pest control measures to reduce weeds, insects, fungi, viruses and bacteria to address this challenge or overcome yield losses (Dwivedi *et al.*, 2022). Using pesticides, farmers have significantly improved food output over the past 60 years. They have done this primarily to avoid or minimise agricultural losses caused by pest activity, which has enhanced production and increased food supply at a fair price throughout the year. The productivity of agriculture has increased significantly in the majority of nations by the usage of pesticides which resulted crop yield of wheat in the UK (Austin *et al.*, 1999), corn in the USA and total crop yield in Russia and other nations increased significantly (Chenkin *et al.*, 1975; Keiserukhsky *et al.*, 1975).

Agrochemicals, such as fertilizers, insecticides, and fungicides, have been used for centuries in agriculture to boost crop yield (Abate *et al.*, 2000) and provide plants with essential nutrients, protect them from pests and diseases, and help increase farm productivity (Cooper *et al.*, 2007). However, excessive use of agrochemicals can also have negative impacts on the environment (Chand *et al.*, 2015). These impact can include the release of harmful gases into the air, contamination of groundwater, and surface water pollution (Yadav *et al.*, 2015).

### CONSEQUENCES OF USE OF PESTICIDES

Pesticides can have a variety of negative consequences on the environment and on human health. Their excessive usage pollutes the environment and endangers human health (Mostafalou *et al.*, 2017; Mesnage *et al.*, 2018). Some of the potential consequences of pesticide use include: Pesticides can be toxic to a wide range of species, including birds, bees, and other beneficial insects. This can lead to declines in these populations and can have cascading effects on the ecosystem (Singh *et al.*, 2015; Atwood *et al.*, 2018).

Pesticides can enter the environment through drift, runoff, and leaching into soil and water. As a result, contamination of land, water and air can occur, which could be harmful to humans as well as other animals and plants. Pesticide resistance occurs when a population of pests is exposed to a particular pesticide over a period of time and some individuals within the population are able to survive the exposure. These survivors may pass on their resistant traits to their offspring, leading to the development of a pest population that is resistant to that pesticide. Overuse

of pesticides can accelerate the development of resistance, as pests are exposed to higher levels of the chemical and are more likely to encounter individuals with resistant traits. This can make it more difficult to control pest populations in the future and may require the use of alternative pest control methods.

The use of pesticides can have both positive and negative economic impacts. On one hand, pesticides can help farmers increase crop yields by controlling pests lead to increased profits for farmers on the other hand use of pesticides can also have negative economic impacts. In addition, the negative effects of pesticides on non-target species, such as commercial insects and crop pollinators, can lead to decreased crop yields. Pesticides can also be harmful to beneficial soil organisms, such as earthworms and microorganisms (Riah *et al.*, 2014), which lead to reduced soil fertility and decreased crop growth. Pesticides can also contaminate soil and water, leading to environmental damage (Smith *et al.*, 2000; Pal *et al.*, 2006; Riah *et al.*, 2014). The negative economic impacts of pesticides can outweigh the benefits, if the use of pesticides leads to long-term damage to the environment. Therefore, it is important to use pesticides carefully and only when necessary to minimize negative impacts on soil health and the environment.

### IMPACT ON HUMAN HEALTH

Some insecticides can be toxic to humans if they are inhaled, ingested, or come into contact with the skin. Farmers who use insecticides frequently may be at increased risk of health problems if they do not use protective equipment or follow the safety instructions. Continued exposure to these chemicals over a long period of time can lead to various diseases, some of which are listed (Table 1).

### ALTERNATIVES TO PESTICIDES

Therefore, it is crucial to develop new pest control techniques immediately (Nicolopoulou-Stamati *et al.*, 2016). There are several alternative for controlling insects that do not involve the use of insecticides (Abate *et al.*, 2000) can be more environmentally friendly cost-effective in the long run. Some options include: Physical control methods such as traps, barriers, and removal of breeding sites can be effective in controlling certain types of insects (Thakur *et al.*, 2021).

