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ORIGINAL RESEARCH ARTICLE

Plant genetic transformation promotes modern agriculture and the food safety of genetically modified plants

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ABSTRACT

The contribution of business marketing of genetically modified (GM) plants to crop improvement, reduced use of pesticides, and the improvement of the ecological environment was presented. The toxicity and allergy of GM food, the ecological risks confronted by GM plant cultivation, and the necessity of government inspection of GM products were also discussed. GM plants and their derived products have been consumed as food for more than 30 years since the commercialization of transgenic plants in 1995. Most scientific papers have proved that there is no significant discrepancy between GM plants and non-GM plants in composition till now. The discovery of natural transgenic sweet potatoes has further demonstrated the safety of GM foods.

Keywords: transgenic plants; crop breeding and improvement; safety of genetically modified food

1. Introduction

Transgenic plants are plants with new characteristics that are obtained through gene cloning or synthesis and gene recombination in the laboratory, and the recombinant DNA is introduced into the genome of the host plant. Among many methods of introducing foreign genes into plant cells, only through *Agrobacterium*-mediated methods can we obtain stable transgenic offspring. *Agrobacterium tumefaciens* is a kind of gram-negative bacteria that infects dicotyledons and commonly exists in soil. It generally lives on the surface of plant roots and depends on the nutrients infiltrated from root tissues. The T-DNA contained in *Agrobacterium tumefaciens* has the function of introducing and integrating foreign genes into the plant genome. Acetylsyringone secreted by the injured part of dicotyledons can activate some genes in *Agrobacterium tumefaciens* T-DNA. The products (protease) of these genes can cut T-DNA, import it, and integrate it into the plant genome.

The similarities and differences between plant transgenic technology and traditional sexual hybridization technology are mainly reflected in the following aspects: a. Both plant transgenic and sexual hybridization have gene exchanges among species, and new genes (proteins) and traits may be produced, which may improve crop yield and quality, disease resistance, and stress resistance (heat, salt, drought, and freezing resistance). b. Plant transgene technology can also break reproductive isolation; that is, it can introduce biological genes with distant genetic relationships into the plant genome. Sexual hybridization usually introduces a large number of genes (many of which bring adverse traits), so it takes a long time (backcrossing many generations) to screen

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useful hybrid offspring in the breeding process. However, the use of transgenic technology can introduce one or several key genes specifically, so as to achieve the goal of plant improvement in a short time. Moreover, due to the breaking of reproductive isolation, the selection range of genes is greatly broadened. Transgenic plants obtained by *the Agrobacterium*-mediated method generally contain some T-DNA of *Agrobacterium*. For the convenience of screening offspring, transgenic plants generally also contain antibiotic resistance genes. However, it is very unlikely that antibiotic resistance genes can be transferred from transgenic plants to intestinal or soil microorganisms[1], and these genes are already common in intestinal or soil microorganisms. In addition, antibiotic resistance genes can also be removed by many methods[2]. In recent years, gene editing technology using the CRISPR/Cas9 system has also been widely used in the study of plant gene improvement[3,4]. The offspring of transgenic plants obtained by gene editing technology can obtain mutants without any foreign genes through character separation and screening, which is different from the breeding process of new varieties through traditional breeding technology.

