European Journal of Nutrition & Food Safety

Volume 14, Issue 12, Page 50-61, 2022; Article no.EJNFS.94189
ISSN: 2347-5641

Genetically Modified Crop vs Hybrid Crops and their Impact on Health and Environment

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/EJNFS/2022/v14i121281

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/94189

Review Article

Received: 03/10/2022
Accepted: 04/12/2022
Published: 27/12/2022

ABSTRACT

Genetically modified crop (GMC) is a technology which includes transferring Deoxyribonucleic acid (DNA) in plant cells. On the other hand, Hybrid Crops are naturally occurring crops but it also involves manmade crosses to have at least 15-20% higher yield potential over high yielding inbred crop varieties using almost the same level of inputs and also can perform better even under unfavourable environments like drought and saline condition. These days, hybrid crops are one of the most commonly consumed foods for humans. In line with this GM crops have high yield potential and adaptive capability under wide range of environments even under fragile ecosystems. There are different aspects of both these types of crops. Human consumption of these crops has been a highly debatable topic in recent times. In this study, a brief discussion on GM crops and hybrid crops will be presented. Additionally, a comparison between them, in terms of health and productivity, will also be discussed.

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Keywords: Carbon sequestration; crops; environment; food; human health.

1. INTRODUCTION

A hybrid crop is a product of two different varieties of the plant which is cross-pollinated to create a new crop or hybrid that contains relatively better traits of each of the parents [1]. In hybridization, pollination is controlled with utmost care to ensure that the right plants are crossed to get the expected combination of characteristics, such as bigger size or more disease tolerance hybrids with assembling of these favorable traits: like, low input cost, early maturity, higher yield, better flavour, target plant size, and/or better disease tolerance. It is one of the notable contributors to the dramatic rise in agricultural output during the last half of the 20th century. In1960s and 1970s Green Revolution was flourished by traditional breeding and adoption of high-yielding crop varieties in developing countries [2]. The more recent development of modern biotechnology, especially genetic engineering (GM crops), extends these processes of biological innovations.

Usually Genetically modified crops developed through DNA transformation using genetic engineering methods. The main objective is to introduce one or more new better traits to the plant which does not naturally occur in the existing plants. For Instance, in food crops, it is done to attain tolerance to specific pests, diseases, environmental stresses, or against chemical treatments. Aside from food crops, this technology is applicable in pharmaceutical agents, biofuels, bioremediation and other industrial goods. Many features, such the ability to withstand insect pests or abiotic stress, are intended to lessen the negative environmental effects of agricultural methods. Because they have a better nutrient profile, genetically modified crops have a lot of positive health effects on people. Soybean, maize, potato, cotton, and canola are the main GM crops cultivated. Genetically modified crops have been widely adopted by farmers, particularly in industrialized nations. The world's fastest-growing crop technology is it. Between 1996 and 2016, the area covered expanded from 1.7 to 185.1 million hectares, or nearly 12% of the world's agriculture. Adoption of GM technology had raised crop yields by 22%, decreased the usage of chemical pesticides by 37%, and increased farmer profitability by 68% [3]. The use of pesticides has decreased, which is good for the environment. In contrast to wealthy countries, yield and profit gains are larger in developing nations (ISAAA, 2015). However, while GM crops may be controversial for a number of reasons, including environmental issues and issues relating to human health, the food produced from GM crops is safe and necessary to meet the world's food demand, regardless of whether the foods are easily accessible to underprivileged farmers in developing nations [4]. Huge expansions of GMC brought about by powerful scientific methods have changed agricultural practices that have a direct and indirect impact on the environment [5]. Concerns regarding food safety and potential environmental effects have arisen as a result of the development of GM crops. Despite the higher yield potential, risks and biosafety issues associated with such GM crops are the major concern need to be addressed [6].

