ISBN: 978-81-972400-8-9

4. Biotechnology and GMOs in Agriculture

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Abstract:

Biotechnology, particularly the application of genetically modified organisms (GMOs), has emerged as a transformative force in modern agriculture, offering promising solutions to address various challenges facing global food production. GMOs, engineered through biotechnological methods, entail the insertion of specific genes into the genetic makeup of organisms to confer desirable traits such as pest resistance, herbicide tolerance, and enhanced nutritional content. These genetic modifications have revolutionized crop cultivation practices, leading to increased yields, reduced pesticide usage, and improved crop resilience to environmental stressors. Furthermore, GMOs have facilitated the development of crops with enhanced nutritional profiles, offering solutions to malnutrition and food insecurity in resource-limited regions. Biotechnology and GMOs hold immense potential to revolutionize agriculture and address pressing global challenges. However, their widespread adoption necessitates careful consideration of ethical, environmental, and socio-economic implications to ensure sustainable and equitable agricultural practices in the 21st century.

Keywords:

Agricultural Biotechnology, GMOs (Genetically Modified Organisms) and Biotechnology.

4.1 Introduction:

Genetically modified organisms (GMOs) are organisms whose genetic material has been altered using biotechnology. GMOs have become more prevalent in the agricultural sector in the last ten years, with 28 countries planting 170 million hectares of GM crops, 25 species of GM organisms approved, and 59 countries issuing 2497 regulatory approvals by the end of 2012. However, GMOs are still controversial, as their potential effects on the environment and human health are not fully understood. Moreover, some GMOs that have not been authorized (UGMs) have been found in the market, posing a risk of uncontrolled dissemination. Therefore, it is essential to develop effective methods for detecting and monitoring GMOs. A single test that can detect most of the GM events, with high specificity, sensitivity, and affordability, is the ideal goal for GMO monitoring. However, none of the existing methods can achieve this goal, as they are limited by the number of samples they can handle. Among these methods, PCR is the most popular one, because it has advantages such as high sensitivity, low cost, and easy operation. Biotechnology is the science of using living things or their products to improve human health and the environment. One of the ways biotechnology works is by creating genetically modified organisms (GMOs), which are living things that have been changed by adding or removing genes using special techniques. GMOs can be used for many purposes, such as making medicine, producing goods, and growing crops. In this essay, I will talk about the use of GMOs in farming, which is one of the most hotly debated issues in biotechnology. Farming is the activity of growing plants and animals for food, clothing, energy, and other uses (Jacobsen et al., 2013). Farming has been very important for human society, as it provides the foundation for food security, economic development, and environmental protection. However, farming also has many problems, such as increasing population, changing climate, soil erosion, water shortage, pests, diseases, and hunger. Agricultural biotechnology is a possible way to improve the quantity, quality, and resilience of crops, as well as the health and welfare of animals, and the environmental impacts. There are three types of GMOs in agriculture, based on their traits and purposes. The first type of GMOs are crops that can resist biotic stresses, such as insects, weeds, and pathogens. For example, Bt cotton makes a toxin that kills bollworms, and Roundup Ready soybean can survive the herbicide glyphosate. The second type of GMOs are crops that can tolerate abiotic stresses, such as drought, heat, and salinity. For example, Drought Gard maize has a gene that helps keep water, and Golden Rice makes beta-carotene, which is needed for vitamin A (Newell-McGloughlin et al., 2014). Bio fortification, nutritional enhancement, and biopharming are novel traits that the third generation of GMOs can offer to consumers and industries. These traits are achieved by modifying the crops to produce substances that are beneficial for human health or industrial applications. For instance, Golden Bananas have high levels of iron and vitamin A, which can prevent anemia and blindness, while Pharming Crops can synthesize pharmaceuticals and industrial enzymes, which can reduce the cost and environmental impact of conventional production methods. Genetically modified organisms (GMOs) are a controversial topic in the field of agriculture, as they have both advantages and disadvantages for different groups of people and the environment. Some of the benefits of GMOs are that they can enhance crop productivity, lower production costs, improve food quality and security, and support sustainable development goals. Some of the drawbacks of GMOs are that they can have negative impacts on human health, biodiversity, and socio-economic systems, and that they are controlled by corporate interests and lack public participation and transparency (Ajoy kumar et al., 2021). The debate over GMOs is shaped by various factors, such as scientific evidence, ethical values and cultural beliefs. GMOs in agriculture have both advantages and disadvantages, and they raise many questions and concerns from different angles. In this chapter, I will explore how GMOs affect the environment, society, and economy, using the concepts of sustainability and agro-ecology. I will also look at the current situation and future potential of GMOs in various parts of the world, and how they relate to global food security and sustainability. I will take into account the views and interests of different actors, and the importance of public participation and regulation in the management of GMOs. I will end with some recommendations and suggestions for the appropriate and efficient use of GMOs in agriculture.

