NexAvens
Scientific Library

OPEN ACCESS

NL Journal of Agriculture and Biotechnology

Review Article

Biotechnology in Indian Agriculture – Need for a Balanced Innovation

Dr. V. Basil Hans*

Corresponding Author: Dr. V. Basil Hans, Research professor at Srinivas University, Mangalore, Karnataka State, India.

Received Date: October 04- 2024
Publication Date: November 13- 2024

Volume 1 Issue 2 December 2024

Abstract: Agriculture has long fuelled India's economy, feeding and employing many. The sector faces climate change, resource constraints, and declining production. From genetically altered crops to advanced breeding, biotechnology can alleviate these issues. This article examines biotechnology's agricultural applications, economic benefits, and environmental impact in India. It concerns ethics, regulation, and public opposition to adoption. The essay uses case studies and government initiatives to demonstrate how biotechnology could transform Indian agriculture for sustainability and resilience. The analysis suggests balanced innovation is essential for food security, and environmental, and social well-being.

Keywords: Biotechnology, GM Crops, Sustainable Agriculture, Indian Agriculture, Tissue Culture, Regulatory Issues

Introduction

Agriculture is crucial to India's economy and society. An overview:

Agriculture accounts for 17-18% of India's GDP, however this has dropped as the service and manufacturing sectors have risen.

Agriculture is the largest sector in India, employing 50% of the workforce.

Rural Economy: 70% of rural India relies on agriculture. Many rural livelihoods depend on agriculture and related activities.

Indian rice, wheat, and pulse production is among the world's largest. Punjab, Haryana, Uttar Pradesh, and West Bengal grow rice and wheat as staples.

Sugarcane, cotton, jute, and oilseeds including mustard and groundnut are major cash crops for domestic and export.

Horticulture: India produces the most mangoes, bananas, potatoes, and onions.

Pepper, turmeric, and cardamom are key exports from the country.

1. Practices in agriculture

Traditional Farming: Small and marginal farmers make up a big component of Indian agriculture, which uses traditional methods.

In the Indo-Gangetic plains, irrigation systems are well-developed, but others depend on monsoons, making agriculture sensitive to weather changes.

Green Revolution: The 1960s Green Revolution increased food grain output by using high-yielding crops, chemical fertilizers, and sophisticated irrigation.

2. Challenges

Indian agriculture relies on monsoons. Uneven rainfall can cause droughts and floods, reducing crop yields.

Fragmented Landholdings: Small plots of land hinder size and mechanization for many farmers.

Low Productivity: Due to old farming methods, poor soil quality, and limited resources, India's per-hectare production is frequently lower than other countries.

Financial stress from crop failure, low prices, and debts has contributed to a high prevalence of farmer suicides in some regions.

3. Governing initiatives

minimal Support Prices (MSP): The government sets MSPs for particular crops to ensure farmers make a minimal profit margin, but this system has been criticized.

Farmer subsidies include seeds, fertilizers, power, and crop insurance and irrigation schemes like Pradhan Mantri Fasal Bima Yojana and Pradhan Mantri Krishi Sinchayee Yojana.

The government promotes organic and sustainable farming to lessen agriculture's environmental impact.

4. Emerging Trends

Agri-Tech: Drones, data analytics, and mobile apps are improving agricultural monitoring, market access, and resource management.

Diversification: Farmers are growing non-traditional crops, horticulture, and livestock to reduce risks and boost incomes.

Contract farming: Predetermined crop-specific partnerships between farmers and companies are growing.

5. Exports

India is a major exporter of grains, spices, cotton, and tea. Agriculture exports boost the economy.

6. Future View

Sustainability and climate resilience: Concerns about climate change are driving efforts to build robust agricultural methods and use resources sustainably.

Policy Reforms: Policy debates and reforms try to modernize agriculture, expand market access, and boost farmers' earnings, but they face resistance and acceptance.

Agriculture in India is complicated by natural circumstances, market dynamics, and government policy. Despite its challenges, it has great growth and innovation potential.

2. Innovation needed in Indian agriculture

Biotechnology in Indian agriculture can boost production, sustainability, and resilience. Innovation must be balanced to address the requirements of farmers, consumers, scientists, and politicians.

