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The Rise of Bt Genetically Modified Crops and Their Impact on Global Food Safety

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Abstract This review aims to explore the rise of Bt genetically modified crops and their impact on global food safety. The review introduced the historical background, basic principles, and application fields of Bt genetically modified crops, and elaborated on their important roles in increasing agricultural production yield, reducing pesticide use, improving soil health, and adapting to climate change. Through genetically modified technology, Bt crops can produce proteins with insecticidal activity, thereby reducing the use of pesticides and increasing yields. This technology is of great significance for the development of modern agriculture. The article also provides a detailed analysis of the global promotion and application of Bt genetically modified crops, as well as international policy and social acceptance. Discussed the food safety assessment of Bt genetically modified crops and their potential risks and issues, and proposed suggestions for relevant regulations and supervision. The rapid development of genetically modified technology has raised a series of global food safety issues. This study will explore the rise of Bt genetically modified crops and their impact on global food safety, while proposing possible solutions and future development directions.
Keywords Bt transgenic crops; Food safety; Pesticide use; Regulations and supervision

In the ever-developing fields of technology and agriculture, Bt transgenic crops have undoubtedly become a hot topic. As a controversial technology, it aims to reduce pesticide use, increase yields and adapt to the challenges of global climate change. As this technology continues to develop, many problems related to it have apparent increasingly. To this end, this review will focus on the rise of Bt genetically modified crops and global food security. Over the past few decades, Bt transgenic crops have experienced rapid development from laboratory research to commercial cultivation. However, it was accompanied by various voices of doubt and opposition. Concerns about the safety of Bt transgenic crops, worries about possible damage to the ecological balance, and disputes over their patent rights and seed monopoly have all contributed to this process (Thea et al., 2017).

The promotion and application of Bt transgenic crops has achieved remarkable results globally. Although its application still faces many challenges, including potential ecological risks, social acceptance, and intellectual property rights issues, these crops have already played an important role in agricultural production. By reducing pesticide use and increasing yields, Bt transgenic crops not only increase farmers' profits, but also help protect the ecological environment and reduce the risk of pesticide residues in food. However, the food safety issues of Bt transgenic crops are still the focus of public attention (Tabashnik and Carrière, 2017). Although years of research and evaluation have shown that these crops have no negative effects on human and animal health, there are still concerns about their potential risks. In addition, patent rights and seed monopoly issues related to Bt transgenic crops have also triggered a series of disputes. In response to these problems, relevant regulations and supervision systems need to be further improved to ensure the sustainability of food safety (Kumar et al., 2008).

Overall, Bt transgenic crops play an important role in the development of global agriculture. Although there are still some problems and controversies regarding its application, through scientific research and public participation, we can better understand and solve these problems. In the future, with the continuous advancement of technology and the improvement of the regulatory system, it is expected that Bt genetically modified crops can play a greater role in the agricultural revolution and make greater contributions to global food security and sustainable development (Nayak and Waterson, 2017) . This review will also provide an in-depth discussion of the

global promotion and application of Bt transgenic crops, including changes in international policy and social acceptance. On this basis, we will comprehensively evaluate the food safety issues of Bt transgenic crops. Discuss in detail its food safety assessment and its potential risks and issues, and make recommendations on relevant regulations and oversight. These recommendations aim to ensure the sustainability of food security while promoting the development of scientific and technological innovation in agriculture. The review summarizes the advantages and limitations of Bt transgenic crops, looks forward to the direction of future research and development, and explores how to overcome these limitations and further leverage the advantages of Bt transgenic crops through further scientific research and technological innovation.

1 Overview of Bt Transgenic Crops

1.1 History and development of Bt genetically modified crops

Bt transgenic crops are genetically engineered crops that contain a bacterial gene called Bt in their bodies. This gene produces a protein called Bt toxin, which can kill some specific pests, such as borers, locusts, etc. The history of Bt genetically modified crops can be traced back to the early 1990s, when scientists began to study how to introduce Bt genes into crops to make them insect-resistant. In the following years, many laboratories conducted a large amount of research and successfully introduced Bt genes into different crops, such as corn (*Zea mays* L), rice (*Oryza sativa* L.), etc (Kumar et al., 2008).

