

# Genetically Modified Plants and Products

Subjects: [Biotechnology & Applied Microbiology](#)

Contributor: Bimal Kumar Ghimire , Chang Yeon Yu , Won-Ryeol Kim , Hee-Sung Moon , Joohyun Lee , Seung Hyun Kim , Ill Min Chung

Genetic transformation has emerged as an important tool for the genetic improvement of valuable plants by incorporating new genes with desirable traits. These strategies are useful especially in crops to increase yields, disease resistance, tolerance to environmental stress (cold, heat, drought, salinity, herbicides, and insects) and increase biomass and medicinal values of plants. The production of healthy plants with more desirable products and yields can contribute to sustainable development goals. The introduction of genetically modified food into the market has raised potential risks. A proper assessment of their impact on the environment and biosafety is an important step before their commercialization.

transgenic plants

genetic transformation

environmental effects

## 1. Benefits of Genetically Modified Plants and Products

### 1.1. Biofortification

Micronutrient deficiencies are posing a serious threat to the health of one-half of the global population <sup>[1]</sup>. Nutritionally enhanced food crops using modern biotechnology, conventional selective breeding, and agronomic practices to enhance nutritional values are considered an effective and alternative approach for mitigating in economically poor countries <sup>[2]</sup>. The production of foods using biotechnology offers both benefits and threats. The production of transgenic plants is not only helpful in developing new varieties with increased nutrition but also increased resistance against biotic and abiotic factors, thereby enhancing the quality and yield of plants <sup>[3]</sup>. In addition, plant production enables the production of materials of industrial interest, such as biodegradable plastics, vaccines (transgenic bananas that produce vaccines against hepatitis B, transgenic potatoes that are resistant to viruses, rice with increased iron and vitamin levels, with increased resistance to extreme weather, and drought, <sup>[4][5]</sup> <sup>[6]</sup>.

GMO consumption maintains a healthy balance by fortifying nutritional quantity in foodstuffs that may not normally occur in them. For example, the production of “golden rice” with elevated vitamin A levels, the development of herbicide- and insecticide-resistant crops, thereby reducing crop losses, and other therapeutic substances of specific interest <sup>[7]</sup>. Moreover, research reports have indicated that proteins produced by GMOs are non-toxic, easily digestible, and cause no allergies <sup>[8]</sup>. Genetically modified fish grow larger, and pigs are grown with less body fat <sup>[9]</sup>. Other studies have reported increased beneficial nutritional profiles, such as increased levels of

antioxidant compounds in GMOs that may provide health benefits to humans [10], and provide useful medicines, such as insulin for treating diabetes, from genetically engineered bacteria [11].

## 1.2. Transgenic Approaches for Improving Phytochemicals and Biological Activities in Plants

Several authors have reported an improvement in the production of antioxidants, such as phenolic compounds, from transgenic plants transformed with the bacteria *Agrobacterium tumefaciens* and *A. rhizogenes*. Increased concentrations of phenolic compounds have also been reported to improve antimicrobial activities in *Cucumis melo* [12]. Furthermore, scientists have produced transgenic lines by overexpressing genes in *Lycopersicon esculentum* Mill. cv. Per with increased phenolic compound content in plants that are involved in phytoremediation [13]. Moreover, an increase in metabolites such as triterpene and steroidal saponins, and phenolics [14], was reported in hairy root cultures of *Trigonella foenum-graecum* L., an elevated amount of phenolics acid, and flavonoids [15] was reported in *Spagneticola calendulacea* (L.) Pruski to increase food value. Increased resistance to *Botrytis cinerea* in transgenic *Morus notabilis* C.K. Schneid [16].

Genetic engineering has been successful in producing transgenic rice that contains 23 times higher concentrations of carotenoids than in previous transgenic golden rice [17]. Similarly, the genetic transformation of phytase in the transgenic soybean resulted in enhanced phytase activity by 2.5 fold compared to non-transgenic soybean [18]. Moreover, methyltransferase genes (*VTE3* and *VTE4*) from *Arabidopsis thaliana* transformed into the soybean genome resulted in an enhanced  $\alpha$ -tocopherol content by 95% more than in non-transgenic plants [19]. The transformation of lactoferrin in dehusked rice successfully enhanced the iron contents by 120% [20]. In another report, expression of soybean ferritin in rice resulted in an increase in the iron contents in Indica cv IRR68144 seeds, in wheat by 1.5–1.9 fold [21], lactoferrin genes enhanced the Fe content in Maize [22], potato, lettuce and tomato [23], Endogenous nicotianamine content was increased by 5–10 fold in transgenic rice over-expressed with HvNaSi [24]. Induces the proliferation of hairy roots, which increases the production of secondary metabolites. Many plant species have been transformed with *A. rhizogenes* for increased production of polyphenolic antioxidants such as phenolic acids and flavonoids. Transformed plants of *Codonopsis lanceolata* and *Perilla frutescens* transformed with *y-tmt* genes present higher concentrations of tocopherol and phenolic compounds, thereby enhancing the antioxidant properties of such plants [25][26]. Another approach to the recombinant production of foodstuffs is the genetic transformation of useful genes that enhance the production of beneficial compounds in plants and improve human health. Recently, researchers introduced genes into *Lycopersicon esculentum* Mill. cv Ailsa Craig, to increase the accumulation of antioxidants, such as phenolic compounds [27]. Similarly, increased amounts of phenolic compounds and resveratrol have been reported in transgenic *Rehmannia glutinosa* transformed by *A. tumefaciens* [28].

## 1.3. Transgenic Approaches for Environmental Protection

The benefits of transgenics can be assessed from an environmental point of view. *Bacillus subtilis* and *Bacillus thuringiensis* (Bt) strains can produce toxic proteins such as Cry or d-endotoxins [29], that are toxic to various kinds

of pests, insects, and pathogens [30]. Bt toxins are also being used in generating transgenic crops effectively control crops pests such as CryIAc in rapeseed to control hairy bugs, diamondback moths, and cotton bollworms [31]. Cry2A gene in transgenic pigeon beans to control pod borers [32], Cry3A gene in transgenic spruce to control bark beetles [33]. According to a recent report, a significant change in the amount of herbicides and pesticide application was observed in the USA with the adoption of herbicides tolerant GM plants [34], such as; transgenic soybean [35], summer corn and cotton. The reduction of herbicides and pesticides can reduce the environmental impacts on cultivated land. The reduction in the application of pesticides also minimizes the use of machinery for spraying them in the field, thus reducing fossil fuel consumption in the agriculture sector.

#### 1.4. Transgenic Approaches for Removing Allergens

Genetic transformation technology successfully incorporated genes in the plants responsible for encoding non-allergic proteins, and hypoallergenic crops, thus improving food protein equality [36]. A significant reduction in peanut allergies was reported by silencing the gene encoding Arah2 using RNAi technology [37]. Similar technology was used by Le et al. [38], to silence the allergens Lyce 1.01 and Lyce 102 in tomato profiling. Similarly, allergic proteins such as Mal d from apple [39], and GlymBd 30K from soybean [40] were silenced using RNAi technology. In other studies, the hypoallergenic approach was effective to reduce allergenic protein in Rye grass pollen [41]. All these studies indicate that engineered plants can also be expected to improve food quality by reducing allergens.

