Popular Article
Domain: Agriculture Science
Vol 4 Issue 10, October 2025, 5202-5206
TRENDS IN AGRICULTURE SCIENCE
ISSN:2583-7850

Genetically modified crops for shaping the future of agricultural innovations

Yashaswini R[1*], Sridhara M R[2], Raghavendra V C[1], Prem Sagar S P[1] and Sanjay M[3]
[1]Department of Genetics and Plant Breeding, University of Agricultural Sciences, Raichur - 584104 (Karnataka), India
[2]Department of Agronomy, University of Agricultural Sciences, Raichur - 584104 (Karnataka), India
[3]Department of Seed Science & Technology, University of Agricultural Sciences, Raichur - 584104 (Karnataka), India
*Corresponding author email: yashaswinirayanki1998@gmail.com
DOI:10.5281/TrendsinAgri.17427863

Abstract

Genetically modified crops have revolutionized modern agriculture by improving yield, pest and disease resistance and tolerance to environmental stresses. This article reviews their history, development process and global adoption. It highlights the benefits of GM crops in enhancing food security, reducing chemical use, conserving natural resources and improving farmer income. The article also discusses nutritional improvements like golden rice and future prospects for sustainable agriculture.

Introduction

Agriculture stands at the heart of human survival, yet it faces an uncertain future. As the global population races toward 10 billion by 2050, the demand for food, feed and fiber is set to soar. However, the very foundations of farming soil, water and climate are under increasing stress. Climate change, shrinking arable land, loss of biodiversity and overdependence on chemical inputs threaten both productivity and sustainability. Meanwhile, farmers must adapt to changing weather patterns, evolving pests and economic pressures, all while producing more with fewer resources. The coming decades will test humanity's ability to balance innovation with conservation to grow enough food without exhausting the planet that sustains us.

What are GM Crops?

Genetically modified (GM) crops are such crop plants whose genome is modified using

genetic engineering techniques to improve the existing traits or for introduction of a new trait that does not occur naturally in the given crop species.

History of GM crops

1982 - First genetically modified plant was produced which was an antibiotic-resistant tobacco plant.

1986 - First herbicide-resistant tobacco plant was produced and its first field trials occurs in USA and France.

1987 - A insect-resistant tobacco plant was produced by Plant Genetic Systems Company (Belgium).

1992 - China was the first country to allow commercialized transgenic plants and introducing a virus-resistant tobacco plant.

1994 - The first genetically modified crop approved for sale in the U.S., which was the *Flavr Savr tomato.*

1995 - *Bt*-potato was approved by the US Environmental Protection Agency

2000 - Vitamin A-enriched golden rice was developed

2011 - US, leading country in production of GM foods as 25 GM crops received regulatory approval.

2015 - 94 % of soybeans, 92 % of corn, and cotton produced in the US were of genetically modified strains.

2016 - A modified white button mushroom (*Agaricus bisporus)* received approval in USA.

Development of genetically modified crop

1. Identifying gene(s) giving a desired trait
2. Make copies of the gene
3. Transfer to plant tissue
4. Regenerate plants
5. Lab analysis and safety testing
6. Development of a variety
7. Field tests
8. Approval by Government agencies
9. Monitoring of safety

Table 1. Cultivation status of GM crops by top 10 countries (ISAAA, 2019)

Ranking	Country	Area (m ha)	Cultivated crop
1	USA	71.5	Maize, soybeans, cotton, alfalfa, canola, sugar beets, potatoes, papaya, squash, apples
2	Brazil	52.8	Soybeans, maize, cotton, sugarcane
3	Argentina	24.0	Soybean, maize, cotton, alfalfa
4	Canada	12.5	Canola, soybeans, maize sugar beets, alfalfa, potatoes
5	India	11.9	Cotton
6	Paraguay	4.1	Soybeans, maize, cotton

7	China	3.2	Cotton, papaya
8	South Africa	2.7	Maize, soybeans, cotton
9	Pakistan	2.5	Cotton
10	Bolivia	1.4	Soybeans,

The area under *Bt* cotton cultivation in India expanded sharply from less than 1 lakh hectare in 2002 to over 117 lakh hectares by 2019, now representing more than 95 per cent of the country's cotton area. This rapid adoption highlights the technology's central role in Indian cotton production, offering increased yields and reduced pesticide use.