2. Debate on the role and safety of transgenic plants

Transgenic plants are generally of the following types: disease-resistant transgenic plants (such as anti-virus transgenic tobacco), insect-resistant transgenic plants (such as insect-resistant cotton), reverse-resistant transgenic plants (such as drought resistance and salt alkali resistance), herbicide-resistant transgenic plants (such as herbicide-resistant transgenic corn, soybean, cotton, and rape), quality-improved transgenic plants (such as golden rice), and transgenic drug plants (such as carrots for cholera vaccine production). Therefore, transgenic plants have the following functions: increasing crop yield, improving crop quality, reducing the use of chemical pesticides and environmental pollution caused by pesticides, reducing production costs, and improving economic benefits. By introducing key genes related to photosynthesis and quality, the yield and quality of transgenic crops can be greatly improved. It is reported that from 1996 to 2014, due to the planting of genetically modified crops, the global use of pesticides decreased by 37%[5], but the use of pesticides in China is still not optimistic. The intensity of pesticide use increased from 5.12 kg per hectare in 1991 to 10.95 kg per hectare in 2013, which is 2.5 times the world average level[5]. Therefore, if China can significantly increase the planting area of insect-resistant and disease-resistant transgenic crops, it will greatly reduce the dependence on and use of pesticides, reduce the risk of pesticide poisoning, and reduce the pollution to the ecological environment caused by the massive use of pesticides. The planting of transgenic plants can not only reduce the use of pesticides but also reduce the safety problems caused by the infection of plant bacteria. For example, a few years ago, Italy used non-transgenic corn as feed, resulting in a large amount of pollution from fumonisins, so that a large number of dead pigs were buried, causing no small ecological problems. The promotion of herbicide-resistant transgenic plants can greatly reduce the labor cost of weeding. To sum up, the planting of transgenic crops can reduce production costs, improve economic benefits, and improve the ecological environment. In addition, transgenic plants obtained through gene knockout and overexpression are widely used in the study of gene function. The study of plant gene function can excavate the key genes to improve crop yield, quality, disease resistance, and stress resistance and further contribute to the genetic improvement of plants.

In recent years, there have been some debates about the safety of genetically modified food, and it has become a hot topic in society. But this topic is a highly focused social hot spot, not a scientific debate. Through searching all SCI papers on the biosafety of transgenic plants by 2016, Yun Jinhui et al.[6] found that more than 90% of the 9333 published papers on the biosafety of transgenic plants proved that there was no significant difference in composition between transgenic plants and non-transgenic plants. Through the follow-up study of all the papers that draw the conclusion that genetically modified food is unsafe, it was found that their research conclusions were drawn under the conditions of the wrong research materials or methods. The debate on the safety of genetically modified food in society has not only failed to lead to the progress of genetically modified science and technology; on the contrary, excessive debate has led to the prevalence of rumors, and the cost of scientific detection to correct rumors is very high[6]. Due to the excessive publicity of many domestic media and the spread of many rumors in Chinese society, gene-agriculture.com (http://www.agrogene.cn/info-1501.shtml). This paper lists more than 30 rumors about transgenic plants circulating in society and points out their truth and details one by one. In recent years, many scholars have devoted themselves to writing popular science papers to correct rumors, but the effect is not very ideal. The above large amount of data shows that the GM products approved for marketing are safe.

3. Safety risks and countermeasures of transgenic plants

In theory, the safety risks of transgenic plants mainly include their toxicity and allergy to food, as well as the ecological risks of gene drift and the food chain of insects and their natural enemies. Indeed, as new proteins are produced through transgenesis, they become new allergens. It is reported that after the sulfur-rich 2S albumin gene of Brazil nut (*Bertholletia excelsa*) is transferred into soybean, the transferred 2S gene will cause allergy, and its allergen is the 2S protein of Brazil nut[7]. Although it increased the sulfur-containing amino acids in soybeans, it was not approved for commercial production because some people were allergic to it. In fact, there are also many toxic ingredients in natural foods, such as cauliflower, old beans, and cassava, which can only be eaten after strict processing and removal of toxic substances. There are not a few toxic edible fungi. A small number of people are sensitive to seafood, and even some people are sensitive to tomatoes and nuts.

Gene drift can be avoided by constructing male, sterile transgenic plants. The ecological risk of insects and their natural enemies in the food chain is actually far less than the harm caused by the excessive use of pesticides. In other words, the wide planting of transgenic plants and the reduction of the use of pesticides are conducive to the restoration of the ecological environment to a certain extent. In addition, many people question the long-term effects of genetically modified food after several generations of consumption. Buzoianu et al.[8] fed mom 810 corn to sows and their offspring for 143 days, indicating that there was no significant change in the blood indicators of sows and their offspring. Buzoianu and other[8,9] follow-up studies showed that GM corn feeding had no adverse effects on the growth and intestinal flora of sows and their offspring and did not transfer to the blood or organs.