By the mid-1990s, some Bt transgenic crops began to be used in commercial production and application. Because these crops can effectively reduce the number of pests and improve crop yield and quality, they have been widely used in some countries. However, some problems have also emerged during the development of Bt transgenic crops. Some studies have shown that Bt toxins also have certain effects on some beneficial insects, which has caused concern among some environmental groups and farmers. In addition, the expression levels of Bt toxins in crops also vary. Some crops have low expression levels of Bt toxins and cannot effectively kill all pests, which has also caused concern among some farmers.

Despite some problems, Bt transgenic crops are still widely used around the world. In recent years, with the continuous progress of technology and in-depth research, scientists have developed some improved Bt transgenic crops, which have higher expression of Bt toxin, stronger lethality to pests and less impact on beneficial insects. In addition, some countries have adopted strict regulatory measures to ensure that the use of Bt genetically modified crops will not cause adverse effects on the environment and human health.

1.2 Scientific principles of Bt genetically modified crops

The principle of Bt transgenic crops is based on genetic engineering and molecular biology technology. By inserting the genes of Bt microorganisms into the DNA of crops, the crops have insect-resistant properties and can produce Bt toxins that are non-toxic to humans and other mammals. Bt is a microorganism found in the soil that produces a protein called Bt toxin. This toxin can kill certain insects, but it is not toxic to other organisms, including humans and other mammals (Thea et al., 2017).

Scientists use genetic engineering technology to insert the Bt gene into the DNA of Bt transgenic crop. The DNA of crops is the genetic information that guides the growth and development of crops. By inserting foreign genes (that is, genes from other organisms), we can change the genetic characteristics of crops. When crops grow, Bt toxins are produced in their bodies. So, how do Bt toxins kill pests? It mainly relies on the specific binding of Bt toxins to intestinal cells of pests. When pests eat crops containing Bt toxins, the toxins bind to intestinal cells and damage the cells, ultimately causing the pests to die. For humans and other mammals, because human cells do not have receptors that bind to Bt toxins, the human body cannot absorb and utilize this toxin, and will not produce a toxic reaction to it.

In addition, apart from the basic poisoning effect, scientists have also improved Bt transgenic crops through genetic engineering technology to enhance their killing power against pests and reduce their impact on beneficial insects. For example, it can be made more specific to certain pests by changing the genetic sequence of Bt toxin;

or make the content in crops can be more reasonable by adjusting the expression level of the toxin, thereby effectively killing pests while reduce impact on beneficial insects.

1.3 Main varieties and application fields of Bt transgenic crops

Bt transgenic crops are transgenic plant varieties using the Bt (*Bacillus thuringiensis*) gene. The Bt gene exists in a soil bacterium and has the ability to produce insecticidal crystal proteins, which have highly selective killing effects on a variety of pests. Therefore, Bt transgenic crops are widely used in the agricultural field, providing farmers with an effective biological control method.

At present, Bt transgenic technology has been successfully applied to multiple crop varieties, the most widely planted of which include corn, cotton, rice and soybeans (Figure 1). By embedding Bt genes to express insecticidal proteins, Bt corn can effectively control pests such as corn borers that burrow into the young ears of corn plants. Bt cotton uses the insecticidal protein encoded by the Bt gene to have a fatal impact on pests such as cotton bollworm, thus reducing farmers' investment in chemical pesticides and environmental pollution. In addition, Bt soybean is also a common Bt transgenic crop variety with aphid resistance (Thea et al., 2017).

Figure 1 Main genetically modified crops in China

Bt transgenic crops are widely used in agriculture. For example, Bt transgenic crops can effectively control pests, reduce farmers' use of pesticides, and reduce crop yield losses. Bt transgenic crops are also environmentally friendly and cause relatively little damage to non-target insects and the natural environment. Bt transgenic crops not only improve the yield and quality of crops, but also protect the ecological environment and human health. In addition, Bt transgenic technology has the potential to be applied to other crops and different fields, such as vegetables, fruit trees, and rice, as well as biopharmaceuticals in the medical field.