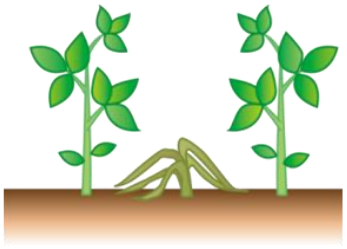
Why to produce GM food?

1. Traditionally, combining the desirable genes in one plant is a tough task that utilizes longer time and so much attention, involving crossing one plant to another plant of the same species or related species.
2. From economical and agricultural standpoints, it is advantageous to grow crops that have higher yield or improved quality, pest or disease resistance or tolerance to heat, cold and drought.
3. Desirable genes may provide means for plants to combat these conditions.
4. The development of transgenic technology allows useful genes from various living sources to be brought together in a relatively simple manner.

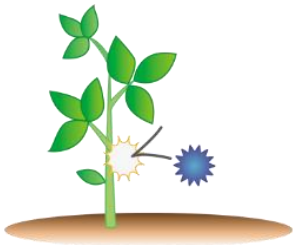
Contributions and potential of genetically modified crops

1. Stable supply of food

Contributions of GM crops that have been cultivated to date



Herbicide-tolerant Crops

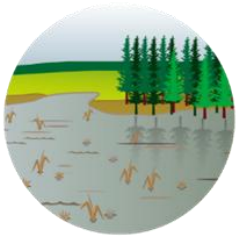


Disease-resistant Crops

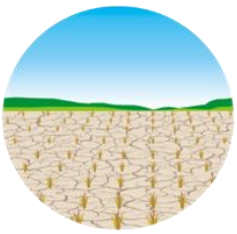
Insect-resistant Crops

GM crops under development

Drought-tolerant Crops



Flood-resistant Crops



Salt-resistant Crops

2. Conservation of the natural environment

- **Suppression of expansion of farmland area -** Without GM crops, 24 million hectares of new land would be required to maintain the production volume.

- **Reduction in the amount of emitted carbon dioxide -** Reduction in carbon dioxide emissions of 23 billion kg (equivalent to 15.27 million automobiles) in 2018, by reducing tractor fuel consumption and reducing soil carbon emissions into the atmosphere via no-tillage cultivation
- **Suppression of soil erosion -** Suppression of soil erosion and outflow of organic substances to rivers by no-tillage cultivation
- **Conservation of water resources -** The WEMA (Water Efficient Maize for Africa) project is developing corn possessing a combination of drought-tolerance and insect-resistance for small-scale farmers in the sub-Saharan region, via a joint effort by the public and private sectors.
- **Reduction in the amount of food waste -** GM apples and potatoes, which are resistant to browning caused by scratches or physical impact, enable the elimination of unnecessary disposal due to poor appearance.

3. Mitigation of the environmental impacts of agricultural chemicals

a. Reduction in agricultural chemical usage

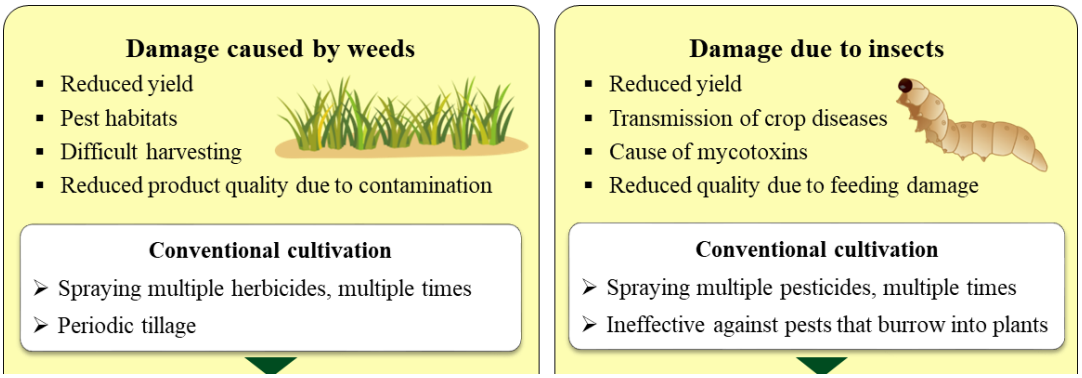
Agricultural chemicals are essential materials for agriculture. However, the impacts on the environment is an issue that must be considered at all times. Normally, farmers need to use pesticides and herbicides several times per year. This frequency can be reduced through the adoption of GM crops.