In recent years, whether Bt protein is toxic to the human body has been the focus of debate. Bt protein refers to the protein produced by *Bacillus thuringiensis* (Bt for short), which includes many varieties of *Bacillus crystallogenes*. It can effectively kill Lepidopera, Diptera, Coleoptera, Hymenoptera, Homoptera, Orthoptera, Mallophaga, and other insects. It is called a toxic protein. However, Bt protein is only toxic to the above insects because the unique alkaline gastrointestinal tract of the above insects can lead to the activation of Bt protein, especially because there are receptors for Bt protein in the above insects. Because the physiological structure is completely different (humans and animals do not have Bt protein receptors, and the gastric juice is acidic and cannot activate Bt protein), Bt protein is harmless to humans and animals. In fact, many studies have shown that there is no significant difference in liver and kidney function and immune protein between the three generations of rats fed with a diet containing Bt protein and the control group[10,11]. Moreover, Bt protein has also been widely used in organic agriculture and other fields as a biological pesticide.

Although there is no significant difference between genetically modified plants and non-genetically modified plants in terms of composition, governments of various countries have promulgated a series of regulatory regulations on the laboratory research and field cultivation of genetically modified plants, the circulation and sales of genetically modified products, and also improved the environmental safety assessment and food safety assessment systems due to the theoretical potential toxicity, allergy, ecological risk, and other reasons. For example, governments of various countries have established legal systems for gene pollution isolation of genetically modified crops and made clear provisions on file management, notification systems, and isolation systems for genetically modified plant cultivation[12]. In addition, governments of various countries have also made detailed provisions on the labeling of genetically modified products[13]. Genetically modified products generally have two categories: voluntary labeling and mandatory labeling. The countries (regions) that adopt voluntary labeling mainly include Canada, the Philippines, Argentina, South Africa, and Hong Kong. The above countries and regions do not have mandatory labeling requirements for genetically modified products. The United States had no mandatory labeling requirements for genetically modified products before 2016[14]. In 2016, the United States government legislated to require mandatory labeling for genetically modified products[13]. According to the difference in marking threshold, the transgenic marking system can also be divided into qualitative marking and quantitative marking. Qualitative identification means that genetically modified components must be identified if they can be detected in products by specified detection methods[13]. China is the only country in the world that requires qualitative identification, while other countries also have great differences in the threshold of quantitative identification[13]. The above large amount of data shows that the GM products approved for marketing are safe.

4. Horizontal gene transfer (transgene) between organisms is a common phenomenon in nature

The commercialization of transgenic plants has been controversial since the first case of transgenic plants appeared in the 1980s. However, in fact, horizontal gene transfer (transgene) between organisms is very common. It is said that mitochondria and chloroplasts in plant cells also come from microorganisms. Aphids cause red or green coloring after obtaining the carotenoid synthesis gene of fungi[15]. *Agrobacterium* genes have been found in the genomes of tobacco (Nicotiana) and linariavulgaris, indicating that these tobacco and linariavulgaris may be natural transgenic plants[16–19]. A large number of DNA fragments similar to the T-DNA of *Agrobacterium tumefaciens* were found in cultivated sweet potatoes through large-scale high-throughput sequencing, suggesting that cultivated sweet potato may also be a natural transgenic plant[20]. Furthermore, Kyndt et al.[21] detected the genes of 291 kinds of cultivated sweet potatoes and found that all sweet potatoes contain the T-DNA of *Agrobacterium*. The scientists of Shanghai Chenshan Botanical Garden found that sweet potatoes do contain *Agrobacterium*[22,23] by sequencing the whole genome of sweet potatoes and confirmed that all cultivated sweet potatoes are natural transgenic sweet potatoes. The above results show that human beings have unconsciously eaten transgenic sweet potatoes without any safety evaluation for thousands of years. In addition, their research also shows that *Agrobacterium* T-DNA has not been detected in the related species of sweet potato, indicating that the probability of gene drift in nature is also very small[21]. Natural transgenic plants may be formed by T-DNA integration into the plant genome after being infected by *Agrobacterium tumefaciens* and domesticated for countless generations. In this process, it should have experienced many events, such as gene mutation, loss, and recombination. Transgenic technology makes use of the characteristics of *Agrobacterium tumefaciens* infecting the host plant and integrating T-DNA into the host plant genome so that the host plant can obtain new genes (traits). Therefore, transgenic plants obtained by modern biotechnology, like natural transgenic plants, have *Agrobacterium* T-DNA. The difference is that transgenic plants obtained by modern biotechnology also contain foreign recombinant genes or synthetic genes. Transgenic plants and new plant varieties obtained through traditional cross-breeding have genes from other species, but transgenic plants also contain *Agrobacterium* T-DNA. Human beings have been eating natural transgenic sweet potatoes containing *Agrobacterium* T-DNA for thousands of years. Therefore, modern biotechnology for obtaining transgenic plants is only different from traditional breeding technology for obtaining new hybrid varieties. The discovery of natural transgenic sweet potatoes is a milestone in the safety of transgenic products.

