Embracing Genetically Modified Crops for Global Prosperity

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This paper advocates for the global implementation of genetically modified crops, highlighting their substantial benefits and addressing prevalent controversies. The primary research question explores their impact on agricultural productivity, nutritional enhancement, and pesticide reduction. Utilizing a comprehensive literature review, the study reveals significant increases in crop yields and productivity, particularly in developing countries. It also emphasizes the nutritional benefits of biofortification, exemplified by β-carotene-enriched rice to combat vitamin A deficiency. Furthermore, the paper discusses their environmental advantages, such as reduced pesticide use and associated health risks. Addressing safety concerns, the research indicates a broad scientific consensus on the safety of GM foods, supported by major health organizations. Despite ecological concerns about biodiversity, studies show minimal adverse effects. The paper concludes by highlighting future prospects in genetic engineering, including cisgenesis and genome editing, which promise to further revolutionize agriculture. These findings suggest that genetically modified crops are a crucial tool for achieving global agricultural prosperity and call for policy reforms and public education to support their adoption.

Keywords: Agricultural Biotechnology, Agricultural Sustainability, Biofortification, Crop Improvement, Genetic Engineering, Genetically Modified Crops, Global Agriculture, Nutritional Enhancement, Pesticide Reduction

Introduction

Amidst humanity's enduring voyage into the realms of scientific and technological progress, possibly one of our greatest achievements is the ability to change the fundamental hereditary code of living organisms, serving a pivotal role in crop improvement within global agriculture [1]. This discovery has been applied to various organisms, but one of the most prominent and practical applications is the genetic modification of the food we eat—specifically, the use of genetic modification to enhance plantation growth and resistance. Tampering with the DNA of our food has sparked much controversy, suspecting the unknown and risky consequences of such an action. Many countries that would heavily benefit from genetically modified crops have still not implemented them within their agriculture [2]. In this paper, I argue for genetically modified crop implementation by showing their contributions to increasing production, enhancing nutritional value, reducing pesticide usage, and addressing controversies surrounding safety, biodiversity impact, and pest resistance, as well as exploring the promising prospects of genetic engineering in the agricultural sector.

But before justifying such claims, we must know what genetic modification is and its history. Genetic modification is when the genome of an organism is modified using genetic engineering techniques to improve the existing traits or the introduction of a new trait that does not occur naturally in said organism [1]. Such discovery opened the window to take desired genes from plants that are not sexually compatible with other plantations for them to express desired genes.

Genetic Modification's History

The first application of genetic engineering that was commercialized was in 1994 on tomatoes; only two years later, 1.66 million hectares of land were planted with genetically modified crops, and by 2020, that number became 185.6 million hectares [3]. This shows that genetically modified crops have had significant growth over time and are now a big contributor to many people's diets. This makes genetically modified crops the fastest crop technology to be adopted in modern agriculture [1]. One study estimates that 80 percent of processed food is genetically modified [4]; another shows that 90 percent of U.S. corn, upland cotton, and soybeans are genetically modified [5]. All of this shows how big an impact genetically modified crops have had on agriculture as a whole.

But how much has genetic modification benefitted crops in terms of production? A global meta-analysis of transgenic crops has shown that genetically modified crops have increased crop yields by 22 percent and increased farmer profits by 68 percent, which have been shown to be greater in developing countries than in developed countries [6]. This shows that not only have genetically modified crops greatly increased the productivity of global agricultural production, but have also significantly benefited economic growth and prosperity, surprisingly and fortunately more so in developing countries. These benefits can only increase in correspondence to the status quo of countries that have not yet implemented genetically modified crops.

Getting into specifics, genetically modified crops have allowed the fortification of much-needed nutrients to various common crops in populations that have deficiencies in certain vitamins and minerals. This process, known as biofortification, is one of the ways that genetically modified crops have the potential to greatly benefit large populations.

