

## Use of Genetically Modified Soybean in Modern Agriculture

Rabia Ameen, Bushra Sadia, Imshal Azam, Esha Rauf and Fathima Jazeela

Centre of Agricultural Biochemistry and Biotechnology, University of Agriculture Faisalabad, Pakistan

\*Corresponding Author: [rabiaameen.bsbt.m.34@gmail.com](mailto:rabiaameen.bsbt.m.34@gmail.com)

### ABSTRACT

Soybeans are produced all over the world as a foundation of protein and oil used for nutrition and silage, also as an industrial raw ingredient for biofuel. Its yield and quality are adversely affected by extreme conditions, particularly during the germination stage. The world's food supply and food security are in danger due to ongoing climate change. Many molecular techniques have been developed to boost soybean output in order to address these problems. Genetically modified (GM) soybeans overcome many of the drawbacks of traditional soybean farming as a revolutionary development in global agriculture. Increased productivity and less chemical input have resulted from the introduction of features including pest resistance, herbicide tolerance, and higher nutritional quality through genetic engineering. The usage of genetically modified soybeans is investigated in consideration of public opinion, legal requirements, environmental effects, and their contribution to sustainable agriculture. It also explores the advantages and disadvantages of genetically modified crops, as well as regulatory implications. While analyzing cutting-edge technology like gene editing and CRISPR, it also draws attention to current issues including resistance development and ethical discussions. The future of GM soybean production globally will be shaped by balanced regulations, scientific progress, and consumer awareness.

**Keywords:** GM crops, Agricultural Biotechnology, Yield improvement, Bt gene, Precision Agriculture

**To cite this article:** Ameen R, B Sadia, I Azam, E Rauf & F Jazeela. Use of Genetically Modified Soybean in Modern Agriculture. Biological Times. 2025. July 4(7): 40-41.

### Introduction

Genetically modified (GM) crops are those whose genomes have been altered by genetic engineering methods in order to introduce a new characteristic that is not naturally present in the crop species or to enhance the qualities that are already there. Transgenic plants have specific foreign nucleic acids or gene sequence segments introduced into their genomes utilizing transformation procedures (such as direct gene transfer or Agrobacterium-mediated change). New genetically engineered soybean seeds are making farming easier and more productive by enabling farmers to grow more harvests with fewer chemicals. China was the first country to domesticate soybeans, which were subsequently brought to the United States and Brazil. Argentina, Brazil, and the United States currently produce the most soybeans worldwide, accounting for 16, 32, and 33% of total production, respectively. The production of soybeans is expected to rise by 311.1 and 371.3 million metric tons worldwide in 2020 and 2030, respectively [1]. Soybeans are a major source of vegetable oil and animal protein feed worldwide. Its oil content (18–22%) is second only to peanuts among dietary legumes, and its protein level (40–42%) is higher than that of any other crop [2].

Soybean has a variety of constraints that disrupt its value chain. The main limitations are the lack of soybean rust-resistant varieties and inoculants. Additionally, a few factors include poor productivity, low grain prices, disease (yellow rust), weed control problems, credit and information shortages, and low output [3]. The first industry to spend heavily in the advancement of genetic technologies is the agricultural sector. Human food crops and feed crops for livestock with marketable qualities have been created by the continuous Agri biotechnology research. The use of such instruments to repress and activate a specific feature in crops and transferring a gene from an incompatible source has led to the remarkable proliferation of genetically engineered crops.[4]. The production of GM crops has increased by more than 100 times in the last 25 years. As of 2019, one of the main GM crops grown is soybean (48.2%). The safety of genetically modified crops is frequently assessed by regulatory bodies based on their acceptability for consumption by humans, their consequences for the environment, and its potential impacts on the economy and society. Unlike transgenic plants which use DNA from foreign sources and mutagens to develop and select the desired traits, New Breeding Techniques (NBTs) use CRISPR/Cas9 technology making genetic alteration simple and quick to enhance agricultural research. Fig.1 [4].