5. Conclusion

To sum up, human beings have been unconsciously eating natural transgenic sweet potatoes for thousands of years, so the safety risk of transgenic products mainly lies in the fact that the toxicity and sensitization of foreign proteins are not T-DNA contained in *Agrobacterium tumefaciens*. Because of the potential toxicity and sensitization of foreign proteins, transgenic plants need government regulation. The Chinese government has implemented the strictest supervision in the world in the research and cultivation of genetically modified plants, the production and circulation of genetically modified products, and the genetically modified foods put on the market have been subjected to rigorous inspection, and there are no safety risks. Transgenic plants can cultivate new varieties that can adapt to different planting conditions according to different planting environments. Therefore, they can improve the yield and should be vigorously promoted. In recent years, due to various reasons, China has rarely approved the application of new genetically modified crops with independent intellectual property rights in agriculture. Although the research of transgenic plants in China has been in a leading position in the world, due to various reasons, the gap between the industrialization level of transgenic plants in China and other transgenic technology countries is widening. Government departments and schools should more widely publicize the scientific theory of transgenic plants, properly guide public opinion, and believe that modern biotechnology such as plant transgenesis gene editing and molecular marker-assisted breeding will play a greater role in China's agricultural modernization and sustainable development.

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Conflict of interest

The authors declare no conflict of interest.

References

1. Kou Y, Shi L. Safety evaluation of using antibiotic resistance genes as markers in transgenic plants (Chinese). *Chinese Journal of Antibiotics* 2006; 10: 577–580.
2. Hohn B, Levy AA, Puchta H. Elimination of selection markers from transgenic plants. *Current Opinion in Biotechnology* 2001; 12(2): 139–143. doi: 10.1016/S0958-1669(00)00188-9
3. Ding Y, Li H, Chen LL, et al. Recent advances in genome editing using CRISPR/Cas9. *Frontiers in Plant Science* 2016; 7. doi: 10.3389/fpls.2016.00703
4. Yu M, Li X, Gao M, et al. Establishment of CRISPR/Cas9 gene editing system for lettuce (Chinese). *Plant Physiology Journal* 2017; 53(4): 736–746.
5. Chen X, Wang C, Bo R. Current situation and countermeasures of pesticide use in China (Chinese). *Pesticide Science and Administration* 2016; 37(2): 4–8.
6. Pang J, Ma C, Feng Y, Hu R. Biosafety of transgenic crops: Scientific evidence (Chinese). *China Biotechnology* 2016; 36(1): 122–138.
7. Nordlee JA, Taylor SL, Townsend JA, et al. Identification of a Brazil-nut allergen in transgenic soybeans. *New England Journal of Medicine* 1996; 334(11): 688–692. doi: 10.1056/nejm199603143341103
8. Buzoianu SG, Walsh MC, Rea MC, et al. High-throughput sequence-based analysis of the intestinal microbiota of weanling pigs fed genetically modified MON810 maize expressing *Bacillus thuringiensis* Cry1Ab (Bt Maize) for 31 days. *Applied and Environmental Microbiology* 2012; 78(12): 4217–4224. doi: 10.1128/aem.00307-12
9. Buzoianu SG, Walsh MC, Rea MC, et al. Transgenerational effects of feeding genetically modified maize to nulliparous sows and offspring on offspring growth and health. *Journal of Animal Science* 2013; 91(1): 318–330. doi: 10.2527/jas.2012-5360
10. Appenzeller LM, Malley L, MacKenzie SA, et al. Subchronic feeding study with genetically modified stacked trait lepidopteran and coleopteran resistant (DAS-Ø15Ø7-1xDAS-59122-7) maize grain in Sprague-Dawley rats. *Food*