It is believed that Cotton Mather's description of corn (*Zea mays*) and squash in 1716 marked the beginning of the scientific identification of hybrid plants (*Cucurbita* spp.). In keeping with this, the first crop to be genetically engineered was a tobacco plant that was resistant to antibiotics. The first field trial was carried out in France and the USA in 1986 with tobacco that was resistant to the first herbicide [7]. By integrating genes that produced insecticidal proteins from Bacillus thuringiensis, Plant Genetic System (Ghent, Belgium), which was created by Marc Van Montagu and Jeff Schell, was the first business to genetically engineer insect-resistant (tobacco) plants [8]. The People's Republic of China initially released a virus-resistant tobacco in 1992 to permit the commercialization of transgenic plants, but that product was later removed [9]. The first genetically modified crop, tamoto, was allowed for sale in the USA in 1994 [10]. Because it took longer to soften after ripening, it had a longer shelf life. The approval of Bt cotton, Bt cotton-resistant to bromoxynil, Bt cotton-resistant to glyphosate, Bt cotton-resistant to glyphosate, Bt soybeans-resistant to virus, and Bt canola with changed oil composition occurred in 1995 [9]. Golden rice with added vitamin A was created in 2000; however, as of 2021, it had not yet entered commercial production but was awaiting approval for farmer-level cultivation [11].

Information on the characteristics, background, and present situation of hybrid and genetically modified (GM) crops, as well as their positive and negative consequences on human health and the environment, has been presented in this paper.

2. HYBRID PLANTS AND GENETICALLY MODIFIED CROPS

A hybrid plant is a cross-breed plant resulting from cross pollinating two or more unrelated inbred plants [1]. Hybridization has made notable improvements in plant kingdom, like more vigorous plants, unregulated disease tolerance, earlier maturity, more uniform growth, and higher yield.

Genetically modified crops may be defined as crops in which the hereditary materials (DNA) have been modified in a way that does not occur spontaneously by mating and/or natural recombination. This technology is also termed as modern biotechnology, gene technology, or genetic engineering. This mechanism permit genes to be transferred from one biomes into another, even between two non-related species [12]. With the development of science and technology hybrid crops are now modified genetically for better results and better characteristics.

2.1 Hybrid Crops

Hybrid varieties are relatively more vigorous and higher productive due to heterosis or hybrid vigour is fully imbedded in these varieties. All the individuals or plants of a hybrid variety are genetically similar. Thus hybrid genotypes are heterozygous but produce homogeneous plant populations [13]. They have higher uniformity and more attractiveness resulting homogeneous in nature. Hybrids have wide range of adaptability to environmental hazards than inbreeds and pure line genotypes due to upregulated inherent buffering capacity and genetic from two divergent alit parents. Hybrids can be derived from both cross and self-pollinated species depending upon the magnitude of heterosis. Nevertheless, hybrids are more common phenomenon in cross pollinated plants than self-pollinated plants. Hybrids are generally more tolerant to biotic and abiotic stresses than inbred and pure-line varieties [14].

2.2 Genetically Modified Crops

Genetic engineering is used in food crops to improve crops, upregulate product attributes, and hasten the development of pest and disease resistance. It is typically created by making specific alterations to plant genomes by introducing Bacillus thuringiensis genes, which usually allow them to develop resistance to diseases and pests [15]. BT (Bacillus thruengensis) corn and BT cotton are two examples. To protect their seedlings from chilling harm, tobacco and potato plants have also incorporated cold water fish genes [16]. Such plant varieties with herbicide tolerance have been created by scientists. For instance, soybeans have been genetically altered so they can grow naturally without being harmed by herbicides.

Aside from the global food deficit, many nations experience famine and malnutrition. They only rely on one diet, such as rice, which cannot supply all the necessary nutrients. It is likely that rice, which has undergone genetic modification to include critical elements, will be able to provide all required nutrients. Because childhood blindness is a prevalent issue, particularly in developing nations. The creation of golden rice (GM), which may give necessary nutrients along with beta carotene, brought about the long-awaited and cherished dream of scientists to create rice that was vitamin-A fortified using a transgenic approach [17]. The overall positive traits of GM crops are shown in Fig. 1.

2.2.1 Current status of GM crops

For biotech-improved seed, the average global adoption rates in 2013 were 79% for soybean, 32% for maize, and 70% for cotton [18]. In 2014, 230 million acres of seeds enhanced through biotechnology were farmed by 16.5 million small farmers in 20 developing nations. These smallholders benefited from a 50% decrease in pesticide treatments on their crops, which resulted in higher income of $16.7 and $16.2 billion for them.