2 Global Promotion and Application of Bt Genetically Modified Crops

2.1 Use of Bt transgenic crops around the world

There are certain differences in the use of Bt genetically modified crops around the world. Bt transgenic crops are widely used in agriculture in many countries to increase crop yields, reduce dependence on chemical pesticides, and control pest damage. The United States is one of the major growing countries of Bt genetically modified crops. According to statistics, about 90% of the corn and cotton planting areas in the United States are planted with Bt genetically modified varieties, including pest-resistant Bt corn and Bt cotton. The widespread use of these genetically modified crops provides U.S. farmers with an effective pest control strategy that reduces pesticide use and helps increase crop yields (Figure 2).

China is also one of the important countries of the growth of Bt genetically modified crops. Currently, the main Bt genetically modified crops grown in China include corn and cotton. The application of Bt transgenic technology has played an important role in Chinese agriculture, reducing the use of external pesticides, improving crop yield and quality, and effectively controlling the damage of pests such as corn borers and cotton bollworms (Choi et al., 2019).

Figure 2 Labeling genetically modified crops in the United States

In addition to the United States and China, many other countries are also growing Bt genetically modified crops. Brazil is one of the world's largest producers of genetically modified cotton and genetically modified soybeans. Canada, Argentina, India, South Africa and other countries also cultivate Bt genetically modified crops to a certain extent. The application of Bt transgenic crops in these countries is mainly to increase crop yields, improve agricultural sustainability, and reduce the environmental impact of pesticide use (Kumar et al., 2008).

However, some countries have adopted policies to restrict or ban Bt genetically modified crops. Many EU member states have restricted or banned the cultivation of Bt genetically modified crops, mainly due to concerns about food safety and environmental impacts. Some other countries, such as Japan, South Korea and Pakistan, are also cautious in planting Bt genetically modified crops. The use of Bt transgenic crops varies around the world. Some countries have widely used Bt transgenic crops and achieved significant agricultural and environmental benefits. Some countries have a conservative attitude towards it or restrict its use. Different countries have their own unique considerations regarding the legislation and management of Bt genetically modified crops, including trade-offs between food safety, environmental protection and economic interests.

2.2 International policies and social acceptance of Bt genetically modified crops

There is a certain degree of diversity and controversy in international policies and social acceptance of Bt genetically modified crops. Different countries have different policy and regulatory formulations and social acceptance of Bt genetically modified crops, which depend on the country's legal framework, policy decision-making process, and public awareness and views on genetically modified technology.

At the international policy level, some countries allow or encourage the cultivation of Bt genetically modified crops, believing that they can increase crop yields, reduce pesticide use, and reduce environmental pollution. These countries have formulated corresponding laws and regulations on the planting, import and sale of genetically modified crops, providing certain support and supervision for agricultural production. However, other countries have a relatively conservative attitude towards Bt transgenic crops and have restricted or banned them. Issues of concern to these countries mainly include food safety, environmental risks and socioeconomic impacts. Some of these countries are concerned about the irreversible effects that genetically modified crops may have on ecosystems, or about the potential risks to human health from genetically modified ingredients in food. In addition, negative public opinion about GM technology has the potential to influence policy decisions and the legislative process.

Social acceptance is one of the important factors affecting the application of Bt transgenic crops. Public awareness and attitudes towards genetically modified technology have an important impact on policy and regulatory formulation. Some communities support Bt transgenic crops and believe that the agricultural and environmental benefits they bring need to be fully utilized (Kumar et al., 2008). However, others have doubts and concerns about genetically modified technology, worried about possible food safety issues, human health risks, and long-term impacts on the ecological environment. This kind of public opinion and controversy makes some governments need to take more into account the opinions and interests of the public when making decisions.

