Genetically Modified, Naturally Controversial

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Abstract

"Plant breeding is the purposeful manipulation of qualities in plants to create new varieties with a set of desired characteristics". However, limitations include gene exchange only between closely related species, uncertain gene combinations, transfer of both desirable and undesirable traits, and time/cost constraints. So, here comes the marker assisted selection (MAS) and genetic modification through which there is significant improvement in agricultural and horticultural crops. As conventional breeding methods have limitations, genetic modification can introduce desirable traits into crops. However, there are many obstacles in the adaptation of transgenic crops like:

Commercializing GM crops involves a lengthy and time-consuming regulatory approval process from government agency. The lack of clarity has fuelled ongoing debates and controversies. There is an urgent need for clear regulatory systems to oversee the development and use of GM crops.

Small and poor developing countries often lack the resources and infrastructure to implement complex and expensive regulatory systems. Therefore, it is essential to have regulatory systems that are tailored to their needs, allowing them to access the benefits of GM crops while ensuring safety and environmental sustainability.

Key words: marker assisted selection, transgenic crops, genetically modified foods, gene guns, electroporation, microinjection

Introduction

Plant breeding has to be considered one of the longest, continuous activities conducted by humans. The evolution of the human civilizations paralleled the successes of plant breeding. Scientific plant breeding developed from the beginning of the twentieth century and was based on understanding the mechanism of inheritance and the mating systems of crop plants. Currently, we know that the process of plant breeding is based on changes brought about in a plant's genetic structure. Since 1900, Mendel's genetic principles have formed the scientific foundation of plant breeding. Conventional plant breeding involves altering a plant's genes to develop a new and improved variety. The goal is to combine the desirable traits of both parent plants while eliminating their undesirable traits to create a single, superior plant variety. Therefore, the offspring from this initial cross inherit a combination of genes from both parent plants, resulting in the inheritance of both desirable and undesirable traits (Robinson, 2001).

Breeders select progeny with desirable traits and backcross them to the original parent plants over multiple generations to enhance these traits. This process, called backcrossing, aims to combine positive traits while eliminating negative ones. For instance, crossing a high-yield, disease-susceptible wheat variety with a low-yield, disease-resistant one can produce a variety with both high yield and disease resistance. Sometimes, breeders use wider crosses, involving unrelated species or genera, with advanced techniques like genetic transformation to achieve their goals. In the 1970s, recombinant DNA technology revolutionized genetics by allowing the direct transfer of DNA fragments between organisms, even across different species, genera, or kingdoms. This led to the creation of transgenic organisms, which have artificially introduced genes known as transgenes. These transgenes can originate from the same species, different species, or entirely unrelated organisms such as bacteria or animals. For example, *Bt* corn contains a gene from the soil bacterium Bacillus thuringiensis, enabling it to produce an insecticidal protein. Once a transgenic plant is created, the transgene can be passed on to offspring through normal pollination, making them transgenic as well. Plant breeders can then use conventional breeding methods to develop various transgenic crop varieties adapted for specific purposes, all incorporating the new trait introduced by the transgenes. The purpose of creating transgenic plants is to enable plant breeders to develop more beneficial and productive crop varieties by utilizing genes from a diverse array of living organisms, beyond those available within the crop species itself (Young, 2004). Transgenic crop varieties, which incorporate genes from other organisms, have the potential to introduce novel traits that would be unattainable through traditional breeding methods (Young, 2004).

The creation of transgenic plants brings to the forefront two primary areas of discussion: scientific and ethical issues. Ethics focuses on what actions we should or should not take, such as refraining from genetic modifications that could threaten human health or harm the environment. Just because an experiment or crop introduction is scientifically feasible doesn't mean it is ethically justified. Determining what is right or permissible requires integrating our scientific knowledge with our ethical principles. This helps us decide on the appropriate course of action, especially considering the advancements in genetic modification (Weil, 1996).It is anticipated that transgenic technology will boost agricultural productivity, aid in the creation of safer and more nutritious foods with extended shelf-life, and support the aim of enhancing food security for the poor in developing countries (Bradford, 2005).In this discussion, we will address the environmental and biosafety concerns related to the adaptability and acceptability of transgenic plants.

Transgenic plant

"A transgenic plant is a modified organism where genes are transferred from one organism to another through genetic engineering techniques". Plant genomes can be engineered using physical methods or Agrobacterium to introduce new traits that don't occur naturally in the species. In food crops, this might include enhancing resistance to pests, diseases, and environmental conditions, reducing spoilage, improving herbicide resistance, or boosting nutrient profiles. In non-food crops, genetic engineering can produce pharmaceutical agents, biofuels, and other industrial goods, as well as assist in bioremediation efforts (Anon.,2021).

History

In 1983, tobacco became the first genetically engineered crop plant. In 1987, Plant Genetic Systems created insect-resistant tobacco using *Bt* genes. China commercialized virus-resistant tobacco in 1992. In 1994, the Flavr-Savr tomato with a longer shelf life was approved in the US, and the Europe approved herbicide-resistant tobacco. In 1995, the *Bt* Potato became the first pesticide-producing crop approved in the US. By 1996, eight transgenic crops and one flower were approved for commercial growth in six countries and the Europe. By 2010, 29 countries grew GM crops, and 31 others approved their import.GM banana cultivar QCAV-4 was approved by Australia and New Zealand in 2024.