Biological control involves the use of natural predators or parasites to control pest populations. For example, introducing ladybugs to control aphids or releasing nematodes to control grubs (Nazir *et al.*, 2019). Planting a diverse range of plants can also help to reduce pest problems, as many insects are host specific and will only feed on a narrow range of plants. Using natural or organic

Table 1: Several pesticide classifications and their impact on humans (Ref. )

Class of Pesticides	Commercial Example	Consequences
Organochlorine Pesticides	Dichlorodiphenyltrichloroethane, Dieldrin, endosulfan, heptachlor, dicofol, and methoxychlor	endocrine disorders (Mnif <i>et al.</i> , 2014) effects on embryonic development effects on lipid metabolism (Witczak <i>et al.</i> , 2014) hematological and hepatic alterations Carcinogenic (Chourasiya <i>et al.</i> , 2015)
Organophosphorus Pesticides	Glyphosate, malathion, parathion, and dimethoate	Neurological disorders (Wesseling <i>et al.</i> , 2002; Rosenstock <i>et al.</i> , 1991) Endocrine disruption (Reiler <i>et al.</i> , 2015) Genotoxic effects (Nougadère <i>et al.</i> , 2012)
Carbamate Pesticides	Aldicarb, carbofuran and ziram	endocrine-disrupting activity (Li <i>et al.</i> , 2014; Zheng <i>et al.</i> , 2001) reproductive disorders (Denison <i>et al.</i> , 1998)
Triazines pesticides	Atrazine, simazine, and ametryn	reproductive toxicity, developmental neurotoxicity (Jin <i>et al.</i> , 2014; Huang <i>et al.</i> , 2014, Ma <i>et al.</i> , 2015; Breckenridge <i>et al.</i> , 2015).
Neonicotinoid pesticides	Imidacloprid, thiacloprid, and guadipyr	endocrine and reproductive systems (Cimino <i>et al.</i> , 2017).
Pyrethroid	Allethrin, cypermethrin, tau-fluvalinate, permethrin	Neurological disorders (Kolaczinski <i>et al.</i> , 2004; Ray <i>et al.</i> , 2006, Jaensson <i>et al.</i> , 2007).

insecticides made from plant extracts or other herbal based materials can be a safer alternative to synthetic chemical insecticides (Fenibo *et al.*, 2021).

Integrated pest management (IPM) is a sustainable approach to pest control that seeks to minimize the use of pesticides and other harmful chemicals by using a variety of methods to manage pest populations. This include cultural methods such as crop rotation, physical methods such as barriers or traps, biological methods such as introducing natural predators of the pest, and chemical methods such as using pesticides. Even genetically modified organisms (GMOs) can be an important tool in integrated pest management (IPM) strategies. GMOs can be engineered to have specific traits that make them resistant to certain pests, diseases, or environmental stresses. This can help to reduce the need for chemical pesticides and other control measures. Using a combination of these methods, IPM aims to reduce pest populations to an acceptable level while minimizing harm to the environment and human health (Peshin *et al.*, 2008; Dara *et al.*, 2019; Deguine *et al.*, 2021).

### GENETICALLY MODIFIED CROPS

Genetic engineering is a set of technologies that allow scientists to modify the genetic makeup of an organism. One application of genetic engineering is the development of transgenic plants, the plants that have had foreign genes introduced into their genome (Perlak *et al.*, 1991). The inserted gene also known as transgene, can come from a variety of sources, including other plants, animals, or

microorganisms. One of the main reasons for introducing foreign genes into plants is to give them new traits that can make them more resistant to pests, diseases, or environmental stress. The transgenic plants can help to control pest populations and reduce the need for traditional pest control methods, such as the use of chemical pesticides (Gilbert *et al.*, 2013; Geoffrey *et al.*, 2014). These transgenic plants with insecticidal properties are one of the examples as they have been genetically modified to produce proteins that are toxic to certain insects (Table 2).