#### 1.5. Transgenic Approaches for Phytoremediation

Phytoremediation is a sustainable solution for solving environmental contaminants caused by pollutants including heavy metals sediments, and inorganic and organic pollutants. Recently, the application of transgenic plants for the removal of heavy metals or organic pollutants has gained more interest [42]. It is possible to transfer genes responsible for the hyperaccumulation of traits into target plants having remediation potential. The introduction of such genes has been reported in several plants including *A. thaliana*, [43]. Metallothioneins (MTs) confer heavy metal tolerance and accumulation in yeast. For example, the overexpression of MT genes increased the Cd tolerance in tobacco and rapeseed plants [44]. Overexpression of *phytochelatin synthase* (TaPCS) in *Nicotiana glauca* significantly increased the tolerance to heavy metals such as Cd and Pb [45]. In another study, overexpression of AtPCS, increased the phytochelatin and high resistance to arsenic [46]. Arsenate (As), mercury (Hg), and selenium (Se) are important pollutants, and transfer approaches have been employed to remove them from the soil [47]. Expression of the *mer B* gene in transgenic *Arabidopsis thaliana* resulted in more tolerance to methylmercury [48]. Similarly, overexpression of ATP sulfurylase and CGS resulted in an increased phytovolatilization in *Brassica* sp. [49]. Enzymes such as peroxidases, laccases, peroxidases, nitroreductases, and phosphatases play important roles in the phytodegradation of organic pollutants [50]. These plant enzymes shown to act on organic pollutants including atrazine, chloroacetanilide, and TNT (2,4,6-trinitrotoluene) [51]. An increased rate of degradation of TNT and chloroacetanilide has been reported previously in poplar plants [52]. Other best example of phytoremediation includes the overexpression of ECS and GS genes in *B. juncea* resulted in increased tolerance to atrazine [53].

## 1.6. Transgenic Approaches for Vaccine Production

The expression of antigens using biotechnology in plants has opened up a new field for the production of plant-based vaccines. Advances in transgenic research have made use of plants to serve as a bioreactor for the production of certain vaccines for curing diseases [54]. Several plant-based vaccine antigens have been successfully expressed in plant tissues as a result of a stable expression or transient expression of genes [55]. Plant-based vaccines are cost-effective, easy to carry, have less chance of contamination and degradation, require no medical professionals, high-tech machines, or preservation, and are less costlier than cell culture bioreactors [56]. By conceiving the idea of an edible vaccine, the antigens genes encoding Rabies Capsid proteins such as HBsAG, and HIVgag have been successfully expressed in transgenic tomatoes [57]. Exciting progress in achieving a high level of protein expression was achieved in transgenic carrots by Daniell et al. [58]. Later, Scotti and their research [59] team obtained chloroplast-based production of pharmaceuticals, vaccines, and antibodies. Transgenic *N. benthamiana* plants were successfully expressed with D antigen (PV3) to use a vaccine against polio diseases Marsian, et al. [60].

## 1.7. Transgenic Approach for Increased Biofuel Capacity in Plants

Lignocellulosic biomass from non-food crops has been considered a potential source of biofuel. Lignin, a major component of plant cell walls is considered a hindrance to cellulosic biofuel production. The application of biotechnology for biofuel production is gaining more interest, especially from the lignocellulosic biomass [61]. Recently, several studies have reported the successful cloning of genes responsible for increased biomass and sugar accumulation and higher production of biofuels in transgenic lines [62]. Several studies have reported the expression of genes in plants that are responsible for the degradation of the plant cell wall for more efficient biofuel production [63]. A low amount of lignin was reported by downregulating the lignin biosynthetic gene 4-hydroxycinnamoyl CoA ligase (4CL) [64]. In another study, the amount of lignin synthesized decreased to facilitate higher biofuel production in transgenic *Miscanthus sinensis* [65]. Overexpression of expansin genes which helps in loosening of cell walls [66] and successfully generated a transgenic plant with a suppressed debranching enzyme that produces soluble phytylglycogen. Vanden Wymelenberg et al. [63] reported the involvement of several genes in the breakdown of lignin from the *Phanerochaete chrysosporium* genome. Moreover, several other studies reported an alteration of lignin biosynthesis in the plant without affecting the vascular structure of plants [24]. They reported downregulating 4-hydroxy cinnamoyl CoA ligase (4cl) responsible for the reduction of the lignin composition and an increase in the biomass of plants. Ralph et al. [67] reported a drastic decrease in the lignin content and structure by decreasing the expression of 4-coumarate 3-hydroxylase (C3H) in alfalfa. A similar result was also observed by Chabannes et al. [68] in transgenic tobacco by deducting the expression of cinnamoyl CoA reductase (ccR). Furthermore, the suitability of biofuel production in transgenic lines of tobacco has been investigated by downregulating O-methyl-transferase (OMT) enzyme by Blaschke et al. [69]. They observed an increase in biomass and reduction in the lignin contents in the transgenic lines of tobacco. Other emphasizes the improvement of the fatty acid composition of plants to enhance biofuel production. Moreover, as compared to the WT plants, the transgenic line showed an increase in biofuel production in soybean by expressing diacylglycerol acyltransferase 2A (DGAT2A) from *Umbelopsis* sps fungus [70]. Furthermore, an increased caprylic acid and capric acid was

observed in transgenic rapeseed by over-expressing a laurate-specific LPAAT gene from coconut [71]. Another approach for increasing biofuel is to increase the biomass production of plants by genetic transformation approach. Manipulation of ADP glucose pyrophosphorylase resulted in an increased starch content and biofuel yield [72]. They observed an increase in photosynthesis and biomass by overexpressing two enzymes from Cyanobacteria in the tobacco plant. Jing et al. [73] reported an increase in the plant height and biomass by expressing the glutamine synthase gene (GSi).

## 1.8. Increased Stress Resistance Capacity in Plants

The excessive use of herbicides and pesticides is causing serious hazards on croplands, which makes cultivating land unsuitable for farming in the future. Recently, the introduction of GMOs has not required the use of these products. Some genetically modified crops are highly tolerant to one herbicide, instead of the multiple types of herbicides used in the field to prevent environmental damage. For example, genetically modified Roundup Ready corn is not only a glyphosate-tolerant GM corn but also is as safe and nutritious as conventional corn grain [74]. Bt rice KND1 expressing Cry1Ab protein show high levels of resistance to insects and possess no toxic effects on human health [75]. Similarly, insect-resistant crops include wheat, potatoes, rice, and sugarcane [76]. Researchers have increased the level of lignin content, monolignol levels, and syringyl (S)/guaiacyl (G) in transgenic *Ipomoea batatas* [L.] Lam., cv. Xushu 29 to enhance stress tolerance [77]. The introduction of Bt corn effectively controls the application of chemical pesticides, thereby controlling the environmental pollution caused by pesticides and reducing the cost of growing crops in the field [78]. Plants that can tolerate high salinity and long periods of drought have been reported [79], which can help people to grow crops in cold and less irrigated areas.

## 2. Disadvantages of Genetically Modified Plants and Products

The introduction of genetically modified food in the market has raised some serious questions regarding human health, environmental economics, and legal issues. For instance, it has been reported that the transfer of genes poses serious genetic hazards and is associated with possible food toxicity [10]. Once GMOs are produced and released into the environment, they can be difficult to control [80] and any harmful products produced by these organisms will remain metabolically active as long as they survive and multiply [80].

### 2.1. Human Health Hazards

Despite the advantages of GMOs, there is increasing concern about food safety and health risks. The transgene may cause undesirable developmental and physiological effects on mammals, including humans. There is a likelihood that the transformed gene may produce toxic protein or allergens or causes allergic reaction in the human body. Moreover, other potential concerns are incomplete digestion of GMO foodstuffs in the gastrointestinal tract, which could result in the horizontal transfer of genes to the microflora and somatic cells of the intestine [81]. Others have emphasized that the transfer of genes could cause infertility in animals, and result in allergic reactions [82].