For instance, one of the first major advances in genetic modification was the implementation of β-carotene into rice. β-carotene is a leaf-specific pigment that the body can use to convert to vitamin A [7]. This was done as a countermeasure against vitamin A deficiency, a worldwide disease and the leading cause of preventable blindness in children; it has also been shown that it is correlated with a higher risk of severe disease and death [8]-[10].

Especially in impoverished populations that heavily consume rice, genetic modification can have substantial potential for preventing blindness. Unfortunately, even after almost 24 years of its creation [11], it has not yet been implemented in populations that would benefit the most from it, such as Southeast Asia [7]. I hope this will change in the future, as it has the potential to completely prevent vitamin A deficiency. This is only one of many nutritional fortifications that were made possible because of genetic modification; other examples include folate biofortification, iron biofortification, essential amino acids, and the elimination of trans fats from oilseed crops [1], [7]. Considering the short history of genetically modified crops, their nutritional value has endless potential for aiding these populations if they were implemented within them.

Besides nutritional fortification, the two main categories of genetically modified crop traits that are most used are tolerance to herbicides and resistance to insect pests [3]. It's important to point out what tolerance to herbicides means here: instead of the crop being altered to resist herbs and weeds (a very arduous task), the crops are instead resistant to the pesticides used upon them. While this might sound like it does not change much, it allows for much more efficient pesticide use and eliminates much of the damage done to crops through the excessive use of pesticides. For instance, herbicide-tolerant genetically modified maize (corn) has reduced active ingredient use by 220 million kg in the U.S. alone [3]. For cotton, it has reduced active ingredient use by 20.5 percent in Australia [3].

This is only one side of the coin. Looking at the other, and much more significant, side, genetic modification for insect resistance has revolutionized modern agriculture by reducing the reliance on chemical pesticides and, in turn, reducing the environmental footprint left by them. Specifically, it has lowered pesticide use on cotton by −338.9 million kg (29.9 percent) worldwide and has lowered the environmental impact of the pesticides used on cotton by 34.4 percent [3].

I can keep giving statistics on how much genetically modified crops have lowered the use of pesticides, but why is this significant? Pesticides have caused much harm to human health; they are known to cause extremely adverse effects, which can be acute as well as chronic. Some examples of acute health effects include diarrhea, rashes, blindness, dizziness, stinging eyes, nausea, blisters, and death; some examples of chronic health effects include reproductive harm, neurological and developmental toxicity, endocrine system disruption, birth defects, cancers, and immunotoxicity [12]. One of the primary goals of modern agriculture is to reduce or eliminate the use of pesticides due to these adverse effects, and genetic engineering has opened the possibility for such an ambition. If these crops were to be implemented globally, humanity would be much closer to achieving such an ambition.

Moving on to the question that much of the controversies around genetically modified crops have asked, are they safe to consume? Before answering such a question, I have to first point out where most of the controversy surrounding genetically modified crops originated from, the "Seralini affair."

The Seralini Affair and Genetically Modified Crop Safety

In 2012, a study was published on genetically modified crops that claimed adverse health hazards, such as (all symptoms found in rats, not humans) high tumor incidences, chronic kidney disease, increased liver congestion, and necrosis in males, and increased female mortality [13]. Since its publication, the study has received extreme criticism from the scientific community because of its flawed experimental design and faulty statistical analysis, eventually leading to the retraction of the article [1]. Two years later, the same group published nearly the exact same work as they did before [14], this time without retracting the article.

With very few exceptions, most studies showed no effects of transgenic food on animals like rodents, poultry, pigs, frogs, cows, and monkeys [15]-[17]. I would think that much of the controversy and concerns surrounding genetically modified crops originated from these two studies, but to answer the question stated previously, scientists generally agree that genetically modified foods are safe to consume, a view that is supported by the American Medical Association, the National Academy of Sciences, the American Association for the Advancement of Science, and the World Health Organization [7], [18]. This leaves no excuse for all countries around the world not to implement genetically modified crops for the betterment of global agriculture.