4.2 What are GMOs:

The term Genetically-Modified Organism is vague and inaccurate. All of our crops and livestock are GMOs in that their genetics have been modified and selected by humans over millennia. This has resulted in significant changes from their wild ancestors (Mueller et al., 2022). Most of them would not be able to survive or compete outside of human intervention. The FAO and the European Commission define a GMO, and its products, as being plants or animals that are produced through techniques in which the genetic material has been changed in a way that does not occur naturally by mating and/or natural recombination. However, this definition is still problematic, as it would include some crops that are considered conventional, such as Triticale. Triticale is a grain crop used in bread and pasta that was developed to provide a more nutritious food source (higher protein and low gluten) (Pattison et al., 2013). It is entirely artificial. It was first created in the laboratory in 1884 by crossing wheat with rye to form a sterile hybrid that could not reproduce in nature (Kingsbury et al., 2011). To produce the crop, fertility had to be restored, and this was done by doubling the chromosomes to create a stable polyploid plant with two copies of each of the parental genomes (rye and wheat). This was done in the late 1930s using in vitro culture technology and treatment of embryos with the chemical colchicine, which disrupts the normal process of cell division (mitosis) to generate polyploid cells (Dhooghe et al., 2011). Clearly, this is a crop that would match the FAO definition of a GMO but it is not labeled as such. A more precise definition would be a modification to The Cartagena Protocol definition for “living modified organisms,” which would then read, “Genetic Modified Organism” means any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology.

4.3 GMOs in Agricultural Biotechnology:

Food crops have changed a lot since their origins. Farmers and scientists have used different methods to improve them. First, they selected the best seeds from the plants that were stronger, bigger or more productive. Then, they used genetics to understand and modify the traits of the plants (Cadotte et al., 2009). They also used techniques like mutagenesis, molecular markers and gene transfer to create new varieties. Now, they can edit genes to insert, delete or change them. This way, they can access more traits than before. Humans have changed food crops for thousands of years. They saved and planted seeds from plants that survived better and produced more. With Mendel's laws of inheritance, genetic selection became more systematic. Scientists also used methods like mutagenesis to create new variants. But they still relied on the plants' own reproduction within the same or similar species. Now, plant breeding can go beyond that limit. GE technologies can help crops adapt to new challenges and demands. They can improve crop traits faster and more precisely than conventional breeding. GE can also lower the costs and impacts of agriculture on the environment and society. GE is a valuable tool for enhancing the resilience and productivity of crops in a changing world.

Transgenic procedures and their safety are a major social concern (Anthony et al., 2004). Science and regulation try to reduce or avoid the unintended consequences of these technologies. We did not find any transgenic accidents that clearly harmed the environment or health. However, nothing is perfect, and new biotechnologies need a rational and robust evaluation by regulators.Transgenic methods can be seen as risky, but we should also look at how they differ from other ways of changing genes. GE technologies are more accurate than breeding or mutagenesis, which change genes by looking at the traits they produce. In breeding, we don't know what other genes are changed besides the ones we want. With GE, we only change one gene to get the trait we want, and leave the rest unchanged.