### Traits of Genetically Modified Soybeans

#### Herbicide tolerance (e.g., glyphosate resistance)

In crop fields lacking proper weed management, yield losses due to weed competition typically range from 14% to 36%, but in severe cases, they can escalate to as high as 90% to 100%. The development of genome editing techniques, particularly CRISPR-Cas9, has created new opportunities for sustainable farming in the contemporary agricultural sector. Glyphosate-Resistant Crops (GR crops) have significantly altered weed control practices across the globe. A novel herbicide resistance technology named GT27TM Soybean Performance System which was first formed by Bayer

Crop Science and associated units deliberates resistance to glyphosate. Additional new HPPD-inhibiting herbicide, isoxaflutole (ALITE 27, formerly Balance Bean) is a useful preemergence only and is pending EPA registration as of July 2019. These technologies have had a significant impact on national agriculture [5]

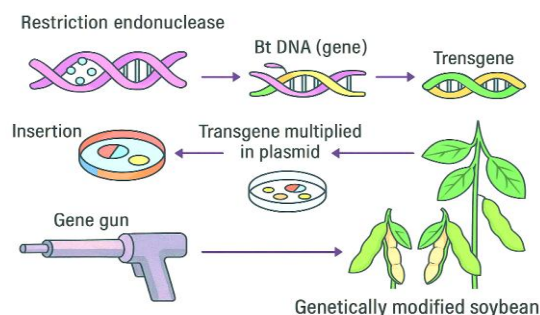


Fig. 1: Process of Creating Genetically Modified Soybean Using Bt Gene Transfer

### Insect resistance

In recent decades, crop yields have been significantly protected by the use of insecticides to control insect pests. Insect resistance is a key study topic in agricultural biotechnology that could increase agricultural output and offer much-needed pesticide substitutes that are economical, effective against pests, and safe for non-target organisms. The invasive soybean aphid, which was initially discovered in Wisconsin in 2000, was the first significant insect pest to endanger soybean production in the Midwest throughout most of its range. The soybean aphid can reduce output by up to 40% if left unchecked. The first of numerous Rag genes (resistance to Aphis glycines) was found by Hartman after screening 1530 cultivars: Rag1, a single dominant gene that confers antibiosis. The first attempts at breeding have concentrated on the Rag1 and Rag2 genes, which are both present in commercial cultivars but have a restricted distribution [6].

### Improved oil or protein quality

Since soybeans are a major oilseed crop that provide plant oil and protein for daily human needs, the two main objectives of soybean breeding are to increase yield and improve nutritional quality (high oil or protein). The amount and make-up of seed storage reserves have a direct impact on seed size. Generally speaking, over 60% of soybean seed storage is made up of protein and oil. Consequently, there is a strong correlation between the agronomical characteristics of soybean seed size, oil content, and protein content [7]. Numerous genotypes with notable variation for seed composition features have been identified as a result of the thorough screening of global soybean germplasm collections. These mutants' gene/QTL mapping and molecular characterization have clarified gene function and greatly expanded our understanding of the molecular underpinnings of seed composition features. The development of targeted mutagenesis methods like CRISPR/Cas9 and contemporary biotechnology

tools like siRNA has further created new avenues for altering the nutritional value of soybeans [8]

### Advantages of GM Soybeans in Modern Agriculture

#### Higher Yields

The main advantages of GM crops have the ability to yield more than conventional types. Characteristics like herbicide and insect resistance result in lower agricultural losses and better plant health.

#### Reduced Chemical Usage

GM crops require fewer chemical inputs such as pesticides and herbicides, particularly those that are developed for pest resistance. Repeated chemical spraying is not necessary with Bt crops since they naturally create proteins that are harmful to particular pests. This not only saves farmers money but also reduces the health hazards associated with exposure to chemicals.

#### Environmental Sustainability

Using GM crops that are resistant to herbicides encourages the use of conservation farming techniques like reduced-till or no-till farming. These methods lessen fuel consumption, minimize erosion, and maintain soil structure. Furthermore, less pesticide uses results in less water body contamination which benefits biodiversity and nearby ecosystems.

#### Economic Gains for Farmers

Because GM crops yield more and require fewer inputs of farmers that grow them are frequently more profitable. Smallholder farmers in developing nations have reported notable increases in income which enhances livelihoods and fosters rural economic growth.