2.2.2 GM Crops in Bangladesh

Insect-resistant Bt brinjal was originally commercialized in Bangladesh. Currently, four types of Bt brinjal are grown by roughly 6,000 farmers [19]. Farmers who plant the crop have reduced their use of insecticides by 80% to 90% as a result of adoption. The GM food crop brinjal has been approved for commercial production for the first time in South Asia by Bangladesh. Bangladesh National Committee on Shoot Borer (FSB) opined that Bt brinjal would significantly reduce the use of pesticides. In Bangladesh more than three crops are under field trial, which are developed through agro-biotechnological approach. These include Golden Rice with added vitamin A, Bt cotton, and potatoes that can withstand late blight. Given the importance of Bangladesh's significant cotton and textile industries, Golden Rice and Bt cotton are being tested in the field to see if they might help Bangladesh's children who now suffer from Vitamin-A deficiency [20].

There is no beta carotene in rice. Due to the predominant use of rice as a food source in South Asia, vitamin-A deficiencies are typically detected in youngsters and pregnant women. Only 150 grams of golden rice should be consumed daily to meet an adult's recommended daily allowance (RDA) for vitamin A. One in every five preschoolers in Bangladesh is vitamin-A deficient, according to the World Health Organization's global database on the condition. 23.7% of pregnant women have a vitamin-A deficiency [21].

Contrarily, cotton is a cash crop used for non-food purposes [22]. The BT cotton seeds have

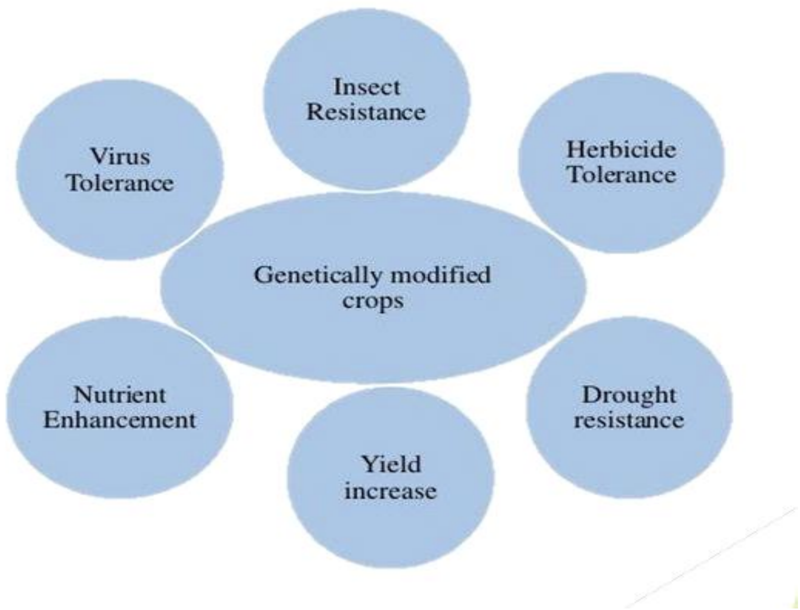

Fig. 1. Beneficial characteristics of GM crops (Brook, 2016)

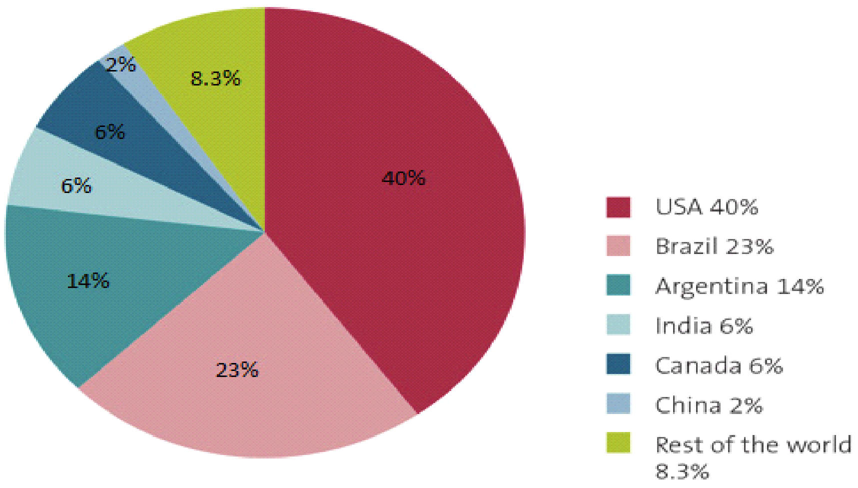

Fig. 2. GM crop producing major countries (by percentage) around the world [4]