### OPPORTUNITES AND CHALLENGES ASSOCIATED WITH GENETICALLY MODIFIED CROPS

There are several potential opportunities and challenges associated with genetically modified (GM) crops (EASAC.2013; Grohmann *et al.*, 2019). GM crop offers a variety of opportunities, such as:

- GM crops may be able to produce higher yields than non-GM crops due to various genetic modifications that increase their resistance to pests and diseases, tolerance to environmental stresses, and improved growth characteristics.
- Some GM crops have been modified to contain higher levels of nutrients such as vitamins and minerals, which help to address deficiencies in the diets of people in developing countries.
- GM crops that are resistant to pests and diseases require fewer pesticides to control these problems, which could lead to reduced environmental

Table 2: Examples of GMOs Resulting from Agricultural Biotechnology

Genetically conferred traits	Example organism	Genetic Change
Herbicide tolerance (Schütte <i>et al.</i> , 2017)	Soybean	Glyphosate herbicide (Roundup) tolerance conferred by expression of a glyphosate-tolerant form of the plant enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) isolated from the soil bacterium <i>Agrobacterium tumefaciens</i> , strain CP4
Insect resistance (Wang <i>et al.</i> , 2018)	Corn	Resistance to insect pests, specifically the European corn borer, through expression of the insecticidal protein Cry1Ab from <i>Bacillus thuringiensis</i>
Altered fatty acid composition (Bell <i>et al.</i> , 2003)	Canola	High laurate levels achieved by inserting the gene for ACP thioesterase from the California bay tree <i>Umbellularia californica</i>
Virus resistance (Kang <i>et al.</i> , 2005)	Plum	Resistance to plum pox virus conferred by insertion of a coat protein (CP) gene from the virus
Vitamin enrichment (Wang <i>et al.</i> , 2018; Dubocket <i>et al.</i> , 2017)	Rice	Three genes for the manufacture of beta-carotene, a precursor to vitamin A, in the endosperm of the rice prevent its removal (from husks) during milling
Vaccines	Tobacco	Hepatitis B virus surface antigen (HBsAg) produced in transgenic tobacco induces immune response when injected into mice
Oral Vaccines	Maize	Fusion protein (F) from Newcastle disease virus (NDV) expressed in corn seeds induces an immune response when fed to chickens
Faster maturation	Coho salmon	A type 1 growth hormone gene injected into fertilized fish eggs results in 6.2% retention of the vector at one year of age, as well as significantly increased growth rates
Flavrsavr Tomatoes	Tomatoes	Tomatoes modified by the removal of genes responsible for the softening of fruit, meaning tomatoes spoil more slowly

(Provide reference)

contamination. Similarly, GM crops that are resistant to herbicides may allow for more efficient weed control, reducing the need for herbicide applications.

- GM crops may be more profitable for farmers due to increased yields and reduced input costs.
- The environmental impacts of GM crops are still being studied and are not fully understood. There is concern that the release of GM crops into the environment could have unintended consequences, such as the spread of genetically modified traits to non-GM crops or the development of herbicide-resistant weeds (Chandler *et al.*, 2008).
- The development and patenting of GM crops by a few large biotech companies has raised concerns about the control of the global food supply by a small number of corporations.
- The regulation of GM crops varies country to country, leading to confusion and potential trade disputes (Herman *et al.*, 2019).
- Some people may be sceptical or opposed to the idea of consuming GM foods, which lead to difficulties in

marketing and selling these products (Herman *et al.*, 2019).

### GM AGRICULTURE: CURRENT TREND

Genetically modified (GM) agriculture is a farming that involves the use of genetically modified organisms (GMOs) to modify crops or animals for the purpose of improving their traits or providing other benefits (ISAAA, 2018). Some current trends in GM agriculture include: Increase use of GM crops: GM crops are being increasingly adopted by farmers around the world, particularly in countries like the United States, Brazil, and India. These crops are modified to be resistant to pests and diseases, tolerate herbicides, and improve yields (Bailey-Serres *et al.*, 2019).

Development of GM animals: Researchers are also working on developing genetically modified animals, such as salmon that grow faster and cows that produce more milk. These animals are modified using techniques similar to those used to create GM crops (Bell *et al.*, 2003).