In India, there are around 47,000 plant species and at least two-thirds as many plant scientists. Traditional knowledge in India dates back over two millennia, while experimental plant research is about a century old. Nearly 200 Indian institutions, including 31 agricultural universities, >90 research institutes and centers, and a few private foundations and enterprises conduct plant biology research. The Indian Council of Agricultural Research (ICAR), Department of Science and Technology (DST), Department of Biotechnology (DBT), Council of Scientific and Industrial Research (CSIR), Department of Atomic Energy (DAE), University Grants Commission (UGC), and, to some extent, the Ministry of Environment and Forests fund most of these organizations' research. India invests ~0.1% of its GNP and 15.0% of its R&D in agricultural research and plant biology (Raghuram, 2002) [1].

More water management and irrigation schemes are needed.

• Rural education empowers farmers to innovate at the grassroots level.

• Private investment should rise, spurring larger technical advancements.

• Shiromani Shri Savata Mali Shetkari Athavade Baajar Abhiyaan for crop control with farmers.

Increase state government autonomy (National Human Rights Commission, 2022) [2].

2.1 Biotechnology's Role in Indian Agriculture

High-yielding, pest-resistant, and drought-tolerant crop varieties can be developed using biotechnology. This is crucial in India, where small landholdings and low productivity are typical.

Pest and Disease Resistance: GM crops can resist pests and diseases, decreasing the need for expensive, environmentally destructive pesticides.

Nutritional Enhancement: Biotechnology can improve staple crop nutrition in India, addressing malnutrition.

Climate resilience: Biotechnology can help develop crops that can endure droughts, floods, and heatwaves, which are becoming increasingly frequent owing to climate change.

Biotechnology can reduce chemical inputs, improve soil health, and conserve water for sustainable farming.

2.2 Issues

Safety and Environmental Impact: GM crops may cause gene flow to wild species and biodiversity loss, raising questions about their long-term safety for human use.

Economic and Social Issues: If small and marginal farmers cannot afford biotechnology, it may worsen economic inequality. Some multinational firms monopolize seeds, which raises concerns.

GM crop regulation in India is delayed, uneven, and opaque. A strong, science-based regulatory structure is needed to evaluate biotech technologies' safety and efficacy.

Public Perception and Acceptance: Due to technological ignorance, Indians are skeptical and resistant to GM crops. This has prompted protests and legal challenges against GM crop approval.

2.3. Indian Agriculture Biotechnology Status

The most successful biotechnology in Indian agriculture is Bt cotton, introduced in the early 2000s. It has greatly enhanced cotton yields and reduced pesticide use. It has also been criticized for raising expenses and relying on seed companies.

Bt brinjal (eggplant) and GM mustard have met regulatory challenges and public hostility, although Bt cotton is widely grown. Bt brinjal was allowed but later halted for safety reasons.

The Indian Council of Agricultural Research (ICAR) and other universities in India are producing GM crops and other biotech solutions. But commercialization of these innovations has been slow.

2.4. The Need for Balance

Regulatory Reforms: The agricultural biotechnology regulatory system must be clear, science-based, and responsive to safety and innovation concerns. This will increase public trust and ensure safe and effective technology approval.

Inclusive Innovation: Small and marginal farmers should have access to biotechnology. Public-sector research and economical biotech solutions can spread biotechnology's benefits.

Sustainability: Biotech breakthroughs should reduce chemical inputs, conserve resources, and protect biodiversity.

Public Engagement: Biotechnology education and engagement are needed. This includes openly discussing GM crop hazards and advantages and addressing stakeholder concerns, such as farmers, consumers, and environmentalists.

Policymakers should balance innovation, safety, ethics, and socioeconomic considerations. This includes encouraging public and private agricultural biotechnology investment with strict control and accountability.

Biotechnology can help Indian agriculture handle low productivity, climate change, and food security. To ensure safety, sustainability, and equity, its implementation must be handled carefully. India can maximise biotechnology's agricultural potential with legislative reforms, inclusive innovation, sustainability, and public participation.