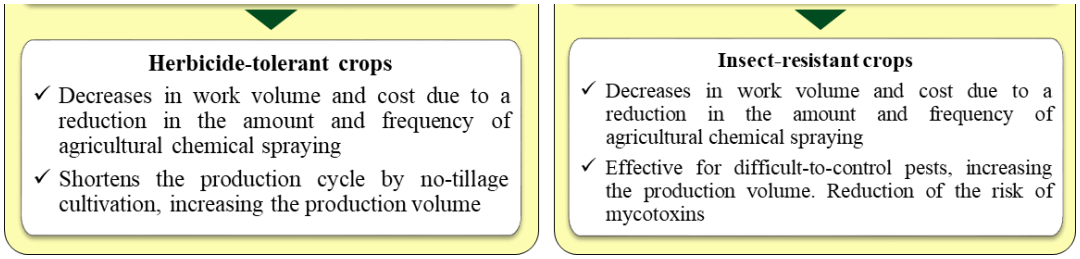
b. Replacement with agricultural chemicals with lower environmental impact

In addition to the reduction in agricultural chemical usage, the environmental impact quotient (EIQ, an index calculated using the toxicity and environmental exposure data of individual products to determine the impact of agricultural chemical use on the environment) has also decreased, because the agricultural chemicals used for GM crops impose a lower impact on the environment, compared with agricultural chemicals previously used.

4. Labor-saving and improved profitability for farmers

In 2018, the adoption of advanced crop technologies, such as *Bt* cotton led to a substantial increase in farmers' profit, averaging 68%. The aggregated rise in farmers' income globally amounted to 18.9 billion dollars with 52% of these economic gains benefiting producers in developing countries and 48% in developed countries. Importantly, 72% of the increased profit was attributable to improved crop yields, while the remaining 28% resulted from cost savings in cultivation practices.





5. Improving n`utritional status in poverty areas

Vitamin A deficiency

More than two billion people are said to be suffering from hidden hunger (micronutrient deficiencies, without a feeling of hunger) worldwide. In developing countries in Africa and Asia, 250,000 to 500,000 children have lost their sight each year due to vitamin A deficiency, half of whom have died within six months after going blind.

Development of golden rice

In order to improve vitamin A deficiency in such poverty-stricken areas through a staple diet, golden rice, which is a GM rice that produces beta-carotene, a precursor of vitamin A, is under development. Developing countries in need can utilize it free of charge.

Conclusion

Genetically modified (GM) crops play a vital role in improving agricultural productivity and sustainability. By introducing specific genes for desired traits, these crops show better yield, pest and disease resistance and tolerance to drought and heat stress. Their adoption worldwide has reduced pesticide use, minimized carbon emissions and increased farmers' income. Nutritionally enhanced crops such as golden rice offer solutions to vitamin and micronutrient deficiencies in developing regions. Continued scientific evaluation and strict regulatory monitoring are essential to ensure safety and public trust. Overall, GM crops provide an effective and science-based approach to meet future food demands under changing environmental conditions.

References

Aziz, M. A., Brini, F., Rouached, H., & Masmoudi, K. (2022). Genetically engineered crops for sustainably enhanced food production systems. *Frontiers in Plant Science, 13*, 1027828. https://doi.org/10.3389/fpls.2022.1027828

Government of India, Ministry of Textiles. (2020). *Cotton sector: Annexure-VII – Note on cotton sector*. Government of India, Ministry of Textiles.

ISAAA. (2019). *ISAAA Brief No. 55-2019: Global status of commercialized biotech/GM crops in 2019 – Biotech crops drive socio-economic development and sustainable environment in the new frontier*. International Service for the Acquisition of Agri-biotech Applications (ISAAA), Ithaca, NY, USA.

U.S. Food and Drug Administration (FDA). (2024). *Science and history of GMOs and other food modification processes*. U.S. Department of Health & Human Services. Retrieved from https://www.fda.gov