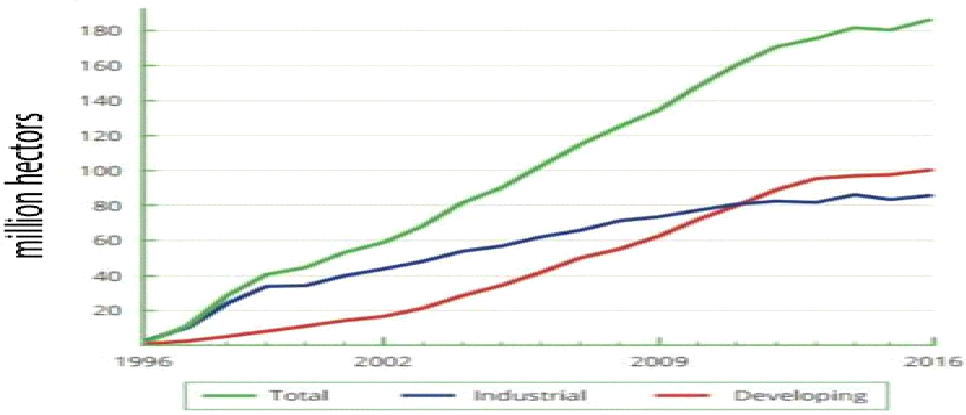

Fig. 3. Areas of individual and developing countries under GM crops and global area in 1996-2016 [4]

genetic features derived from the soil-dwelling bacterium Bacillus thuringiensis (Bt.), which successfully combats the bollworm, a dangerous caterpillar that reduces cotton output. Bangladesh can only produce 0.15 million cotton bales annually, but to meet demand, it imports an additional 5 million bales for about Tk. 20,000. Typical synthetic pesticides are losing their ability to control cotton bollworm, which results in crop losses of up to 20% [23]. BT cotton is tolerant to important insect pests, especially cotton bollworms. It is reported that BT cotton adoption down-regulates the use of chemical pesticide and increases yields in farmers' fields, moreover Bt cotton had relatively higher yield (18%) than the non-Bt cotton across the season [24].

3. POSITIVE EFFECTS OF GM CROPS ON HUMAN HEALTH

Human health is being benefited by GM crops as it is designed to fight against specific nutrient deficiency. Food security through the adoption of GM crops also affects human health indirectly.

3.1 Improvement of Nutrient Contents

Since genetically modified crops were initially commercialized in the USA in 1996, the biotechnology sector has asserted that a "second generation" of GM will really benefit consumers, for instance by enhancing the nutritional content of food use [25]. With second generation nutritionally enhanced GM crops, the biotech sector now aims to expand its market and contribute to the reduction of malnutrition and the improvement of health. However, there are different types of nutritionally enhanced food claims: improved vitamins (greater levels of beta carotene), enhanced minerals (more iron), enhanced amino acids (tryptophan), enhanced protein (in potatoes), enhanced levels of antioxidants to combat cancer, and lower risk of allergic responses (by silencing or removing genes such as wheat and peanuts) [26].

3.2 Recovery of Vitamin-A Deficiency

In Southeast Asia and Africa, vitamin-A deficiency (VAD) is a significant public health issue. Every year, between 250 and 500 thousand youngsters lose their vision due to vitamin-A insufficiency. Since 2000, "Golden Rice" has used an amid solution to treat VAD. Given that Golden Rice was genetically altered to synthesize beta carotene utilizing a gene originally from the daffodil and later from maize. Following the daffodil mediated, which received harsh criticism for the amount of rice needed to be consumed to meet the prescribed intake of beta carotene, adjustments employing maize genes enhanced the amount of beta carotene generated by the rice [27].

3.3 Omega-3 Enhancement

Some nutritionists have placed a stronger emphasis on the components of a diet high in omega-3 polyunsaturated fatty acids that promote health, particularly in the prevention of cardiovascular disease [28]. Oily fish (like mackerel) and other sea biomes, which pick them up from marine algae, are the sole direct suppliers of omega-3s. The Food Standards Agency now advises consuming at least one portion of oily fish per week as a result of this. Although the idea of growing marine algae has been discussed, it has not yet become widely commercialized. Fish oil is added to some animal feed, and the resulting animal products are promoted as having a high omega-3 content [29]. The genetic modification of common foods to increase levels of antioxidants (which are believed to reduce the risks of cancer) has been given a good deal of publicity. Very recently It is reported that “purple tomatoes” of the John Innes Centre (JIC), are relatively higher in anthocyanins [30].