## 2.2. Environmental Risks

The release of such products and their possible impacts on the environment regenerate high monitoring of environmental biosecurity to reduce or complete eradication of risk induced by them. Apart from direct effects on human health, GM plants have environmental effects on non-target organisms such as fish, worms, bees, and insects, biodiversity loss, and gene instability [83]. In other studies, Bt toxin produced by transgenic cotton killed many species of insect larvae, causing an imbalance in the ecosystem and food chain [84]. It has been argued that GM crops have a serious impact on farmers and their indigenous products because they compete with GMO products [85]. However, several previous studies reported the no-targeted impacts of novel genes transformed into the plant genome. For example, Bt maize showed potential hazards and toxic to monarch butterfly larvae that feed on milkweed leaves contaminated with pollens from Bt strains and caused delayed development, and increased maturity reported in *Ostrinia nubilalis* and *Spodoptera littorals* ingested with corn leaves expressing Bt CryIAS toxins [86].

## 2.3. Gene Flow

The most serious problem associated with gene flow is the loss of biodiversity and often cited as potential risk. Chances of accidental cross pollination between GM crops with its wild relatives are very high, making them super-weeds that resist diverse herbicides and become difficult to control. There are several examples where gene flow from crops to the relatives weeds such as in *Beta vulgaris* [87], in *Avena strigose* [88], in *Brassica napus* [89].

## 2.4. Increased Antibiotic Resistance

GM products enter the human body through food, vaccines, bacteria, or viruses. There is concern that the GM plants with bacterial resistance genes in their genome and might act as the source of drug resistance genes to the bacteria of clinical importance. Moreover, the possibility of developing antibiotic-resistant bacteria has been reported because of the frequent use of antibiotics in the genetic transformation process [90]. Most GM products contain marker genes and genes for certain useful traits. These marker genes can build resistance to particular antibiotics, and constant consumption of these foods could result in antibiotic resistance in the human body [91].

## 2.5. GMO Products Can Trigger Immune Reactions and Allergies

The introduction of new genes into plants can cause allergies by producing unexpected products (proteins and metabolites) in the plants [92]. For instance, the immune systems of rats respond more slowly to genetically modified potatoes than to normal plants [93]. In other studies, Bt bacteria can effectively control insects that attack crops. However, there is an equal chance of consuming Bt toxins and reacting to the mammals causing allergies [94]. Insects, birds, and other animals that feed on certain crops may not consume genetically modified crops due to allergic reactions or poisonous products. As a result, a great number of fauna can face starvation, affecting entire food chains and causing serious threats to ecosystems [95].

# 3. Biosafety Regulatory of GMO Foods and Products

Considering the importance of GMOs, several countries have managed to develop biosafety regulatory systems for the safety of GM foods and products. The regulations surrounding GMOs are complex and the rate of consumer acceptance is crucial, which results in reduced usage of GMOs. GMOs and their products have been facing severe controversies and hurdles from the public sector, NGOs, and environmental organizations [96]. Different governments have different approaches to tackling the products of GMOs, which vary widely, and are country-specific [97]. Within the European Union (EU), Directive 2001/18/EL contains the biosafety regulation for the use of GMOs. It defines and control environmental release (case by case) evaluation of the environmental risk of GMOs [98]. Other directives such as 98/81/CE for the number of GM microorganisms, directive 1946/2003 for transboundary movement of GMOs, 1829/2003 for GM food and feed have been authorized [98]. GMO products have already been supplied to the EU market with appropriate labelling and identification methods under the title NOVWL-FOOD classification in May 1997 [99]. Currently, European Union-based legislation accepted the products of natural gene transfer methods, such as conjugation, auto-cloning, and gene transduction, and are considered non-genetically modified organisms [100]. However, EU has banned the application of clustered regularly interspaced short palindromic repeats genome (CRISPR-Cas9) editing technology, but the US has allowed the use of Cas9, which enables geneticists and medical researchers to edit parts of the genome [101]. Similarly, The Canadian Food Inspection Agency (CFIA) is responsible for regulating GM plants, a field trial of GM crops, their approval and commercial release in Canada. It also plays a major role in assessing impacts on biodiversity and environment, possible gene flow and impacts on non-targeted organisms [102]. In India, safety guidelines for GMOs such as research, field trails of GM foods and products assessment environmental risk assessment have been adopted from Rules 1989 [102]. Ministry of Environment Forest, Forest and Climate Change (MoEFCC) in association with the department of Biotechnology (DBT) recently adopted new guidelines for the environmental risk assessment of GE plants in India [103]. So far, Bt cotton (insect-resistant transgenic cotton) is the only GM plant to have been approved for commercial cultivation in India. Over 20 different GM plants with insect resistance, abiotic resistance, herbicidal resistance, enhance nutritional traits etc. have been under field trials [104].

The adoption of biosafety regulations is strongly impacted by the economical and political situation of countries. Despite their differences in approach and adoption of GMOs regulations framework, countries such as Brazil, Argentina, Chile, Mexico, Honduras, Costa Rica, and Uruguay were the first Latina America to approve GM crops [105][106]. Other Latin American nations such as Peru, Venezuela, and Ecuador implemented a complete ban on the application/test and import of GMOs [107][108]. To harmonize the regulations concerning GM products, Latin American countries such as Brazil, Argentina, Paraguay, Uruguay and Chile signed a declaration which legalizes the application of gene-edited products (case by case) amid strict regulation [109]. Countries such as Brazil and Argentina are major exporters of GM crops (cotton, soybean and Maize) and recently adopted legal provisions to allow the cultivation of GM crops [109], which not only play a bigger role in their economy but also play a key role to rapid adaption of biosafety law and regulations [109][110][111][112]. The Secretariat of Agriculture, livestock, fisheries and Food (SAGyO) is responsible for the regulation of GMOs, for conducting field tests, release and commercial application in Argentina [113]. While, national technological Biosafety committee (CTNBio), is responsible for scientific research on GMOs, field tests, risk assessment and assessing the safety of GMOs in Brazil [113]. Legal provisions of biosafety regulations are under discussion in the countries such as El Salvador, Mexico, Peru, Costa

Rica, The Dominican Republic, and Ecuador. Other Latin American countries including Barbados, Dominica, Guyana, Haiti, The Bahamas, and Belize has no legal provision to deal with GMOs so far [114].

African nations can benefit from the adoption of the biosafety regulation to mitigate the food crisis, nutrition and economic livelihood [115][116][117]. The rapid adoption of GM crops regulations can address the existing food crises and ease hunger that exists in African countries. Some African countries welcomed GM technology and rapidly proceed for adopting GM crops to enhance agricultural production efficiency and increase the nutritional values of plants [118][119]. While, other African countries oppose GM technology stating its safety concerns, environmental and human health issues, intellectual property rights and ethical uncertainties [120][121][122]. However, several anti-GMO debates and controversies related to the safety of GMOs, and their impacts on human health and environmental issues are major hindrances in adopting biosafety regulations among African nations [123][124]. Despite hindrances, the majority of African nations (47 countries) currently allow the cultivation of GMO crops [125]. South Africa is the first African nation to enact the regulatory framework to allow the cultivation, export and import of GM crops [125], and other African countries are interested in collaborating and harmonising the regulation concerning GM crops (African Biosafety network of expertise ABNE, 2019 [126]. Successful confined field trials have been conducted for maize, sorghum, cassava and Bt cotton with a wide range of traits in Kenya [126][127]. It has been reported that early acceptance of biosafety regulation has been hindered by inadequate GM technology knowledge in Kenya, and less awareness and knowledge of GM technology in the countries like Ghana and Nigeria, [128]. Moreover, a slow and delayed GM adoption rate in Tanzania have been reported [129]. The restrictive regulations, lack of information and awareness of the GM crops regulations have played an important role to obstruct the commercialization of GM crops in African nations [130][131]. In addition, opposition to biosafety bills, laws and regulations from NGOs, media, political parties social and economic factors and multinational companies have further helped to restrict the adoption of GM crops regulations in these countries [132][133][134][135].