3. Indian Agriculture Biotechnology History

Early global biotechnology developments

Modern biotechnology emerged in the 20th century, however biotechnology has a long history of thousands of years. The advanced techniques utilized in agriculture, health, and industry today were built on traditional and modern biotechnology. Key worldwide milestones:

3.1. Traditional Biotech

Fermentation: Microorganisms were used for fermentation in early biotechnology. Fermentation produced bread, beer, wine, and cheese in ancient civilizations. Early biological processes were used for human benefit.

Ancient Selective Breeding: Farmers and animal breeders have used selective breeding to better crops and livestock for thousands of years. Selecting plants or animals with favorable features and breeding them to improve them in future generations.

3.2. Nineteenth-century developments

Gregor Mendel's Pea Plant Experiments (1860s): Mendel discovered heredity and founded modern genetics. His work was not well known until the early 20th century, but biotechnology relied on it.

In the 1850s and 1880s, French microbiologist Louis Pasteur pioneered microbiology and biotechnology. He created the germ hypothesis of disease and pioneered pasteurization to eliminate hazardous bacteria in food and drinks.

3.3. Early 20th Century Innovations

The discovery of deoxyribonucleic acid (DNA) by Friedrich Miescher in 1869 and its double-helix structure by James Watson and Francis Crick in 1953 were landmarks in biotechnology. Genetic engineering required knowledge of DNA's role in inheritance.

In 1902, German botanist Gottlieb Haberlandt invented plant tissue culture, which permits plant cells to grow in a controlled environment. This early cellular biotechnology is now employed for plant propagation and genetic modification.

3.4. Mid-20th Century Innovations

Antibiotic Production (1928-1940s): Alexander Fleming discovered penicillin in 1928 and mass-produced it during World War II, starting the pharmaceutical industry's biotechnology application. Biotech study focused on microorganism-based antibiotic synthesis.

In the 1940s and 1950s, hybrid crops, especially hybrid corn, changed agriculture. Scientists increased agricultural yields and disease resistance by crossbreeding.

3.5. Modern Biotechnology Begins

In the early 1970s, scientists including Paul Berg, Stanley Cohen, and Herbert Boyer developed recombinant DNA technology, which launched modern biotechnology. This method lets scientists cut and splice DNA from diverse creatures to create GMOs.

Genentech and Synthetic Insulin (1978): The 1976-founded biotechnology company is the first to synthesize human insulin using recombinant DNA. Synthesising insulin in bacteria in 1978 led to the introduction of synthetic insulin for diabetics.

Cesar Milstein and Georges Kohler discovered monoclonal antibodies in 1975, allowing large-scale production of identical antibodies. This technology underpinned biotechnology in medicine, treating many ailments.

3.6. Late 20th-century advances

Kary Mullis invented the groundbreaking Polymerase Chain Reaction (PCR) (1983) to amplify DNA sequences. Genetic research, medical diagnostics, and forensics relied on it.

The first genetically engineered crops were commercialized in the 1990s. Monsanto introduced glyphosate-resistant Roundup Ready soybeans in 1996. This saw the widespread use of GM crops, changing farming practices worldwide.

The worldwide Human Genome Project (1990–2003) finally mapped the human genome in 2003. This major achievement paved the way for individualized medicine and sophisticated biotechnology in health and disease.

3.7. Ethical and regulatory developments

Biotechnology Regulation: As genetic engineering became more common, countries developed biotechnology regulations to protect safety and ethics. The FDA and EFSA set biotech product approval and monitoring guidelines.

Biotechnology's rapid achievements, especially in genetic alteration and cloning, spurred ethical questions. The patenting of life forms, GMOs' influence on biodiversity, and genetic prejudice were discussed.

From ancient fermentation and selective breeding to DNA discoveries and GM crops, biotechnology has changed modern agriculture, medicine, and industry. Biotechnology has grown significantly to solve global issues including food security, health, and environmental sustainability since these achievements.

4. Indian agriculture biotechnology adoption

The introduction of biotechnology in Indian agriculture has proven transformational but complicated. Biotechnology, especially genetic modification, can solve low productivity, pest infestations, and climate change. However, its implementation has been successful and controversial. How Indian agriculture has incorporated biotechnology:

4.1. Beginnings & Development

India began studying agricultural biotechnology in the 1980s, focusing on genetic engineering, molecular biology, and tissue culture. The Indian Council of Agricultural Research (ICAR) and agricultural universities were crucial to this research.