3.4 Food Security

Food security refers to the situation in which everyone has both physical and financial access to adequate, wholesome food [31]. Unfortunately, a sizable segment of the world's population lacks food security. Three potential effects of GMC on food security exist. First, GM crops may help boost food production, which will raise both the global and local availability of food. Second, GM crops may impact the quality and safety of food. Thirdly, GM crops may affect farmers' social and economic standing, affecting how easily they can afford to buy food. In 2012, Globally 170 million hectares (~12% of the global arable land) of land were under cultivation of GM crops, such as soybean, corn, cotton, and canola, but most of these crops were not grown primarily for direct food use [25]. GM crop technology has increased average yield which leads farmers' economic development. Economic development makes it possible for farmers to lead a standard living with better health.

4. NEGATIVE EFFECTS OF GM CROPS ON HUMAN HEALTH

Since they have undergone risk analyses and are already available for purchase internationally, genetically modified foods are unlikely to pose health concerns to people [32]. GMOs, however, may pose a number of risks to human health, according to specialists in food safety. The risks include the potential for adding new toxins or allergens to food, a drop in nutritional value, and antibiotic resistance. According to survey findings from Europe and Japan in particular, where consumers are concerned about potential adverse effects on people and the environment, the International Union for Conservation of Nature (IUCN) is portraying GMOs negatively on a global scale, which is reflected in the IUCN-GMO resolutions [33].

4.1 Allergenicity

Worldwide there is controversy about allergenicity of GM crops and suspected to adverse health effects. They found that beans generated by soybean plants modified with a gene from Brazil nuts provoked an allergic reaction in certain people. It wasn't until 2005 that researchers from the Australian government's national research organization, CSIRO, found that genetically modified pest-resistant peas caused allergic lung damage in mice. A gene for the common bean protein that can kill the pest pea weevils had been inserted by researchers into the pea plant. When taken from the bean, the harmless protein does not cause an allergic reaction, but when expressed in the pea, it has a different structural makeup than the original bean. The unanticipated immune system observed in mice may be the result of this significant alteration, illustrating the unpredictable effects of gene transfer and the value of utilizing animal models to investigate the allergenic potential of GM foods [34]. Contrarily, it has been claimed that GM foods do not seem to be more allergenic than their traditional counterparts, and there is no evidence to suggest that eating GM proteins speeds up the development of allergy in people who are not already allergic to that food [35].

4.2 Toxicity

The possible negative impact of toxicity on both humans and animals is another risk associated with GMOs. The GM maize line MON 863 (Yield Guard Rootworm Corn), which was approved in the US in 2003 and specifically targets the corn rootworm, is one of the most recent GMC to be suspected of causing toxicity. MON 863 produces the Bt toxin predominantly in the roots, the western corn rootworm's point of entry, and has significantly less of it than most Bt maize types. A food supplement created using GM microorganisms in the late 1980s proved hazardous, which led to the deaths of 37 Americans and the serious illness of more than 5,000 others [36]. When soya beans were modified with a Brazil nut gene, it caused allergic reactions in people who are allergic to Brazil nuts [37]. Several experimental GM food products (not commercialized) were also discovered to be dangerous.

4.3 Antibiotic Resistance

In order to increase the success rate of genetic modification, researchers have developed an approach that involves the evolution of antibiotic resistance genes alongside the desired gene to identify which plants have effectively absorbed the injected gene. Although it is still used to treat many human illnesses, the antibiotic kanamycin is a regularly used marker for plant modification [38]. Human infections may become more resistant to antibiotics since the genes are typically derived from bacteria. Public health professionals are nevertheless concerned about these drug-resistant strains because they are more challenging to treat in patients who require therapy, even though there is no conclusive evidence that they are necessarily more dangerous for humans [39]. The use of antibiotic resistance markers in food is opposed, for instance, by the British Medical Association. The risk is deemed significant enough to motivate researchers to utilize methods to eliminate the flag genes before a crop plant is created for industrial use [40]. Additionally, a different marker made from tobacco rather than bacteria has just just been created by researchers [41].

5. POSITIVE EFFECTS OF GM CROPS ON ENVIRONMENT

Initially GM crops after its application in the field have drawn the attraction of a number of scientists in this research area with a number of advantages.