Methods

Genetically engineered crops involve adding or removing genes using techniques like gene guns, electroporation, microinjection, and Agrobacterium, with newer methods such as CRISPR and TALEN offering more precision. Gene guns shoot DNA-coated particles into plant cells, while Agrobacterium transfers genes naturally into plants. Electroporation introduces DNA through pores created by electric pulses, and microinjection directly inserts DNA into cells. These methods are applied to food crops for traits like pest resistance and enhanced nutrition, and to non-food crops for industrial uses. Tobacco and *Arabidopsis thaliana* are common model organisms in research. Introducing new genes requires specific promoters and optimized codons to ensure proper expression in the target plant area.

Ethical issues

The agricultural field is a part of the "ecological theatre" in which the "evolutionary play" is continuously being played. Key "actors" in this "ecological theatre," such as other plant species, herbivores, and natural pollinators, interact with transgenic plants. Detritivores and decomposers, which feed on dead plant parts, also play roles in soil ecology, fertility, nutrient cycling, and plant growth. This interaction raises concerns about invasiveness and gene spread. When transgenic plants are introduced into agricultural fields, they interact with various species that perform essential ecological functions. Although scientific consensus deems GE crops safe for consumption, public apprehension persists. The integration of transgenic crops into traditional food production has sparked societal controversy due to ethical and risk concerns.The introduction of transgenic plants in agriculture, amidst a growing global population and food supply challenges, has sparked significant criticism due to concerns about environmental impact, biosafety, and ethical issues (Choudhury *et al*. 2012).

Five Concerns regarding GM crops include potential harm to human health, environmental damage, negative impacts on conventional agricultural practices, excessive corporate control and the perceived "unnaturalness" of the technology.

Human health - There is currently no conclusive evidence that genetically modified foods are more likely to cause allergic reactions than traditional foods. Genetic modification itself does not create allergies. However, the specific genes introduced into the modified host plant could potentially trigger allergic reactions. Horizontal gene transfer from genetically modified crops to intestinal microbiota is primarily due to microbial transgenes (Kleter*et al*., 2005). Transgenic plant contains foreign DNA that is not naturally present in that plant. These DNA fragments often come from either similar plants (trans) or entirely different species (cis), such as viruses and bacteria. There is growing concern about whether consuming "foreign" DNA poses any risks to human or animal health (Bawa and Anilakumar, 2013). Large-scale cultivation of GM plants may indirectly impact human health due to their negative environmental effects. Concerns include harm to the environment, animal populations, biodiversity, and gene transfer to non-GM wild species. Specific environmental impacts of GM crops include:

- Harm to monarch butterflies
- Crop to weed gene transfer
- Antibiotic resistance
- GM protein leakage into soil
- Reductions in pesticide spraying: are they real?

Crop hybridization with surrounding weeds may lead to herbicide-resistant weeds. Gene flow from GM plants to wild plants, especially in areas of delicate biodiversity, is a significant concern. Over 40 countries have enacted legislation requiring the labelling of genetically modified foods (CBC News Online, 2004). Mandatory labelling legislation for genetically modified foods (GMF) is urgently needed to ensure consumer rights and informed decision-making. Despite its importance, a universally agreed-upon labelling system is unlikely to be established soon (Maghari and Ardekani, 2011). Intellectual property rights (IPR) play a significant role in the GMF debate, with agri-business corporations patenting GM crops, leading to monopolization of the global food supply and distribution control. Social activists argue that biotech companies aim to privatize GM crops, unlike conventional crops, which are considered public property (Maghari and Ardekani, 2011). The lengthy regulatory licensing process hinders the rapid adoption of transgenic crops. There is an urgent need for science-based, cost-effective, and time-efficient regulatory regimes that are accountable and rigorous but not burdensome for small and developing nations. Intellectual property rights (IPR) are crucial in the GMF debate, as agri-business corporations patent GM crops, leading to monopolization of the global food supply and control over food distribution. Social activists contend that biotech companies aim to produce GM crops because they can be privatized, unlike conventional crops, which are considered the common property of all people (Maghari and Ardekani, 2011). The lengthy regulatory licensing process hinders the rapid adoption of transgenic crops. There is an urgent need for science-based, cost-effective, and efficient regulatory systems that are accountable and rigorous, yet not overly burdensome for small and developing nations.

Other problem associated with the gene transfer is gene integration, it is a random event, and if it occurs in heterochromatin regions, it won't be expressed. Introgression can lead to gene silencing or co-suppression, making gene expression unpredictable. Multiple transgene insertions, often seen during particle bombardment, can also cause gene silencing. Due to Mendelian segregation patterns, transgenes often lack stability over subsequent generations, rendering the entire effort futile (Stam *et al*., 1997).

Conclusion: Transgenic breeding presents both opportunities and challenges. While it offers potential benefits such as increased crop yields, pest resistance, and improved nutritional content, it also raises significant concerns. These include potential risks to human health, environmental impacts, ethical dilemmas, and issues related to intellectual property rights. The stability of transgenes, gene silencing and the lengthy regulatory processes further complicate the adoption of transgenic crops. Addressing these concerns requires a balanced approach that considers scientific evidence, ethical considerations, and the needs of small and developing nations

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