The 1986-founded Department of Biotechnology (DBT) and the Genetic Engineering Appraisal Committee (GEAC) under the Ministry of Environment, Forest, and Climate Change regulate biotechnology research and GMO release.

4.2. Bt Cotton: A Pioneering Adoption

The 2002 clearance of Bt cotton was India's biggest biotechnology milestone in agriculture. First commercially grown GM crop in India was bollworm-resistant Bt cotton.

Cotton production impact:

Bt cotton improved cotton yields, making India the world's largest cotton producer.

Since Bt cotton proved bollworm-resistant, chemical pesticide use decreased.

Due to improved yields and cheaper pesticide expenses, many farmers made more money.

4.3. Expanding Biotechnology in Agriculture

After the success of Bt cotton, research moved into Bt brinjal (eggplant), GM mustard, and GM rice. To improve yields, insect resistance, and nutrition, these crops were developed.

In 2009, Bt brinjal, genetically modified to withstand the fruit and shoot borer pest, was approved for commercial use. In 2010, public and environmental concerns prevented its marketing and imposed a cultivation moratorium.

4.4. Challenges and Disagreements

Public Disapproval and Ethics:

GM crops have been opposed by farmers, environmentalists, and consumers. GM crop health issues, biodiversity loss, and small farmer economic impacts are concerns.

Monopoly and Seed Dependency: Critics say GM crops have increased seed dependency on multinational firms, creating worries about seed sovereignty and GM seed pricing.

Issues with regulation and policy

lengthy Regulatory Approvals: India's GM crop approval process is lengthy and uneven, leaving farmers and biotechnology businesses uneasy.

GM crop bans in several states complicate adoption. Kerala and West Bengal strongly oppose GM crops.

4.5. Indian Agriculture Biotechnology Status

Bt Cotton Dominance: India's only commercially grown GM crop, Bt cotton, covers over 90% of cotton acreage. Pest resistance and higher cultivation costs have marred its success.

Research: India invests in agricultural biotechnology research to generate GM rice, maize, wheat, and oilseeds. Nutritional enhancement, drought tolerance, and salinity resistance are also studied.

In addition to GM crops, Indian agriculture is adopting biotechnology applications including biofortification and tissue culture to boost crop nutrition and plant propagation.

4.6. Government Support and Initiatives

Biotechnology Policies and Programs: The National Biotechnology Development Strategy, National Agricultural Innovation Project, and Department of Biotechnology financing encourage biotechnology in agriculture in India.

Biotechnology infrastructure, including research institutions and biotech parks, receives government subsidies. Public institutions should explore biotech solutions for small and marginal farmers.

4.7. Sustainability and Future

Sustainability Focus: Biotechnology is being used to generate climate-resilient crops that require fewer inputs (water, fertilizers, pesticides).

Despite biotechnology's popularity, India's organic and non-GM farming movements are robust. Biotechnology uptake and sustainability are difficult to balance.

GM Crop Expansion: India's GM crop future is questionable. Regulatory approvals, public acceptance, and government policy will determine expansion, especially in food crops like GM mustard.

Biotechnology in Indian agriculture has had a major influence, especially with Bt cotton. However, safety, economic impact, and sustainability issues have plagued it. For India to succeed in agriculture, biotechnology must be explored with a balanced strategy that balances innovation and stakeholder concerns.

5. Major events and government initiatives

The Indian biotechnology industry has grown rapidly, with notable milestones. Some prominent ones:

National Biotechnology Board established 1978

The NBTB was India's first government biotechnology promotion agency. This became the Department of Biotechnology (DBT) within the Ministry of Science and Technology in 1986.

Biotechnology Department established in 1986

DBT was created to promote biotechnology in India. It has helped advance field research, innovation, and entrepreneurship.

1990s: Vaccine Industry Growth

India became a vaccination powerhouse during this time. Serum Institute of India and Bharat Biotech became vaccine manufacturers.

2001: National Biotech Development Strategy launch

This plan guided India's biotechnology sector's people resources, infrastructure, research, and industrial expansion. It started an organized biotech development process.