Similarly, China adopts strict safety evaluation of GM plants and products and promulgated a whole set of biosafety laws, regulations and management systems considering its national situation and international norms and regulations. For the implementation of biosafety regulation, the Ministry of Agriculture (MOA) played a pioneering role in the implementation of regulations, and administrative Measures for the Safety Assessment of Agricultural GMOs [136], and developed the guidelines for safety inspection of field trials, research, processing, import and exports of GM crops [137]. Recently, MOA has promulgated a set of new regulations to shorten the process involved commercialization of GM crops [138] and introduced biosafety guidelines to regulate gene-edited crops [139]. Similarly, Korea has released a set of laws and regulations guidelines for GMOs and GMO products. To ensure biosafety, proper assessment of GMOs is carried out according to the guidelines of the Korea Food and Drug Administration (KFDA) [140]. It is clear from the above data that there exists a diverse range of regulations and frameworks supporting the research and commercialization of GM crops. For the efficient and successful functioning of these regulations, there is a need for a collective and synergetic approach, and closer interaction among the different government, non-government agencies, and private sectors which may play a diverse role in coordinating and harmonizing biosafety issues. Moreover, for adopting unified biosafety regulations, regional and

international agencies should focus on the proper dissemination of information on biosafety regulations and public awareness about biosafety measures.

---

## References

1. United Nations. United Nations. United Nations System Standing Committee on Nutrition (SCN). In 5th Report on the World Nutrition Situation Nutrition for Improved Development Outcomes; SCN: Geneva, Switzerland, 2004.
2. Szenkovics, D.; Tonk, M.; Balog, A. Can genetically modified (GM) crops act as possible alternatives to mitigate world political conflicts for food? *Food Energy Secur.* 2021, 10, e268.
3. Kamthan, A.; Chaudhuri, A.; Kamthan, M.; Datta, A. Genetically modified (GM) crops: Milestones and new advances in crop improvement. *Theor. Appl. Genet.* 2016, 129, 1639–1655.
4. Fischer, R.; Emans, N. Molecular farming of pharmaceutical proteins. *Transgenic Res.* 2000, 9, 279–299.
5. Singh, O.V.; Ghai, S.; Paul, D.; Jain, R.K. Genetically modified crops: Success, safety assessment, and public concern. *Appl. Microbiol. Biotechnol.* 2006, 71, 598–607.
6. Taylor, S.L.; Goodman, R.E.; Hefle, S.L. The development of safety assessment for genetically modified foods. *Asia Pac. Biotech. News* 2006, 10, 614–616.
7. American Medical Association. Report 2 of the Council on Science and Public Health: Labeling of Bioengineered Foods; American Medical Association: Washington, DC, USA, 2012.
8. Gilbert, P.R. *Biotechnology Industries and Entrepreneurs*; Darya Ganj: New Delhi, India, 2008; pp. 25–180.
9. Houdebine, L.M. Impacts of genetically modified animals on the ecosystem and human activities. *Glob. Bioeth.* 2014, 25, 3–18.
10. Schubert, D. A different perspective on GM food. *Nat. Biotechnol.* 2002, 20, 969.
11. Wong, M.S.; Hawthorne, W.J.; Manolios, N. Gene therapy in diabetes. *Self Nonself Pharm.* 2010, 1, 165–175.
12. Matsuda, Y.; Toyoda, H.; Sawabe, A.; Maeda, K.; Shimizu, N.; Fujita, N.; Fujita, T.; Nonomura, T.; Ouchi, S. A hairy root culture of melon produces aroma compounds. *J. Agric. Food Chem.* 2000, 48, 1417–1420.
13. Oller, A.L.W.; Agostini, E.; Talano, M.A.; Capozucca, C.; Milrad, S.R.; Tigier, H.A.; Medina, M.I. Overexpression of a basic peroxidase in transgenic tomato (*Lycopersicon esculentum* Mill. cv. Pera) hairy roots increases phytoremediation of phenol. *Plant Sci.* 2005, 169, 1102–1111.

14. Garagounis, C.; Beritza, K.; Georgopoulou, M.E.; Sonawane, P.; Haralampidis, K.; Goossens, A.; Aharoni, A.; Papadopoulou, K.K. A hairy-root transformation protocol for *Trigonella foenum-graecum* L. as a tool for metabolic engineering and specialised metabolite pathway elucidation. *Plant Physiol. Biochem.* 2020, 154, 451–462.
15. Kundua, S.; Salma, U.; Ali, M.N.; Hazra, A.K.; Mandal, N. Development of transgenic hairy roots and augmentation of secondary metabolites by precursor feeding in *Sphagneticola calendulacea* (L.) Pruski. *Ind. Crops Prod.* 2018, 121, 206–215.
16. Xin, Y.; Ma, B.; Zeng, Q.; He, W.; Qin, M.; He, N. Dynamic changes in transposable element and gene methylation in mulberry (*Morus notabilis*) in response to *Botrytis cinerea*. *Hortic. Res.* 2021, 8, 154.
17. Paine, J.A.; Shipton, C.A.; Chaggar, S.; Howells, R.M.; Kennedy, M.J.; Vernon, G.; Wright, S.Y.; Hinchliffe, E.; Adams, J.L.; Silverstone, A.L.; et al. Improving the nutritional value of Golden Rice through increased pro-vitamin A content. *Nat. Biotechnol.* 2005, 23, 482–487.
18. Gao, Y.; Ma, Y.; Li, M.; Cheng, T.; Li, S.W.; Zhang, J.; Xia, N.S. Oral immunization of animals with transgenic cherry tomatillo expressing HbsAg. *World J. Gastroenterol.* 2003, 9, 996–1002.
19. Van Eenennaam, A.L.; Lincoln, K.; Durrett, T.P.; Valentin, H.E.; Shewmaker, C.K.; Thorne, G.M. Engineering vitamin E content: From *Arabidopsis* mutant to soil oil. *Plant Cell.* 2003, 5, 3007–3019.
20. Suzuki, Y.A.; Shin, K.; Lönnerdal, B. Molecular cloning and functional expression of a human intestinal lactoferrin receptor. *Biochemistry* 2001, 40, 15771–15779.
21. Xiaoyan, S.; Yan, Z.; Shubin, W. Improvement Fe content of wheat (*Triticum aestivum*) grain by soybean ferritin expression cassette without vector backbone sequence. *J. Agric. Food Biochem.* 2012, 20, 766–773.
22. Drakakaki, G.; Marcel, S.; Glahn, R.P.; Lund, E.K.; Pariagh, S.; Fischer, R.; Christou, P.; Stoger, E. Endosperm-specific co-expression of recombinant soybean ferritin and *Aspergillus* phytase in maize results in significant increases in the levels of bioavailable iron. *Plant Mol. Biol.* 2005, 59, 869–880.
23. Goto, F.; Yoshihara, T. Improvement of micronutrient contents by genetic engineering development of high iron content crops. *Plant Biotechnol.* 2001, 18, 7–15.
24. Masuda, H.; Usuda, K.; Kobayashi, T.; Ishimaru, Y.; Kakei, Y.; Takahashi, M.; Higuchi, K.; Nakanishi, H.; Mori, S.; Nishizawa, N.K. Overexpression of the barley nicotianamine synthase gene HvNAS1 increases iron and zinc concentrations in rice grains. *Rice* 2009, 2, 155–166.
25. Ghimire, B.K.; Seong, E.S.; Lim, J.D.; Heo, K.; Kim, M.J.; Chung, I.M.; Juvik, J.A.; Yu, C.Y. Agrobacterium-mediated transformation of *Codonopsis lanceolata* using the c-TMT gene. *Plant Cell. Tiss. Organ. Cult.* 2008, 95, 265–274.