This means that GMOs are less likely to have unwanted effects than plants made by breeding. GE applications can be classified into three groups based on their traits. The first group has traits that help crops resist pests or herbicides (Mitchell et al., 2016). The second group has traits that enhance crop quality or resilience to environmental stress. The third group has traits that enable plants to produce useful chemicals, such as medicines, industrial materials, or biofuels. However, only a few of these traits have been commercialized, because the regulations of agricultural biotechnology are very expensive and discourage field trials of many promising varieties. Gene editing is a new type of GE that uses SSNs to change specific genes. It has tools like ZFNs, TALENs, and CRISPR systems. CRISPR-Cas9 is the newest and easiest tool. It can change many genes in one plant. This can make plants better, like more resistant to pests. Gene editing can modify major crops, such as barley, maize, rice, soybean, sweet orange, tomato, and wheat, as shown by 2015 studies. Some of the traits under study are herbicide resistance, drought tolerance, improved nutrition, salt resistance, and biotic stress resistance (Pandey et al., 2017). Gene editing is more precise and predictable than transgene-based methods, which may increase public acceptance of gene edited crops compared to previous GMOs.

4.3.1 Regulations of GMOs:

Global legislative landscape on GM crops, with a focus on how gene edited crops fit into the existing frameworks. It synthesizes the applicable regulatory documents across the globe and compares the process-oriented and product-oriented approaches to GM regulation (Turnbull et al., 2021). Different countries have different regulations for labeling food or feed products that contain or are made from approved GMOs. For example, in the EU, such products must be labeled if they have more than 0.9% GMO content, while in Korea and Japan, the thresholds are 3% and 5%, respectively. The individual country regulations of some of the top GM cropproducing countries, such as the United States, Canada, Australia, Spain, Portugal, Brazil, Argentina, China, and India. It examines the factors that allowed them to cultivate GM crops on large scales and how they deal with gene edited crops.There are some international agreements and standards that aim to harmonize the regulation of GMOs and ensure their safety for human health and the environment. These include the Cartagena Protocol on Biosafety, the Codex Alimentarius Commission, the International Plant Protection Convention, and the World Organisation for Animal Health (Sendashonga et al., 2005). The benefits and challenges of GM crops, as well as the biosafety regulations and public acceptance issues in various countries (Huesing et al., 2016). It also presents the current status and future prospects of GM crops in different regions of the world, such as Asia, Africa, Europe, and Latin America.

The current regulations for GM organisms and how they can be adapted to accommodate genome editing technologies (Georges et al., 2017). It also proposes some recommendations for improving the regulatory frameworks, such as harmonizing definitions, criteria, and procedures, and enhancing transparency and public engagement.

4.3.2 Positive and Negative Impacts of GMOs on Human Health:

GMOs are often used to create crops that have desirable traits, such as resistance to pests, herbicides, or harsh environmental conditions. Many people and countries are reluctant to accept GMOs for various reasons. Some of these reasons are: (i) lack of public knowledge and trust in biotechnology, (ii) different and strict regulations for GMO approval and trade, and (iii) limited capacity and resources for developing and regulating GMOs in some public institutions. Additionally, GMOs that are resistant to insects need to be managed carefully to avoid the emergence of resistant pest (Naranjo et al., 2019). However, some concerns about the possible effects of GMOs on human health and the environment (Godheja et al., 2013). Basically, two types of impacts those are as follows:

Positive impacts of GMOs: GMOs can improve the quality, quantity, and diversity of food production. They can enhance the taste, nutritional value, and shelf life of foods. They can also reduce the need for pesticides and fertilizers, which can lower the environmental impact of agriculture. GMOs can also help address the challenges of food insecurity, malnutrition, and climate change by creating crops that can grow in different regions and conditions.

Negative impacts of GMOs: GMOs can pose potential risks to human health and the environment. They can cause allergic reactions, toxicity, organ damage, or gene transfer if the modified genes are harmful or interact with other genes in unpredictable ways. They can also affect the natural balance of ecosystems by creating superweeds, reducing biodiversity, or harming beneficial insects and animals. GMOs can also have social and economic impacts, such as increasing the dependence of farmers on biotechnology companies, creating trade barriers, or violating the rights of indigenous communities (Gonzalez et al., 2006).