#### Increased Food Security

GM technology provides crops that are resistant to pests, diseases, and environmental stress, ensuring consistent yields even in harsh climates. This consistency in production is essential for ensuring food availability and accessibility, especially in areas that are vulnerable to pest outbreaks, floods, or drought [9].

#### Environmental and Health Concerns

Genetically modified (GM) crops provide viable ways to increase agricultural output in the face of manmade challenges including climate change and the coronavirus disease 2019 (COVID-19) as well as the world's expanding population and rising food demand. Five EU nations cultivated 143,016 hectares of biotech crops in 2014, a 3% decline from the year before. In 2018, 26 countries cultivated 191.7 million hectares of biotech crops. Countries with the highest adoption rates were the United States, Brazil, Argentina, Canada, and India. Studies conducted in Southern Africa have demonstrated that the use of GMOs has increased crop resistance to a variety of biotic and abiotic stressors, farmer incomes, and food access. This development tackles issues that affect agricultural productivity and food production, including pests and illnesses, population expansion, starvation, COVID-19 pandemics, the unpredictability of climate change, and life-threatening weather occurrences like floods and droughts.

#### Public Perception and Regulatory Policies

GM crop policy implications include strict risk assessment and open regulation to protect the environment and promote innovation. Through science-based regulations, the approval process should be guided by clear guidelines, preserving public trust. Research has shown that the adoption of genetically modified crops varies by region. In Kenya, the Authority ensures safe GMO procedures via an open scientifically approved evaluation process, publishes biosafety guidelines, and authorizes importation, exportation, transit, and field test submissions for commodities like fiber, corn, and sorghum molasses. South Africa's engrained GMO controlling plan which covers every phase after growth and transportation to investigate, manufacture, and general publication, guarantees the ethical creation and usage of GMOs. Promoting the use of IPM techniques in conjunction with GM crops is one way that farmers can reduce pesticide use and maintain ecological balance. Encouraging crop diversification and rotation helps to integrate GM crops into larger sustainable farming systems by preserving soil health and lowering insect load. Farmers are also better prepared to manage GM crops when they get information and working out on GM crop organization with stewardship techniques and on resistance observation [10].

#### Challenges and Limitations

The cost and time required to generate a new variety have significantly increased due to public concerns and stringent government regulations on the arbitrary incorporation of transgenes in the genome. There are three primary limitations in the existing soybean transformation method for GE application: target genotype dependence, explant specificity, and GE result dependent. Technical difficulties like the inability to precisely mutate any target site, the lack of viable methods for transporting genome-editing agents into soja cells, the inability to choice anticipated proceedings and

redevelop whole plants with targeted alteration and offsite targeting are additional bottlenecks. Moreover, creating transgene- or DNA-free plants is still challenging and frequently takes several generations. Regulations and unresolved intellectual property rights, particularly in relation to CRISPR technology makes the marketing of genetically engineered soybean products even more challenging [11].

Furthermore, nothing is known about how soybeans can use CRISPR/Cas9 systems to resist biotic stressors such viruses, fungi, insects, etc. Up until now, the mainstream of study has intensive on improving CRISPR/Cas9 systems in soybeans. Genes that confer resistance to biotic stress, including resistance to bacteria, fungi, viruses, and insects, will be essential. Future research on CRISPR-assisted thorough analysis of soybean anti-nutritional genes will benefit the food sciences and animal feed sector. It has been observed that Agrobacterium genetic transformation of soybeans has a very poor efficiency. In such systems, promoters are helpful, but their efficiency and selectivity are quite poor. The CRISPR/Cas9 system benefits greatly from one such promoter system, germline-based promoters. The number of chimeras in converted soybeans is decreased by using germline-based promoters. Enhancing the effectiveness of NPBTs in soybeans may require the use of germline-based promoters [12].

