Transgenic Plants: Indian Perspective

Sreeya Baiju, Neha Senan, Amina. S

Department of Molecular Biology and Biotechnology, College of Agriculture, KAU, Vellayani, Kerala

Sreeya14baiju@gmail.com

Transgenic plants, often referred to as genetically modified organisms (GMOs), have transformed agriculture by introducing novel traits that enhance crop yield, resistance to pests, and tolerance to environmental stresses. The incorporation of foreign genes into plant genomes has led to the development of crops that promise to address food security, reduce reliance on chemical pesticides, and adapt to changing climatic conditions. Despite their potential, the acceptance of transgenic plants varies widely across the globe, with India taking a cautious approach. This article delves into the history and success stories of transgenic plants worldwide and in India, explores the specific genes incorporated into these crops, and discusses why India remains hesitant to fully embrace transgenics. Furthermore, it highlights the advantages of gene editing technologies over traditional transgenic approaches.

The History and Success of Transgenic Plants

The journey of transgenic plants began in the 1980s when scientistssuccessfully introduced foreign genes into plant genomes. The first commercially successful transgenic crop was the *Flavr Savr* tomato, released in the United States in 1994. It was engineered to have a longer shelf life by incorporating a gene that delayed the ripening process. Although the *Flavr Savr* tomato eventually failed in the market, it paved the way for the development of other transgenic crops that have had a profound impact on global agriculture.

One of the most significant successes in transgenic plants is the development of insect-resistant crops, such as Bt cotton. The *Bacillus thuringiensis* (Bt) gene was incorporated into cotton plants to produce a protein toxic to certain pests, particularly the bollworm. Since its commercial release in the United States in 1996, Bt cotton has been widely adopted in several countries, including China, India, and the United States. The introduction of Bt cotton dramatically reduced the need for chemical insecticides, leading to environmental and economic benefits.

Another landmark transgenic crop is herbicide-tolerant soyabeans, developed by incorporateing a gene from a bacterium that allows the plant to withstand the application of glyphosate, a common herbicide. This innovation has enabled farmers to control weeds more effectively, reducing labor costs and increasing yields. Today, herbicide-tolerant soybeans are widely grown in the United States, Brazil, and Argentina, among other countries.

In India, the adoption of transgenic crops has been limited, with Bt cotton being the only commercially approved transgenic crop. Introduced in 2002, Bt cotton has since been cultivated on millions of hectares, making India one of the largest producers of cotton globally. The incorporation of the Bt gene into cotton has significantly reduced pest infestations and increased cotton yields, benefiting millions of Indian farmers. However, despite the success of Bt cotton, the Indian government has been reluctant to approve other transgenic crops, such as Bt brinjal (eggplant) and genetically modified mustard, due to concerns over biosafety and potential impacts on biodiversity.

Genes Incorporated into Transgenic Plants and Their Purpose

The success of transgenic plants hinges on the strategic incorporation of foreign genes that confer desirable traits. One of the most widely used genes in transgenic crops is the Bt gene, derived from the bacterium Bacillus thuringiensis. This gene encodes a protein that is toxic to specific insect pests but safe for humans and other non-target organisms. The incorporation of the Bt gene into crops like cotton, maize, and rice has revolutionized pest management, reducing the need for chemical insecticides and minimizing environmental damage.

Another commonly used gene is the EPSPS (5-enolpyruvyl-shikimate-3-phosphate synthase) gene, derived from the bacterium *Agrobacterium tumefaciens*. This gene confers resistance to glyphosate, a broad-spectrum herbicide. By incorporating the EPSPS gene into crops such as soybeans, maize, and canola, scientists have created herbicide-tolerant plants that allow farmers to apply glyphosate to control weeds without harming the crop itself. This technology has simplified weed management and increased agricultural productivity.

In addition to pest and herbicide resistance, transgenic plants have been developed to enhance nutritional content, such as Golden Rice. Golden Rice is engineered to produce beta-carotene, a precursor of vitamin A, by incorporating genes from daffodils and bacteria. This biofortified crop

was developed to address vitamin-A deficiency in developing countries, a major cause of preventable blindness and child mortality. Although Golden Rice has faced regulatory and public acceptance challenges, it represents a significant advancement in using transgenic technology for nutritional improvement.

India's Caution towards Transgenics

Despite the potential benefits of transgenic crops, India has adopted a cautious approach to their commercialization. Several factors contribute to this hesitancy. One major concern is biosafety. Critics argue that the long-term environmental and health impacts of transgenic crops are not fully understood, and there is a risk of unintended consequences, such as gene flow to wild relatives, the emergence of resistant pests, and loss of biodiversity.

Another concern is the potential socio-economic impact on smallholder farmers. In India, agriculture is predominantly small-scale, and there are fears that the introduction of transgenic crops could lead to the marginalization of small farmers, who may struggle to afford the seeds and associated technologies. Additionally, there is apprehension that multinational corporations, which often hold patents on transgenic technologies, could monopolize the seed market, reducing farmers' autonomy.

Cultural and ethical considerations also play a role in India's stance on transgenics. Many in India view genetically modified organisms with suspicion, influenced by a combination of traditional agricultural practices, religious beliefs, and a desire to preserve indigenous biodiversity. Public opposition to transgenics has led to protests and legal challenges, further complicating the regulatory landscape.

The Advantages of Gene Editing Technologies

While transgenic approaches have faced opposition, the emergence of gene editing technologies, such as CRISPR-Cas9, offers a promising alternative. Unlike traditional transgenics, which involve the insertion of foreign genes into a plant's genome, gene editing allows for precise modifications of the plant's existing DNA. This can involve the deletion, insertion, or alteration of specific genes to achieve desired traits.

One of the key advantages of gene editing is its precision. Gene editing can target specific locations in the genome, reducing the risk of unintended effects. This precision also allows for the modification of traits that may be more difficult to achieve through traditional transgenics, such as drought tolerance or enhanced nutrient content.

Gene editing technologies are also more likely to gain public and regulatory acceptance. Since gene editing does not necessarily involve the introduction of foreign DNA, it is often viewed as a more "natural" approach to crop improvement. This perception, coupled with the potential for reduced regulatory hurdles, could accelerate the adoption of gene-edited crops in countries like India.

Moreover, gene editing is more accessible to a wider range of researchers and institutions, including those in developing countries. The technology is less expensive and easier to implement than traditional transgenic methods, which require sophisticated laboratories and extensive regulatory approval processes. This democratization of biotechnology could empower local scientists and farmers to develop crops tailored to specific regional needs, without reliance on multinational corporations.

Conclusion

Transgenic plants have undoubtedly transformed global agriculture, offering solutions to some of the most pressing challenges facing food production. However, their adoption has been uneven, with countries like India taking a cautious approach due to concerns over biosafety, socio-economic impacts, and public acceptance. As the debate over transgenics continues, the emergence of gene editing technologies offers a promising alternative that could overcome many of the limitations associated with traditional GMOs. With their precision, accessibility, and potential for broader acceptance, gene-edited crops could play a crucial role in the future of sustainable agriculture, both in India and around the world.

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