26. Ghimire, B.K.; Seong, E.S.; Lee, C.O.; Lim, J.D.; Lee, J.G.; Yoo, J.H.; Chung, I.M.; Kim, N.Y.; Yu, C.Y. Enhancement of  $\alpha$ -tocopherol content in transgenic *Perilla frutescens* containing the  $\gamma$ -TMT gene. *Afr. J. Biotechnol.* 2011, 10, 2430–2439.
27. Long, M.; Millar, D.J.; Kimura, Y.; Donovan, G.; Rees, J.; Fraser, P.D.; Bramley, P.M.; Bolwell, G.P. Metabolite profiling of carotenoid and phenolic pathways in mutant and transgenic lines of tomato: Identification of a high antioxidant fruit line. *Phytochemistry* 2006, 67, 1750–1757.
28. Lim, J.D.; Yang, D.C.; Yun, S.J.; Chung, I.M.; Sung, E.S.; Kim, M.J.; Heo, K.; Yu, C.Y. Isolation and Biological Activity of Resveratrol-3-O- $\beta$ -D-Glucoside in Transgenic *Rehmannia glutinosa* L. Transformed by Peanut Resveratrol Synthase Gene (RS3). *Korean J. Med. Crop Sci.* 2004, 12, 406–414.
29. Ayaz, M.; Ali, Q.; Farzand, A.; Khan, A.R.; Ling, H.; Gao, X. Nematicidal volatiles from *Bacillus atrophaeus* gbsc56 promote growth and stimulate induced systemic resistance in tomato against *Meloidogyne incognita*. *Int. J. Mol. Sci.* 2021, 22, 5049.
30. Peng, D.; Wan, D.; Cheng, C.; Ye, X.; Sun, M. Nematode-specific cadherin CDH-8 acts as a receptor for Cry5B toxin in *Caenorhabditis elegans*. *Appl. Microbiol. Biotechnol.* 2018, 102, 3663–3673.
31. Stewart, C.N., Jr.; Adang, M.J.; All, J.N.; Raymer, P.L.; Ramachandran, S.; Parrott, W.A. Insect control and dosage effects in transgenic canola containing a synthetic *Bacillus thuringiensis* cryIAc gene. *Plant Physiol.* 1996, 112, 115–120.
32. Singh, S.; Kumar, N.R.; Maniraj, R.; Lakshmikanth, R.; Rao, K.Y.S.; Muralimohan, N.; Arulprakash, T.; Karthik, K.; Shashibhushan, N.B.; Vinutha, T. Expression of Cry2Aa, a *Bacillus thuringiensis* insecticidal protein in transgenic pigeon pea confers resistance to gram pod borer, *Helicoverpa armigera*. *Sci. Rep.* 2018, 8, 8820.
33. Bríza, J.; Pavingerová, D.; Vlasák, J.; Niedermeierová, H. Norway spruce (*Picea abies*) genetic transformation with modified Cry3A gene of *Bacillus thuringiensis*. *Acta Biochim. Pol.* 2013, 60, 395–400.
34. Heimlich, R.E.; Fernandez-Cornejo, J.F.; McBride, W.; Klotz-Ingram, C.; Jans, S.; Brooks, N. Adoption of Genetically Engineered Seed in US Agriculture: Implication for Pesticide Use; sld001; USDA Publication: Washington, DC, USA, 2000.
35. United States Department of Agriculture. Genetically Engineered Crops: Has Adoption Reduced Pesticide Use? *Agricultural Outlook* August. 2000. Available online: [www.ers.usda.gov/publications/agoutlook/aug2000/ao273f.pdf](http://www.ers.usda.gov/publications/agoutlook/aug2000/ao273f.pdf) (accessed on 31 August 2000).
36. Losada, O.A.; Fonseca, C.A.G. Alimentos transgenicosy alergenicidad. *Rev. Fac. Med.* 2007, 55, 251–269.

37. Dodo, H.W.; Konan, N.K.; Chen, F.C.; Egnin, M.; Viquez, O.M. Alleviating peanut allergy using genetic engineering: The silencing of the immunodominant allergen Ara h 2 leads to its significant reduction and a decrease in peanut allergenicity. *Plant Biotechnol. J.* 2008, 6, 135–145.
38. Le, L.Q.; Mahler, V.; Lorenz, Y.; Scheurer, S.; Biemelt, S.; Vieths, S.; Sonnewald, U. Reduced allergenicity of tomato fruits harvested from Lyc e 1-silenced transgenic tomato plants. *J. Allergy Clin. Immunol.* 2006, 118, 1176–1183.
39. Gilissen, L.J.; Bolhaar, S.T.; Matos, C.I.; Rouwendal, G.J.; Boone, M.J.; Krens, F.A.; Zuidmeer, L.; Van Leeuwen, A.; Akkerdaas, J.; Hoffmann-Sommergruber, K.; et al. Silencing the major apple allergen Mal d 1 by using the RNA interference approach. *J. Allergy Clin. Immunol.* 2005, 115, 364–369.
40. Herman, E.M.; Helm, R.M.; Jung, R.; Kinney, A.J. Genetic modification removes an immunodominant allergen from soybean. *Plant Physiol.* 2003, 132, 36–43.
41. Bhalla, P.L.; Swoboda, I.; Singh, M.B. Reduction in allergenicity of grass pollen by genetic engineering. *Int. Arch. Allergy Immunol.* 2001, 124, 51–54.
42. Garbisu, C.; Hernandez, A.J.; Barrutia, O.; Alkorta, I.; Becerril, J.M. Phytoremediation: A technology using green plants to remove contaminants from polluted areas. *Rev. Environ. Health* 2002, 17, 173–188.
43. Sun, L.; Ma, Y.; Wang, H.; Huang, W.; Wang, X.; Han, L.; Sun, W.; Han, E.; Wang, B. Overexpression of PtABCC1 contributes to mercury tolerance and accumulation in Arabidopsis and poplar. *Biochem. Biophys. Res. Commun.* 2018, 497, 997–1002.
44. Pilon-Smits, E. Phytoremediation. *Annu. Rev. Plant Biol.* 2005, 56, 15–39.
45. Gisbert, C.; Ros, R.; Haro, A.D.; Walker, D.J.; Bernal, M.P.; Serrano, R.; Avino, J.N. A plant genetically modified that accumulates Pb is especially promising for phytoremediation. *Biochem. Biophys. Res. Commun.* 2003, 303, 440–445.
46. Li, Y.; Dhankher, O.P.; Carreira, L.; Lee, D.; Chen, A.; Schroeder, J.I.; Balish, R.S.; Meagher, R.B. Overexpression of phytochelatin synthase in Arabidopsis leads to enhanced arsenic tolerance and cadmium hypersensitivity. *Plant Cell Physiol.* 2004, 45, 1787–1797.
47. Moreno, F.N.; Anderson, C.W.; Stewart, R.B.; Robinson, B.H. Mercury volatilisation and phytoextraction from base-metal mine tailings. *Environ. Pollut.* 2005, 136, 341–352.
48. Bizily, S.P.; Rugh, C.L.; Meagher, R.B. Phytodetoxification of hazardous organomercurials by genetically engineered plants. *Nat. Biotechnol.* 2000, 18, 213–217.
49. Van Huysen, T.; Abdel-Ghany, S.; Hale, K.L.; LeDuc, D.; Terry, N.; Pilon-Smits, E.A. Overexpression of cystathionine-gamma- synthase enhances selenium volatilization in Brassica juncea. *Planta* 2003, 218, 71–78.