#### Future Prospects and Innovations

Future investigations should concentrate on carrying out extensive, enduring studies towards evaluation of the environmental effects of genetically modified harvests by keeping an eye on biodiversity, gene flow, and soil health during several growing seasons. Understanding the wider ecological ramifications of GM crops requires examining their effects on ecosystem services including pollination, nitrogen cycling, and soil microbial communities. To fully understand the eco-friendly effects of particular GM traits across various crops and environments, trait-specific research is also required. Additionally, investigating the socioeconomic aspects of GM crop implementation such as grower maintenances and buyer receipt is essential aimed at well-knowledgeable policy development and executive. In general, optimizing the advantages of genetically modified crops while reducing environmental hazards requires well-informed legislation, sustainable practices, and ongoing research [13]

#### Conclusion

Genetically modified soybean is a resolution for many of the contests faced by traditional farming which represent a momentous progression in agronomic science. By reassuring justifiable farming practices, they lessen dependence on hazardous agrochemicals, upsurge yields, and inferior production expenses. However, there are downsides to the technique counting moral, legal, and biological apprehensions. The future of genetically modified soybeans depends on continued research, vibrant regulatory error, and open public statement. If GM soybeans are twisted and used appropriately, they could play a substantial role in feeding the world's intensifying population and guaranteeing agronomic suppleness in the aspect of ecological challenges.

#### References

- [1] Islam MS, Muhyidiyn I, Islam MR, Hasan MK, Hafeez AG, Hosen MM, Saneoka H, Ueda A, Liu L, Naz M, Barutçular C. Soybean and sustainable agriculture for food security. In: Soybean-recent advances in research and applications 2022 Apr 8. IntechOpen.
- [2] Hamza M, Basit AW, Shehzadi I, Tufail U, Hassan A, Hussain T, Siddique MU, Hayat HM. Global impact of soybean production: A review. *Asian Journal of Biochemistry, Genetics and Molecular Biology*. 2024 Jan 30;16(2):12-20.
- [3] Achamyelh K. Challenges and opportunities of soybean marketing in Chewaka District, Ethiopia. *Asian Journal of Economics, Business and Accounting*. 2020.
- [4] Sandhu R, Chaudhary N, Shams R, Dash KK. Genetically modified crops and sustainable development: navigating challenges and opportunities. *Food Science and Biotechnology*. 2025 Jan;34(2):307-23.
- [5] Kuang Y, Yu H, Qi F, Zhou X, Li X, Zhou H. Developing herbicide-resistant crops through genome editing technologies: A review. *Crop Protection*. 2024 Sep 1;183:106745.
- [6] Tilmont KJ, Michel A, O'Neal ME. Aphid resistance is the future for soybean production, and has been since 2004: efforts towards a wider use of host plant resistance in soybean. *Current Opinion in Insect Science*. 2021 Jun 1;45:53-8.
- [7] Duan Z, Li Q, Wang H, He X, Zhang M. Genetic regulatory networks of soybean seed size, oil and protein contents. *Frontiers in Plant Science*. 2023 Mar 7;14:1160418.
- [8] Gupta SK, Manjaya JG. Advances in improvement of soybean seed composition traits using genetic, genomic and biotechnological approaches. *Euphytica*. 2022 Jul;218(7):99.
- [9] Riaz M, Yasmeen E, Saleem B, Hameed MK, Saeed Almheiri MT, Saeed Al Mir RO, Alameri G, Khamis Alghafri JS, Gururani MA. Evolution of agricultural biotechnology is the paradigm shift in crop resilience and development: a review. *Frontiers in Plant Science*. 2025 Jun 19;16:1585826.
- [10] Ngongolo K, Mmbando GS. Necessities, environmental impact, and ecological sustainability of genetically modified (GM) crops. *Discover Agriculture*. 2025 Feb 22;3(1):29.
- [11] Xu H, Zhang L, Zhang K, Ran Y. Progresses, challenges, and prospects of genome editing in soybean (Glycine max). *Frontiers in Plant Science*. 2020 Oct 22;11:571138.
- [12] Rahman SU, McCoy E, Raza G, Ali Z, Mansoor S, Amin I. Improvement of soybean: A way forward transition from genetic engineering to new plant breeding technologies. *Molecular Biotechnology*. 2023 Feb;65(2):162-80.
- [13] Abdullah HM, Atta M, ul Haq I, Shah MA, Mubashar M, Hayat MK. SOYBEAN'S GENETIC ODYSSEY: UNVEILING DIVERSE TRANSFORMATION STRATEGIES.