Effects of Genetically Modified Crops on Biodiversity and the Environment

One of the most frequent concerns of genetically modified crops is their unknown and potentially adverse effect on biodiversity and the environment due to the inability to account for all possibilities of nontarget organisms when changing the genetic makeup of plantations. Specifically, many ecologists are debating their effects on nontarget invertebrates that are ecologically important to plant nutrient availability and recycling of organic matter [19]. Such organisms include earthworms, termites, woodlice, snails, millipedes, beetles, and mesofauna [20].

One primary subject of the debate is the *Bacillus thuringiensis* (*Bt*) transgenic crops, which have been genetically modified to include a gene from *B. thuringiensis*, a species of bacteria that lives in soil [21]. The gene that is inserted into the plant's genome allows the plant to express a Cry toxin that provides resistance against insect pests [19]. In a meta-analysis that considered a total of 6110 titles, it concluded that "there was no significant effect of *Bt* on soil invertebrates."

While this example may sound very specific and irrelevant, *Bt* crops are an extremely significant advancement in genetic modification and are one of the main genetically modified crops used commercially. For instance, 80 percent of all corn in the U.S. is genetically modified to include the *Bt* trait, and 85 percent of all cotton is *Bt* as well [22]. The fact that the *Bt* trait does not correlate with any harm to biodiversity [19] leaves no reason for countries that haven't implemented or banned genetically modified crops.

One argument that can be made against pesticide resistance development through genetic modification is the causation of the development of resistance by the pests themselves due to the overreliance on the no longer harming pesticides. This is an argument that has solid ground, as much of the environmental gains associated with more efficient pesticide use have diminished over time, however, as of 2020, the adoption of herbicide-resistant genetically modified crops still shows a net environmental gain [3]. Considering the agricultural environment of countries that have not implemented them yet, there is still much potential for their environmental gain.

Not only this but many prospects in the field of genetic engineering could potentially revolutionize modern agriculture. Such prospects include Cisgenesis and intragenesis, and genome editing.

Prospects of Agricultural Genetic Engineering

Cisgenesis and intragenesis allow genetic engineers to take only the desired genetic trait from the same crop species (in intragenesis some parts of the gene can be from different species), as conventional agricultural breeding does, only without the undesired traits that come along with it [1]. This practice has already shown great success, such as in blight resistance in potatoes [23] and scab resistance in apples [24]. Genome editing would allow genetic engineers to edit genes however they like, whether it be to replace, remove, or add a gene [1].

These tools open an infinite window of possibilities that have the potential to increase crop production, promote abiotic and biotic resistances in crops, meet consumers' nutritional needs, and eliminate every possible concern surrounding the genetic modification of plantations [1], leaving countries that have not implemented genetically modified crops yet with no argument. I hope to see global prosperity achieved through them, and to see no bans, restrictions, or concerns surrounding them in the future for the betterment of global agriculture.

Conclusion

This paper has presented a comprehensive argument for the global implementation of genetically modified crops, demonstrating their substantial benefits in enhancing agricultural productivity, nutritional value, and environmental sustainability. Through a thorough literature review, we have established that they significantly increase crop yields and farmer profits, particularly in developing countries, and offer crucial nutritional benefits through biofortification, such as *β*-carotene-enriched rice to combat vitamin A deficiency. Additionally, they contribute to environmental sustainability by reducing the need for chemical pesticides, thus lowering associated health risks and environmental damage.

Addressing the controversies surrounding genetically modified crops, the evidence supports a broad scientific consensus on their safety, with endorsements from major health organizations like the American Medical Association and the World Health Organization. Concerns about biodiversity and ecological impact, while valid, have been shown to have minimal adverse effects when managed appropriately. Furthermore, the potential for future advancements in genetic engineering, such as cisgenesis and genome editing, promises to overcome current limitations and enhance the benefits of genetically modified crops.

The findings of this paper advocate for policy reforms and public education to support the adoption of genetically modified crops worldwide. By leveraging the advantages of genetic modification, we can achieve global agricultural prosperity, improve food security, and address pressing nutritional deficiencies. The future of agriculture lies in embracing these technological advancements, ensuring that the benefits of genetically modified crops are realized on a global scale for the betterment of humanity and the environment.

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