50. Wolfe, N.L.; Hoehamer, C.F. Enzymes used by plants and microorganisms to detoxify organic compounds. In *Phytore-Mediation: Transformation and Control of Contaminants*; McCutcheon, S.C., Schnoor, J.L., Eds.; New Wiley: New York, NY, USA, 2003; pp. 159–187.
51. Collins, C.; Laturus, F.; Nepovim, A. Remediation of BTEX and trichloroethene. Current knowledge with special emphasis on phytoremediation. *Environ. Sci. Pollut. Res. Int.* 2002, 9, 86–94.
52. Gullner, G.; Komives, T.; Rennenberg, H. Enhanced tolerance of transgenic poplar plants overexpressing g-glutamylcysteine synthetase towards chloroacetanilide herbicides. *J. Exp. Bot.* 2001, 52, 971–979.
53. Flocco, C.G.; Lindblom, S.D.; Smits, E.A. Overexpression of enzymes involved in glutathione synthesis enhances tolerance to organic pollutants in *Brassica juncea*. *Int. J. Phytochem.* 2004, 6, 289–304.
54. Yoshida, T.; Kimura, E.; Koike, S.; Nojima, J.; Futai, E.; Sasagawa, N.; Watanabe, Y.; Ishiura, S. Transgenic rice expressing amyloid  $\beta$ peptide for oral immunization. *Int. J. Biol. Sci.* 2011, 7, 301.
55. Rybicki, E.P. Plant-made vaccines for humans and animals. *Plant Biotechnol. J.* 2010, 8, 620–637.
56. Xu, J.; Ge, X.; Dolan, M.C. Towards high-yield production of pharmaceutical proteins with plant cell suspension cultures. *Biotechnol. Adv.* 2011, 29, 278–299.
57. Sala, F.; Rigano, M.M.; Barbante, A.; Basso, B.; Walmsley, A.M.; Castiglione, S. Vaccine antigen production in transgenic plants: Strategies, gene constructs and perspectives. *Vaccine* 2003, 21, 803–808.
58. Daniell, H.; Kumar, S.; Dufourmantel, N. Breakthrough in chloroplast genetic engineering of agronomically important crops. *Trend. Biotechnol.* 2005, 23, 238–245.
59. Scotti, N.; Rigano, M.M.; Cardi, T. Production of foreign proteins using plastid transformation. *Biotechnol. Adv.* 2012, 30, 387–397.
60. Marsian, J.; Fox, H.; Bahar, M.W.; Kotecha, A.; Fry, E.E.; Stuart, D.I.; Macadam, A.J.; Rowlands, D.J.; Lomonossoff, G.P. Plant-made polio type 3 stabilized VLPs—A candidate synthetic polio vaccine. *Nat. Commun.* 2017, 8, 1–9.
61. Gressel, J. Transgenics are imperative for biofuel crops. *Plant Sci.* 2008, 174, 246–263.
62. Smith, A.M. Prospects for increasing starch and sucrose yields for bioethanol production. *Plant J.* 2008, 54, 546–558.
63. Vanden Wymelenberg, A.; Sabat, G.; Mozuch, M.; Kersten, P.J.; Cullen, D.; Blanchette, R.A. Structure, organization, and transcriptional regulation of a family of copper radical oxidase genes

- in the lignin-degrading basidiomycete *Phanerochaete chrysosporium*. *Appl. Environ. Microbiol.* 2006, 72, 4871–4877.
64. Li, L.; Zhou, Y.; Cheng, X.; Sun, J.; Marita, J.; Ralph, J.; Chiang, V. Combinatorial modification of multiple lignin traits in trees through multigene co-transformation. *Proc. Natl. Acad. Sci. USA* 2003, 100, 4939–4944.
65. Yoo, J.H.; Seong, E.S.; Ghimire, B.K.; Heo, K.; Jin, X.; Yamada, T.; Clark, L.V.; Sacks, E.J.; Yu, C.Y. Establishment of *Miscanthus sinensis* with decreased lignin biosynthesis by *Agrobacterium*-mediated transformation using antisense COMT gene. *Plant Cell Tissue Organ Cult.* 2018, 133, 359–369.
66. Myers, A.M.; Morell, M.K.; James, M.G.; Ball, S.G. Recent progress toward understanding the biosynthesis of the amylopectin crystal. *Plant Physiol.* 2000, 122, 989–998.
67. Ralph, J.; Akiyama, T.; Kim, H.; Lu, F.; Schatz, P.F.; Marita, J.M.; Ralph, S.A.; Reddy, M.S.S.; Chen, F.; Dixon, R.A. Effects of coumarate 3-hydroxylase down-regulation on lignin structure. *J. Biol. Chem.* 2006, 281, 8843–8853.
68. Chabannes, M.; Barakate, A.; Capierre, C.; Marita, J.M.; Ralph, J.; Peem, M.; Danoun, S.; Halpin, C.; Grima-Pettenati, J.; Boudet, A.M. Strong decrease in lignin content without significant alteration of plant development is induced by simultaneous down-regulation of cinnamoyl CoA reductase (CCR) and cinnamyl alcohol dehydrogenase (CAD) in tobacco plants. *Plant J.* 2001, 28, 257–270.
69. Blaschke, L.; Legrand, M.; Mai, C.; Polle, A. Lignification and structural biomass production in tobacco with suppressed caffeic/5-hydroxy ferulic acid-O-methyl transferase activity under ambient and elevated CO<sub>2</sub> concentrations. *Physiol. Plant* 2004, 121, 75–83.
70. Lardizabal, K.; Effertz, R.; Levering, C.; Mai, J.; Pedroso, M.; Jury, T.; Aasen, E.; Gruys, K.; Bennett, K. Expression of *Umbelopsis ramanniana* DGAT2A in seed increases oil in soybean. *Plant Physiol.* 2008, 148, 9–96.
71. Wiberg, E.; Edwards, P.; Byrne, J.; Stymne, S.; Dehesh, K. The distribution of caprylate, caprate and laurate in lipids from developing and mature seeds of transgenic *Brassica napus* L. *Planta* 2000, 212, 33–40.
72. Van Camp, W. Yield enhancement genes: Seeds for growth. *Curr. Opin. Biotechnol.* 2005, 16, 147–153.
73. Jing, Z.P.; Gallardo, F.; Pascual, M.B.; Sampalo, R.; Romero, J.; Torres de Navarra, A.; Cañovas, F.M. Improved growth in a field trial of transgenic hybrid poplar overexpressing glutamine synthetase. *New Phytol.* 2004, 164, 137–145.
74. Hammond, B.; Dudek, R.; Lemen, L.; Nemeth, M. Results of a 13 week safety assurance study with rats fed grain from glyphosate tolerant corn. *Food Chem Toxicol.* 2004, 42, 1003–1014.