2.3 Capital investment and research and develop progress of Bt transgenic crops

For the research and development of Bt transgenic crops, many companies, research institutions and agricultural departments have invested a lot of money and human resources in the development and commercialization of Bt transgenic crops. In terms of research and development, research on Bt transgenic crops usually involves expertise in the fields of genetic engineering, biology, agricultural science and food safety. Many companies, such as Monsanto (now Bayer), the Australian Cotton Association and the Chinese Ministry of Science and Technology, have been committed to the research and development of Bt genetically modified crops over the past few decades. They continue to improve and optimize the traits, insect resistance and yield of Bt transgenic crops through gene cloning, construction of transgenic plant models, verification and testing (Tabashnik and Carrière, 2017).

Financial investment is one of the important driving forces for promoting the research and development of Bt transgenic crops. Large agricultural science and technology companies and national and regional government departments usually invest a lot of resources to support the research and development projects of Bt genetically modified crops. These funds are used for seed improvement, production technology research, long-term trials and market promotion. In addition, agricultural research institutions and universities also raise funds through government grants, partnerships, and private donations to promote the research and development of Bt transgenic crops.

With the continuous progress of research and development, Bt transgenic crops have been successfully commercialized and widely used in agricultural production in many countries. The scale of the genetically modified seed market continues to grow, and farmers' demands for higher yields, better insect resistance, and lower pesticide use have driven the promotion and cultivation of Bt genetically modified crops. Besiedes, new business opportunities have emerged in the market related to Bt genetically modified crops, such as the sale of genetically modified varieties and seed production.

3 Bt Transgenic Crops and Food Safety

3.1 Food safety assessment of Bt genetically modified crops

Bt transgenic crops are a widely used genetically modified crop whose genes have been modified to produce a protein called Bt toxin, which is expressed in plant cells to fight specific pests. However, given the potential presence of these GM crops in the food chain, food safety assessment becomes critical. Food safety assessment is a systematic process designed to evaluate any potential hazards or risks present in food. For Bt transgenic crops, the food safety assessment mainly focuses on the potential impact of Bt toxins. The assessment process is based on international regulations and conducted by experts to ensure its scientificity and reliability (Tabashnik, 2008) (Figure 3).

Food safety assessments need to determine whether Bt toxins have any negative effects on human health. Laboratory studies and animal testing are used to evaluate the acute toxicity, chronic toxicity, and allergenicity properties of Bt toxins. These experiments help determine whether Bt toxins are harmful to human consumers and identify potential risks. Food safety assessments also need to take into account the possible effects of Bt toxins on other organisms such as non-target insects, beneficial insects and soil organisms (Székács et al., 2018). This means that potentially exposed organisms in the environment need to be assessed to understand the potential harm to them from Bt toxins. In addition, when conducting food safety assessment, assess whether there are obvious changes in the genetically modified crops by comparing the composition and agricultural traits of the genetically modified crops with traditional control varieties (Figure 3). On the one hand, this is to ensure the food safety of genetically modified crops, and on the other hand, it is also to determine their potential environmental risks (James, 2003).

The aim of food safety assessment is to ensure the safety of Bt transgenic crops while also assessing their potential risks to the environment. This requires an assessment of potentially exposed organisms to understand the potential hazard of Bt toxins to other organisms. The entire process strictly follows international regulations and is conducted by experts to ensure the scientificity and reliability of the assessment.

Figure 3 Safety testing of genetically modified crops

3.2 Potential risks and problems of Bt genetically modified crops

Bt transgenic crops are widely used in agriculture, but their potential risks and problems have also attracted some attention. A major concern is the potential for negative effects on non-target insects. Bt transgenic crops resist specific pests by producing Bt toxins, but this toxin may also have a killing effect on other insects, including some insect species that are critical to agricultural ecosystems and biodiversity (Fung et al., 2018).

Another potential risk is evolutionary resistance. Long-term use of Bt transgenic crops may result in some pest populations becoming resistant to Bt toxins. This resistance may be caused by mutations in individual pests, and these resistance genes can be passed on in the population, thereby reducing the effectiveness of Bt transgenic crops against pests. Therefore, measures are needed to manage and delay the development of pest resistance to Bt toxins, which is crucial for long-term maintenance of the insect resistance of genetically modified crops (Smith, 2023).