5.1 Reduction in Pesticide Use

With 26 million ha of cultivation worldwide, HT soybeans are presently the most popular transgenic crop [42]. The overall rate of pesticide use in GM soybeans decreased by almost 10% between 1997 and 1998. Additionally, according to a research from [43], 2.5 million kg of glyphosate replaced 3.3 million kg of products that contained other synthetic herbicides as imazethapyr, pendimethalin, and trifluralin. The most thorough analysis of how HT soybeans affect pesticide use has likely been done by the Dutch Centre for Agriculture and Environment. According to the report's findings, pesticide use in the USA varied between GM and conventional soybeans from +7 to -40% (1995 to 1998), with an average decrease of 10% [44].

To predict the impacts of introducing HT soybeans on herbicide use, data from 431 farms in 20 sites across the USA were used. According to their preliminary findings, HT soybean will reduce herbicide use by up to 10% [45]. Additionally, 15 million fewer spray applications per ha, or around 22% fewer pesticide applications, were made (Table 1).

5.2 Carbon Sequestration

According to reports, the usage of GM crops is lowering greenhouse gas (GHG) emissions, which has already been proven through numerous researchers' trials [47]. Nitrous oxide (N2O), carbon dioxide (CO2), and methane are the three primary greenhouse gases (CH4). Three primary factors influence the potential for GM crops to reduce GHG emissions. Overall, the amount of carbon dioxide removed from the atmosphere due to decreased fuel consumption and increased carbon storage in the soil due to no or reduced tillage techniques can be used to quantify the reduction of GHGs [48].

Since 1996, 203,560 million tonnes of CO2 that would have otherwise been released into the environment have been held in the atmosphere as excess soil carbon. When the benefits of carbon sequestration from reduced fuel consumption and enhanced soil carbon storage are summed up, the total carbon dioxide reductions in 2013 rise to about 28,005 million kg, which is equivalent to removing 12.4 million cars from the road per year. This is roughly equivalent to 43% of the registered cars in the UK [49]. Table 2 illustrates the possible contribution of carbon sequestration savings with the adoption of many GM crops in different countries throughout the world.

Table 1. Reduction in pesticide and environmental impact quotient during 1996-2015

	1996-2014	1996-2015	2014 alone	2015 alone
Reduction in pesticides (million kgs actives ingredients, a.i.)	583.5	619	40.4%	37.4%
Pesticides saving	8.2%	8.1%	6.4%	6.1%
Reduction in (EIQ)*	18.5%	19%	17.6%	18.5%

**Environmental Impact Quotient (EIQ) = a composite measure based on the various factors contributing to the environmental impact of an individual active ingredient*

Source: [46]

Table 2. Relationship between carbon sequestration and adoption of GM crops

Crop / Trait/Country	Additional Carbon Stored in Soil (mkg C)	Potential Additional Soil Carbon Sequestration Savings (mkg CO2)
US: GM HT Soybean	291	1,066
Argentina: GM HT Soybean	3,111	11,418
Brazil: GM HR Soybean	1,889	6,931
Bolivia, Paraguay, Uruguay: GM HT Soybean	700	2,569
US: GM HT Maize	815	2993
Canada: GM HT Canola	254	932
Total	7060	25 ,909

Source: [46,50]

6. NEGATIVE EFFECTS OF GM CROPS ON ENVIRONMENT

GM crops also have considerable negative impacts on the environment.

6.1 Conversion of Biodiversity

Both generally and specifically in the context of the Convention on Biological Diversity, the possible effects of GM crops on biodiversity have become a heated topic. The conversion of natural ecosystems into agricultural land is what has a direct negative impact on biodiversity most often associated with GM crops. In that situation, it is most reasonable to think about how GM crops might affect current agricultural methods [51]. The widespread cultivation of uniform, high yielding crop varieties, which has resulted in the displacement and eradication of traditional crop varieties from agro-ecosystems, is another critique of conventional agricultural practices. At least 1,350 different breeds are reportedly in danger of going extinct right now, with two types going extinct on average every week [52]. Experts are concerned that a rising reliance on a single gene in cultivating a range of crops could be hazardous, much as using monocultures may increase insect issues in traditional agricultural approaches [53].