75. Schroder, M.; Poulsen, M.; Wilcks, A.; Kroghsbo, S.; Miller, A.; Frenzel, T.; Danier, J.; Rychlik, M.; Emami, K.; Gatehouse, A. A 90-day safety study of genetically modified rice expressing Cry1Ab protein (*Bacillus thuringiensis* toxin) in Wistar rats. *Food Chem. Toxicol.* 2007, 45, 339–349.
76. Setamou, M.; Berna, J.S.; Legaspi, J.C.; Mirkov, T.E. Parasitism and location of sugarcane borer (*Lepidoptera*: *Pyralidae*) by *Cotesia flavipes* (*Hymenoptera*: *Braconidae*) on transgenic and conventional sugarcane. *Environ. Entomol.* 2002, 31, 1219–1225.
77. Lee, C.J.; Kim, S.E.; Park, S.U.; Lim, Y.H.; Choi, H.Y.; Kim, W.G.; Ji, C.Y.; Kim, H.S.; Kwak, S.S. Tuberos roots of transgenic sweet potato overexpressing IbCAD1 have enhanced low-temperature storage phenotypes. *Plant Physiol. Biochem.* 2021, 166, 549–557.
78. Moellenbeck, D.J.; Peters, M.L.; Bing, J.W.; Rouse, J.R.; Higgins, L.S.; Sims, L.; Nevshemal, T.; Marshall, L.; Ellis, R.T. Insecticidal proteins from *Bacillus thuringiensis* protect corn from corn rootworms. *Nat. Biotechnol.* 2001, 19, 668–672.
79. Hu, L.; Zhou, K.; Liu, Y.; Yang, S.; Zhang, J.; Gong, X.; Ma, F. Overexpression of MdMIPS1 enhances salt tolerance by improving osmosis, ion balance, and antioxidant activity in transgenic apple. *Plant Sci.* 2020, 301, 110654.
80. Prakash, D.; Verma, S.; Bhatia, R.; Tiwary, B.N. Risks and Precautions of Genetically Modified Organisms. *ISRN Ecol.* 2011, 2011, 369573.
81. Deepa, A. *Genetically Modified Foods: Benefits and Risks*; Massachusetts Medical Society: Boston, MA, USA, 2015.
82. Pelletier, D.L. Science, law, and politics in FDA's genetically engineered foods policy: Scientific concerns and uncertainties. *Nutr. Rev.* 2005, 63, 210–223.
83. USDA. *Biotechnology Frequently Asked Questions*; USDA: Washington, DC, USA, 1998.
84. Yul, R.J.; Choi, J.Y.; Li, M.S.; Jin, B.R.; Je, Y.H. *Bacillus thuringiensis* as a Specific, Safe, and Effective Tool for Insect Pest Control. *J. Microbiol. Biotechnol.* 2007, 17, 547–559.
85. Hall, J.; Matos, M.; Langford, C.H. Social exclusion and transgenic technology: The case of Brazilian agriculture. *J. Bus. Ethics.* 2008, 77, 45–63.
86. Hilbeck, A.; Baumgartner, M.; Fried, P.M.; Bigler, F. Effects of transgenic *Bacillus thuringiensis* corn-fed prey on mortality and development time of immature *Chrysoperla carnea* (*Neuroptera*: *Chrysopidae*). *Environ. Entomol.* 1998, 27, 480–487.
87. Arnaud, J.F.; Viard, F.; Delescluse, M.; Cuguen, J. Evidence for gene flow via seed dispersal from crop to wild relatives in *Beta vulgaris* (*Chenopodiaceae*): Consequences for the release of genetically modified crop species with weedy lineages. *Proc. R. Soc. B Biol. Sci.* 2003, 270, 1565–1575.

88. Ellstrand, N.C.; Scierenbeck, K.A. Hybridization as a stimulus for the evolution of invasiveness in plants? *Proc. Natl. Acad. Sci. USA* 2000, 97, 7043–7050.
89. Gressel, J. Molecular biology of weed control. *Transgenic Res.* 2000, 9, 355–382.
90. Ricroch, A.E.; Berge, J.E.; Kuntz, M. Evaluation of genetically engineered crops using transcriptomic, proteomic, and metabolomic profiling techniques. *Plant Physiol.* 2011, 155, 1752–1761.
91. Keese, P. Risks from GMOs due to Horizontal Gene Transfer. *Environ. Biosaf. Res.* 2008, 7, 123–149.
92. Dutton, A.; Klein, H.; Romeis, J.; Bigler, F. Uptake of Bt-toxin by herbivores feeding on transgenic maize and consequences for the predator *Chrysoperia carnea*. *Ecol. Entomol.* 2002, 27, 441–447.
93. Tudisco, R.; Lombardi, P.; Bovera, F.; Cutrignelli, M.I.; Mastellone, V.; Terzi, V.; Avallone, L.; Infascelli, F. Genetically Modified Soya Bean in Rabbit Feeding: Detection of DNA fragments and evaluation of metabolic effects by enzymatic analysis. *J. Anim. Sci.* 2006, 82, 193–199.
94. Romeis, J.; Dutton Bigler, F. *Bacillus thuringiensis* toxin (Cry 1 Ab) has no direct on larvae of the green lacewing *Chrysoperla carnea* (stephens) (Neuroptera: Chrysopidae). *J. Insect. Physiol.* 2004, 50, 175–183.
95. Bob, B.M.W.; Candolin, U. Behavioral responses to changing environments. *Behav. Ecol.* 2015, 26, 665–673.
96. Chekol, C. The Health Effects of Genetically Modified Foods: A Brief Review. *Int. J. Nutr. Sci.* 2021, 6, 1047.
97. Papparini, A.; Romano-Spica, V. Public health issues related with the consumption of food obtained from genetically modified organisms. *Biotechnol. Annu. Rev.* 2004, 10, 85–122.
98. Alexandrova, N.; Georgieva, K.; Atanassov, A. Biosafety regulations of GMOs: National and International aspects and regional cooperation. *Biotechnol. Equip.* 2005, 19, 153–172.
99. de Vendômois, J.S.; Roullier, F.; Cellier, D.; Séralini, G.E. A Comparison of the effects of three GM corn varieties on mammalian health. *Int. J. Biol. Sci.* 2009, 5, 706–726.
100. Wozniak, E.; Tyczewska, A.; Twardowski, T. Bioeconomy development factors in the European Union and Poland. *New Biotechnol.* 2021, 60, 2–8.
101. Cribbs, A.P.; Perera, S.M. Focus: Genome editing: Science and bioethics of CRISPR-Cas9 gene editing: An analysis towards separating facts and fiction. *Yale J. Biol. Med.* 2017, 90, 625.
102. Vibha Ahuja Regulation of emerging gene technologies in India. *BMC Proc.* 2018, 12, 14.