and Chemical Toxicology 2009; 47(7): 1512–1520. doi: 10.1016/j.fct.2009.03.041

11. MacKenzie SA, Lamb I, Schmidt J, et al. Thirteen week feeding study with transgenic maize grain containing event DAS-Ø15Ø7-1 in Sprague–Dawley rats. *Food and Chemical Toxicology* 2007; 45(4): 551–562. doi: 10.1016/j.fct.2006.09.016
12. Zhang M. Specific measures to improve my country's constitutional review system (Chinese). *Legality Vision* 2016; 14: 195–196.
13. Xu L, Liu P, Xiong L, et al. Identification system of agricultural genetically modified products in major countries and regions in the world (Chinese). *Journal of Biosafety* 2014, 23(4): 301–304.
14. Chrispeels MJ. Yes indeed, most Americans do eat GMOs every day! *Journal of Integrative Plant Biology* 2014; 56(1): 4–6. doi: 10.1111/jipb.12147
15. Moran NA, Jarvik T. Lateral transfer of genes from fungi underlies carotenoid production in aphids. *Science* 2010; 328(5978): 624–627. doi: 10.1126/science.1187113
16. White FF, Garfinkel DJ, Huffman GA, et al. Sequences homologous to *Agrobacterium rhizogenes* T-DNA in the genomes of uninfected plants. *Nature* 1983; 301(5898): 348–350. doi: 10.1038/301348a0
17. Furner IJ, Huffman GA, Amasino RM, et al. An *Agrobacterium* transformation in the evolution of the genus nicotiana. *Nature* 1986; 319(6052): 422–427. doi: 10.1038/319422a0
18. Matveeva TV, Bogomaz DI, Pavlova OA, et al. Horizontal gene transfer from genus *Agrobacterium* to the plant linaria in nature. *Molecular Plant-Microbe Interactions*® 2012; 25(12): 1542–1551. doi: 10.1094/mpmi-07-12-0169-r
19. Matveeva TV, Lutova LA. Horizontal gene transfer from *Agrobacterium* to plants. *Frontiers in Plant Science* 2014; 5. doi: 10.3389/fpls.2014.00326
20. Kreuze JF, Perez A, Untiveros M, et al. Complete viral genome sequence and discovery of novel viruses by deep sequencing of small RNAs: A generic method for diagnosis, discovery and sequencing of viruses. *Virology* 2009; 388(1): 1–7. doi: 10.1016/j.virol.2009.03.024
21. Kyndt T, Quispe D, Zhai H, et al. The genome of cultivated sweet potato contains *Agrobacterium* T-DNAs with expressed genes: An example of a naturally transgenic food crop. *Proceedings of the National Academy of Sciences* 2015; 112(18): 5844–5849. doi: 10.1073/pnas.1419685112
22. Yang J, Moeinzadeh MH, Kuhl H, et al. The haplotype-resolved genome sequence of hexaploid *Ipomoea batatas* reveals its evolutionary history. Available online: https://www.biorxiv.org/content/10.1101/064428v1.full.pdf (accessed on 6 July 2019).
23. Yang J, Fan W, Wang H, et al. Latest progress in genome sequencing of *Ipomoea* plants (Chinese). *Plant Physiology Journal* 2017; 53(5): 768–771.