Moreover, Bt transgenic crops also face the risk of potential impacts on soil organisms and ecosystems. Bt toxins may enter the soil through the residues of genetically modified crops and interact with microorganisms and other organisms in the soil. This may have an impact on the ecological functions of soil organisms and pose a potential threat to the stability and health of the soil ecosystem. Therefore, it is crucial to assess and monitor the long-term effects of Bt transgenic crops on soil ecosystems to ensure their sustainability in agricultural production.

3.3 Regulations and supervision of Bt genetically modified crops

Regulations and supervision of Bt genetically modified crops are important measures to ensure their safety and sustainability. Many countries have formulated relevant approval systems and regulations for genetically modified crops. These regulations require rigorous food safety assessments to ensure that Bt transgenic crops undergo adequate scientific evaluation and supervision before being marketed. Regulations require manufacturers to provide detailed data and research results to prove the safety and environmental suitability of genetically modified crops (Clark et al., 2005).

Regulators, of course, play an important role in the commercial promotion and use of GM crops. These agencies are responsible for supervising and controlling the production, sale and cultivation of genetically modified crops. They have strict requirements and standards for the introduction of genetically modified crops, setting and monitoring of planting areas, etc. to ensure their safety and traceability. Regulators also conduct sampling testing and regular monitoring of areas where genetically modified crops are grown to monitor the potential impact on the environment and non-target organisms.

Furthermore, international organizations and agreements also play an important regulatory role. For example, international agencies such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) have developed a series of norms and guiding principles for the evaluation and supervision of genetically modified crops. These agencies also assist countries in formulating standards and regulations for genetically

modified crops, strengthen international cooperation and information sharing, and promote global regulation of genetically modified crops and food safety.

The state formulates relevant regulations and approval systems, and regulatory agencies are responsible for supervising and controlling its production and planting processes. International organizations and agreements have strengthened international cooperation on genetically modified crop supervision and food safety. These measures collectively ensure the safety of Bt transgenic crops and the reliability of supervision.

4 Conclusion and Outlook

As an advanced agricultural technology, Bt transgenic crops have obvious advantages and some limitations. Overall, Bt transgenic crops show high insect resistance, reduce dependence on chemical pesticides, and reduce the risk of pesticide residues and environmental pollution. Besides, Bt transgenic crops also have great potential in reducing agricultural production costs, increasing yields and increasing farmers' income. However, Bt transgenic crops also face challenges, such as possible effects on non-target insects, the development of evolutionary resistance, and potential impacts on soil organisms and ecosystems.

Bt transgenic crops have a profound impact on global agriculture and food security. The most important point is that it provides a viable option to solve global food security problems. By improving the insect resistance of crops, Bt transgenic crops can increase crop yields and alleviate the shortage of agricultural products. In addition, reducing reliance on pesticides can improve food quality and reduce health risks from pesticide residues. Bt transgenic crops also have a positive impact on sustainable agriculture and environmental protection. Reducing the use of chemical pesticides can reduce the negative impact of agriculture on the environment and help protect ecosystems and maintain biodiversity. Nevertheless, supervision and risk assessment also need to be strengthened to ensure their safety and sustainability when promoting and applying Bt transgenic crops.

Future research and development of Bt genetically modified crops is recommended to strengthen scientific and transparent risk assessment and supervision systems. Continued research on non-target insects, pest resistance and soil ecosystems to better understand and manage potential risks. In addition, promote regional adaptability research on genetically modified crops and customize genetically modified crop varieties adapted to the characteristics of different regions and agricultural ecosystems to ensure their sustainability and effectiveness in various places. Through continued investment in research, strict supervision and rational use, its advantages can be further utilized to solve the pressure of global food demand and achieve sustainable agricultural development. Yet we also need to remain vigilant, conduct in-depth research on potential risks, and strengthen resource management and scientific supervision to ensure the sustainable development of Bt transgenic crops in a wider range and maximize their contribution to global agriculture and food security.

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