The discussion over GMOs is complex and ongoing, and there is no definitive answer to whether they are good or bad for human health and the environment. Different GMOs may have different effects, depending on the type of modification, the crop, and the context. Therefore, it is important to evaluate each GMO case by case, based on scientific evidence and ethical considerations.

4.3.3 How Agricultural Biotechnology Helps in Sustainable Development Goals:

GMOs are agricultural technologies that can help achieve the SDGs, especially those related to poverty, hunger, and climate change. However, GMOs face resistance in Europe and other regions, which affects their adoption in the developing world. The main challenges are the excessive use of precautionary principle and the absence of a global GMO regulation (Huesing et al., 2016).

Developing countries should evaluate GMOs based on their local context, rather than following developed countries.

4.3.4 Can GMOs Achieve the end Hunger and Resolve the Issue of Malnutrition?

Genetically modified organisms (GMOs) are organisms whose genetic material has been altered using biotechnology. Some proponents of GMOs claim that they can help address the global challenges of hunger and malnutrition by increasing crop yields, enhancing nutritional quality, and reducing the use of pesticides and fertilizers. However, there are also many uncertainties and controversies surrounding the safety, environmental impact, and social implications of GMOs. Therefore, it is not clear whether GMOs can achieve the end of hunger and resolve the issue of malnutrition, or whether they may pose more risks than benefits for human health and the planet. GM food of biotech crops is seen as a possible solution to world hunger. These foods are made by altering the genes of crops using biotechnology methods, resulting in plants with better traits such as resistance to pests and drought. GM crops could help to improve global food security by providing a stable source of food for the growing population and reducing the damage of crop losses caused by climate change and pests (Tyczewska et al., 2018). For instance, GM crops that can resist pests can lower the amount of chemical pesticides needed for farming, leading to healthier and more sustainable food production. However, GM food is still a contentious issue with the rising worries of the potential health risks, environmental impact and ethical issues. Opponents claim that the GM crops could lead to increased reliance on single types of crops, leading to loss of biodiversity and making crops vulnerable to new diseases. Despite these worries, some GM crops have been widely used in many countries such as the United States, Brazil, and Argentina. Moreover, scientific studies have shown that GM crops are safe for consumption and the environment, providing a strong case for their continued use. In summary, GM food has the potential to play an important role in solving world hunger, but it must be done with care (Taheri et al., 2017). More research is needed to fully understand the effects of GM crops and to ensure that they are produced in a responsible and sustainable way.

4.4 Conclusion and Future Prospective:

The findings of a scientific assessment of the potential impacts of genetically modified organisms (GMOs) on food and agriculture, environment and health, and socio-economic aspects (CatacoraVargas et al., 2018). It also provides recommendations for policy and research in this field. The benefits and challenges of transgenic technology in crop improvement, and discusses the alternative technologies such as cisgenesis and genome editing that may address some of the concerns and facilitate the development of genetically engineered crops with multiple favourable traits. The positive impacts of GMOs in terms of socioeconomic and environmental benefits and considers their potential role in addressing the challenges presented in the 2030 development agenda. It also highlights the need for public awareness, education, and participation in decisionmaking regarding GMOs.The potential of GMOs from the perspectives of various stakeholders, such as innovators, farmers, consumers, and regulators (Adenle et al., 2013). GM technologies offer great potential for meeting the global demand for food, feed and fiber in a sustainable and responsible way. Conventional breeding methods, enhanced by genome level technologies, can also contribute to this goal by creating and using genetic variation to select beneficial alleles of genes for yield, disease resistance, pest resistance etc. Organic farming practices can also be part of the global solution where they are appropriate. It also identifies the areas of scientific disagreement and uncertainty regarding the risks and benefits of GMOs, and suggests ways to improve the communication and governance of this technology.

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