Herbicide-resistant genes from the canola were discovered to have spread to the bacteria and yeast inside the intestines of baby bees, according to a three-year German study. These results suggest horizontal gene transfer between species that are not typically compatible and, at the very least, raise questions that need more research [54]. In contrast, studies from China revealed that insect-resistant cotton had no overtly harmful effects on honeybees [55], showing that while GM technology may enhance the likelihood of horizontal gene transfer, this is not always the case. No evidence of direct effects of Bt plants on the natural enemies of the target species has been found, according to laboratory and field investigations [56].

In addition to this, invasive alien species (IAS) have been identified as the second-leading driver of habitat loss in terms of harming the world's biodiversity, right behind species endangerment and extinction. This is why any threat of GMO encroachment must be treated seriously. The following risk criteria [57] for invasive species and pest management are used to assess the possible invasiveness of GM crops: First, alterations in adaptive traits (that may increase the potential for establishment and spread). Second, unfavorable impacts of gene flow that could lead to the creation of new pests or the establishment and spread of existing pests. Thirdly, unfavorable effects on organisms that are not the target, genotypic or phenotypic instability that leads to the establishment and spread of organisms with new pest traits, such as the loss of sterility genes intended to prevent outcrossing. Other hazards exist in addition to this, such as increased viral combination potential. A GMO must harm or be potentially harmful to plants or plant products under conditions in the pest risk analysis area in order to be classified as a pest.

6.2 Risks of Overused Glyphosate

Globally more than 80% genetically modified (GM) crops are engineered to tolerate glyphosate herbicides. All of the field's plants, excluding the crop, are destroyed by the herbicide. These plants are referred to as glyphosate-tolerant plants. Such crops were developed with the intention of making weed control easier for farmers. To eliminate all weeds without harming the crop, the farmer might spray glyphosate herbicide across the entire field. According to a survey from the industry, 61.2 million acres of US agriculture were plagued with glyphosate-resistant weeds in 2012. In the US, the use of herbicides increased by 239 mkg (527 million pounds) between 1996 and 2011 compared to the amount that would have been used if the same acres had been planted to non-GM crops. Most of this increment is due to the spread of glyphosate-resistant super weeds [57].

6.3 Insecticidal Toxins from *B. thuringiensis* (Bt)

B. thuringiensis creates protoxins known as d-endotoxins in the form of crystalline inclusions during sporulation. When an insect consumes these so-called cry proteins, digestive proteases cleave and dilute them in the gut, activating the poison. After the toxin binds to certain glycoprotein receptors on the surface of gastrointestinal cells, an imbalance in ion concentration results, the cells are destroyed, and the insect dies [58]. Additionally, before sporulation, some strains of *B. thuringiensis* release "vegetative insecticidal proteins" (VIPs) [59]. Nonetheless, the widespread use of Bt insecticides by farmers has been constrained by the instability and breakdown of cry proteins when exposed to UV radiation as well as their brief duration on plants (easily washed by rain and irrigation). Around 100 holotype toxins produced by *B. thuringiensis* are distributed among 40 groups (cryl, cry2, etc.), each with a number of subgroups and a specific host range [60]. The development of transgenic plants that are resistant to pests and diseases makes use of this heterogeneity.

7. FUTURE OUTLOOK AND CONCLUSION

Every technological advancement has advantages and disadvantages, but we cannot dismiss a health technique because of the potential for abuse. Utilizing technology responsibly is the straightforward solution. An in-depth pre-market approval review is advised to stop potential risks from getting into the food supply. GMOs are not currently being tested before being put into the environment according to any set protocols. Government laws can range from lax ones requiring testing, traceability, and labeling of GMOs to companies notifying authorities as they sell biotech crops. There are both direct and indirect consequences on the environment from GM crops with certain features, as well as from crops that are insect-, drought-, and virus-resistant. These effects may have both good and negative components, while they might be either positive or negative. GM crops are a contentious issue that has generated a lot of debate; they are widely used in some regions of the world while being outlawed in others. Concerns concerning potential environmental harm from the usage of GM crops have been raised as a result of their commercial production on a global scale. As a result, before and during their commercial cultivation, the dangers of GM crops for the environment—and particularly for biodiversity—have been thoroughly evaluated. Today, there is a wealth of scientific information on the environmental impacts of the commercially accessible GM crops. It is aspirated that in the future, only GM crops that do not have a higher detrimental impact on the environment than their non-GM counterparts would be introduced to the market.

ACKNOWLEDGEMENT

Authors are grateful to the University of Dhaka and Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh providing the facilities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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