103. MoEFCC; DBT. Guidelines, User's Guide and Risk Analysis Framework. In Environmental Risk Assessment of GE Plants; MoEFCC: New Delhi, India, 2016.
104. MoEFCC; BCIL. Frequently Asked Questions About GE Plants. In Phase II Capacity Building Project on Biosafety; MoEFCC: New Delhi, India, 2015.
105. Ishii, T.; Araki, M. A future scenario of the global regulatory landscape regarding genome-edited crops. *GM Crop. Food* 2017, 8, 44–56.
106. Rosado, A.; Craig, W. Biosafety regulatory systems overseeing the use of genetically modified organisms in the latin america and caribbean region. *AgBioForum* 2017, 20, 120–132.
107. Global Agriculture. Venezuela passes new seed law banning genetically modified crops. 2016. Available online: <https://www.globalagriculture.org/whatsnew/news/en/31519.html>. (accessed on 11 January 2023).
108. APBREBES. The New Seed Law of Venezuela; APBREBES: Geneva, Switzerland, 2016.
109. Gatica-Arias, A. The regulatory current status of plant breeding technologies in some Latin American and the Caribbean countries. *Plant Cell Tissue Organ Cult.* 2020, 141, 229–242.
110. Smith, P.; Katovich, E. Are GMO policies “trade related”? Empirical analysis of Latin America. *Appl. Econ. Perspect. Policy* 2017, 39, 286–312.
111. ISAAA. Brief 55–2019. Executive Summary, Biotech Crops Drive Socio-Economic Development and Sustainable Development in the New Frontier; ISAAA: Nairobi, Kenya, 2019.
112. Turnbull, C.; Lillemo, M.; Hvoslef-Eide, T. Global regulation of genetically modified crops amid the gene edited crop boom—A review. *Front. Plant Sci. Plant Biotechnol.* 2021, 12, 1–19.
113. Zarrilli, S. International trade in gmos and gm products: National and multilateral legal frameworks. In Policy Issues in International Trade and Commodities Study Series no. 29; United Nations: New York, NY, USA, 2005; pp. 1–16.
114. Rosado, A.; Eriksson, D. Biosafety legislation and the regulatory status of the products of precision breeding in the Latin America and the Caribbean region. *Plants People Planet* 2021, 4, 214–231.
115. Akaakohol, M.A.; Aye, G.C. Diversification and farm household welfare in Makurdi, Benue state, Nigeria. *Dev. Stud. Res.* 2014, 1, 168–175.
116. ASSAf (Academies of Science of South Africa). GMOs for African agriculture: Challenges and opportunities. Workshop Proceedings Report. ASSAf: 2010. Available online: [www.assaf.org.za](http://www.assaf.org.za) (accessed on 11 January 2023).
117. EFSA (European Food Safety Authority). Guidance on the environmental risk assessment of genetically modified plants. *EFSA J.* 2010, 8, 1879.

118. Bawa, A.S.; Anilakumar, K.R. Genetically modified foods: Safety, risks and public concerns-a review. *J. Food Sci. Technol.* 2013, 50, 1035–1046.
119. Tung, O.J.L. A comparative analysis of the South African and burkinabe experiences with genetically modified crop regulation. In *Verfassung und Recht in Übersee/Law and Politics in Africa, Asia, Latin America*; Nomos Verlagsgesellschaft: Baden-Baden, Germany, 2017; pp. 3–29.
120. Anderson, K.; Nielsen, C. *Golden Rice and The Looming Gmo Trade Debate: Implications for the Poor*; CEPR. Discussion Papers 4195; CEPR: London, UK, 2004.
121. Deffor, E.W. Consumer acceptance of genetically modified foods in the greater accra region of Ghana. *J. Biosaf. Health Educ.* 2014, 2, 116.
122. Newell-McGloughlin, M.; Burke, J. Biotechnology crop adoption: Potential and challenges of genetically improved crops. *Encycl. Agric. Food Syst.* 2014, 2014, 69–93.
123. Akinbo, O.; Obukosia, S.; Ouedraogo, J.; Sinebo, W.; Savadogo, M.; Timpo, S.; Mbabazi, R.; Maredia, K.; Diran Makinde, D.; Ambali, A. Commercial release of genetically modified crops in Africa: Interface between biosafety regulatory systems and varietal release systems. *Front. Plant Sci.* 2021, 12, 605937.
124. Cooke, J.G.; Downie, R. *African Perspectives on Genetically Modified Crops: Assessing the Debate in Zambia, Kenya and South Africa. A Report of the Csis Global Food Security Project*; Centre for Strategic & International Studies: Washington, DC, USA, 2010.
125. ISAAA. *Global Status of Commercialised Biotech/GM Crops in ISAAA Brief Ithaca*; ISAAA: New York, NY, USA, 2019.
126. ABNE. *African biosafety network of expertise (ABNE) african union development agency NEPAD (AUDA-NEPAD)*; ABNE: Midrand, South Africa, 2019.
127. ISAAA. *Global Status of Commercialized Biotech/GM Crops in 2018: Executive Brief*; ISAAA: Ithaca, NY, USA, 2018.
128. Kimenju, S.C.; De Groote, H.; Karugia, J.; Mbogoh, S.; Poland, D. Consumer awareness and attitudes toward GM foods in Kenya. *Afr. J. Biotechnol.* 2005, 4, 1–10.
129. Nyinondi, P.S.; Dulle, F.W.; Nawe, J. Perception of agricultural biotechnology among farmers. Journalists and Scientists in Tanzania. *Univ. Dares Salaam Libr. J.* 2017, 12, 106–120.
130. ISAAA. *Global Status of Commercialised Biotech/Gm Crops in 2017: Biotech Crop Adoption Surges as Economic Benefits Accumulate in 22 Years*; ISAAA Brief: New York, NY, USA, 2017; Volume 53, pp. 25–26.
131. ISAAA. *Global Status of Commercialised Biotech/GM Crops in ISAAA Brief no. 54*; ISAAA: Ithaca, NY, USA, 2018.

132. Aerni, P. Stakeholder attitudes towards the risks and benefits of genetically modified crops in South Africa. *Environ. Sci. Policy* 2005, 8, 464–476.
133. Aerni, P.; Bernauer, T. Stakeholder attitudes toward GMOs in the Philippines, Mexico, and South Africa: The issue of public trust. *World Dev.* 2006, 34, 557–575.
134. Marques, M.D.; Critchley, C.R.; Walshe, J. Attitudes to genetically modified food over time: How trust is, and the media cycle predict support. *Public Underst. Sci.* 2015, 24, 601–618.
135. Rock, J.; Schurman, R. The complex choreography of agricultural biotechnology in Africa. *Afr. Affairs* 2020, 119, 499–525.
136. MOA (Ministry of Agriculture). Measures of Labelling Administration of Agricultural GMO–Decree 10 (in Chinese), 2002. Available online: [http://www.moa.gov.cn/fwllm/zxbs/xzxk/bszl/201405/t20140527\\_3917464.htm](http://www.moa.gov.cn/fwllm/zxbs/xzxk/bszl/201405/t20140527_3917464.htm) (accessed on 11 January 2023).
137. MOA (Ministry of Agriculture of China). Guideline for Safety Inspection of Field Trials of GM Crops, 2012. Available online: [http://www.moa.gov.cn/zwl/m/zcfg/qtbm/gz/200606/t20060612\\_627852.htm](http://www.moa.gov.cn/zwl/m/zcfg/qtbm/gz/200606/t20060612_627852.htm) (accessed on 22 August 2015).
138. Xiao, Z.; Kerr, W.A. Biotechnology in China—regulation, investment, and delayed commercialization. *GM CROPS FOOD* 2022, 13, 86–96.
139. Loppacher, L.J.; Kerr, W.A. Biotechnology in China: Food policy and international trade issues. In *Food Policy Control and Research*; Riley, A.P., Ed.; Nova Science Publishers: New York, NY, USA, 2005; pp. 1–15.
140. Kim, H.Y.; Kim, J.H.; Mi-Hwa Oh, M.H. Regulation and detection methods for genetically modified foods in Korea. *Pure Appl. Chem.* 2010, 82, 129–137.

---

Retrieved from <https://encyclopedia.pub/entry/history/show/93642>