Controversy and regulation: GM agriculture has been a controversial topic, with some people expressing concerns about the safety of GM crops and animals for

human consumption and the environment. As a result, there are strict regulations in place to govern the development and use of GM organisms (Herman *et al.*, 2019). Potential benefits: Despite the controversy, proponents of GM agriculture argue that it has the potential to provide numerous benefits, such as increasing food security, reducing the use of pesticides, and improving the nutritional content of foods (Nicolia *et al.*, 2014; Tsatsakis *et al.*, 2017).

### GM AGRICULTURE FUTURE DIRECTIONS

Genetically modified (GM) crops are plants with their DNA modified using genetic engineering techniques. These techniques help in the introduction of new traits to the plants that are not naturally found in the species. GM crops have been developed for a variety of purposes, such as improving crop yields, enhancing resistance to pests and diseases, and improving the nutritional content. There are several potential future directions for GM agriculture. The possibility to develop GM crops with more resistant to environmental stresses such as extreme drought and cold. This could help to increase crop yields in areas that are prone to these types of stresses (Tuteja *et al.*, 2014). This could lead to more sustainable and environmentally friendly agricultural practices. Similarly development of GM crops which are able to remove or remediate contaminants from the environment. Few GM plants are able to absorb and store heavy metals from contaminated soil have already been in practice. The future of GM agriculture is likely to involve a combination of various approaches, with the goal of improving crop yields, sustainability, and environmental protection.

### GM CROPS: OBSTACLES

The cultivation of GM crops is controversial largely because of fear-based agricultural policies fuelled by limited public understanding, ineffective information sharing by scientists, and inaccurate reports from NGOs and anti-GM lobbyists. Beside social and economic concerns such as ownership, governance, product regulation and market development, a major concern related to GM crops is the extensive use of certain agrochemicals (such as glyphosate) in conjunction with herbicide-tolerant GM crop varieties and their retention of antibiotic resistance genes from the production pipeline in the GM Variety. These concerns have led to the adoption of strict regulations on GM crops, not only make the end products more expensive, but also delay the delivery of new varieties to farmers and make it difficult for breeders to produce varieties suitable for current crop threats.

The adoption of GMOs has been a controversial topic, with some people supporting their use and others opposing it. Those who support the use of GMOs argue

that they can help to increase crop yields, reduce the need for certain agricultural chemicals, and improve the nutritional content in certain foods. Others oppose the use of GMOs, citing concerns about their safety, the potential for negative impacts on the environment, and the potential for GMO crops to cross-pollinate with non-GMO crops (Fernandez-Cornejo *et al.*, 2002).

GMOs are regulated by government agencies in many countries, and the safety and potential risks of GMOs are regularly evaluated by these agencies. In some countries, GMO products must be labelled as such, while in others they are not required to be labelled. The adoption of GMOs varies widely around the world, with some countries banning their use altogether, while others have widely adopted them in agriculture and other industries.

### CONCLUSIONS

Pest resistance, secondary pests, hazardous residues and pest resurgence are all consequences of conventional pesticide use. As a result, they pose a threat to human health and the environment. Therefore, there is urgent need to develop new pest control strategies. Genetically modified crops can be a solution if used wisely. Genetically modified organisms (GMOs) are a controversial topic and their future prospects are difficult to predict (Nicolia *et al.*, 2014; Tsatsakis *et al.*, 2017). Some people believe that GMOs have the potential to solve many of the world's problems, including food insecurity, while others are concerned about the potential risks to human health and the environment. One of the main arguments in favour of GMOs is that they have the potential to increase crop yields and improve resistance to pests and diseases, which could help to feed a growing global population. There is also some evidence that GMOs can have environmental benefits, such as reducing the need for chemical pesticides and herbicides. On the other hand, there are concerns about the safety of GMOs for human consumption, as well as the potential for negative impacts on the environment (Tsatsakis *et al.*, 2017). Group of people worry that genetically modified crops could cross-pollinate with non-GMO crops, leading to the spread of genetically modified genes. There are also concerns about the potential for GMOs to harm beneficial insects and other non-target organisms. Overall, the future prospects for GMOs depend on a variety of factors, including advances in technology, regulatory frameworks, and people acceptability (Kramkowska *et al.*, 2013; Klümper *et al.*, 2014). It is important for people to carefully consider the potential benefits and risks of GMOs and make informed decisions about their use.

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