2005 launched Biotechnology Industry Partnership Program

The BIPP promoted biotechnology public-private partnerships. It funded biotech firms with creative, socially beneficial projects.

6. Biotechnology Industry Research Assistance Council launched in 2010.

DBT created BIRAC as a non-profit to support biotech startups and SMEs. It has been vital in funding and mentoring biotech businesses.

2014: Make in India

This government program promoted India as a biotechnology industrial hub. Investments in biotech and pharmaceutical manufacturing increased.

India's COVID-19 Vaccine Development in 2020

Indian enterprises like Serum Institute of India and Bharat Biotech were crucial to the global COVID-19 vaccination initiative. By developing Covaxin by Bharat Biotech and mass producing Covishield by Serum Institute, India showed its biotechnology skills.

Launch of the 2021-2025 National Biotechnology Development Strategy

This new strategy sought to solidify India's biotechnology leadership. It promotes innovation, entrepreneurship, and a strong biotech environment.

Biopharma and Biosimilars Grow in 2022

India's biopharma sector, especially biosimilars, has flourished. Biocon leads biosimilar manufacture and global distribution, making India a prominent participant.

These milestones show India's growth from a biotech startup to a global hub for research, production, and innovation.

The Indian government has promoted biotechnology with many projects. These initiatives promote field research, innovation, entrepreneurship, and infrastructure. Here are some major Indian biotechnology government initiatives:

Department of Biotechnology

The principal government biotechnology development agency in India is DBT, founded in 1986. It supports research, infrastructure, and biotechnology in agriculture, healthcare, and industry.

The Biotechnology Industry Research Assistance Council

BIRAC, founded in 2012 under DBT, helps biotechnology startups and SMEs. It supports biotech research and commercialization through funding, mentorship, and incubation.

The Biotechnology Industry Partnership Program

DBT founded BIPP to promote biotechnology public-private collaborations. It funds biotech businesses' novel vaccination, diagnostic, and biofuel initiatives with great social benefit.

National Biotechnology Development Strategy

The 2007 strategy and 2021-2025 version aim to make India a biotechnology leader. It promotes innovation and entrepreneurship while enhancing research infrastructure, human resources, and the biotech industry.

National Biopharma Mission

This 2017 mission aims to accelerate biopharmaceutical product development in India. It targets vaccines, biosimilars, and medical devices to make India a biopharma hub for manufacturing and research.

Biotech Parks/Incubators

The government has created various biotechnology parks and incubators nationwide to support biotech startups and firms. These parks house R&D, testing, and pilot-scale production.

Indian Make Initiative

This 2014 project promotes India as a biotechnology manufacturing powerhouse. It promotes foreign and domestic biotech manufacturing investments to create jobs and strengthen the economy.

Atal Innovation Mission

AIM promotes biotechnology innovation and entrepreneurship under the NITI Aayog. It funds and supports entrepreneurs and promotes school and university innovation laboratories.

National Bio Entrepreneurship Contest

BIRAC's biennial NBEC competition promotes biotech entrepreneurship. Innovators can demonstrate their ideas and obtain cash, mentorship, and business development support.

India Startup Initiative

This 2016 effort assists biotechnology startups and others. Financial incentives, tax exemptions, and easier regulatory compliance help Indian biotech businesses grow.

Indian Grand Challenges

Grand Challenges India, a DBT-Bill & Melinda Gates Foundation partnership, funds research and innovation projects to address India's health and development issues. The initiative promotes vaccination, diagnostic, and maternal-child health innovation.

The National Mission on Quantum Technologies and Applications

Quantum computing for drug development and molecular modeling are the focus of this 2020 endeavor.

BIG Biotech Launch Grant

BIG, managed by BIRAC, funds biotech firms and entrepreneurs early on. It helps innovators commercialize their ideas.

National Integrated Bio-Ethanol Development Mission

This mission develops renewable biomass biofuels, including bio-ethanol. Biotechnology is used to minimize India's fossil fuel dependence and develop sustainable energy.

Indian innovation (i3)

This National Biopharma Mission project develops cheap vaccinations, biotherapeutics, and medical devices. It supports R&D, capacity building, and infrastructure to grow India's biopharma sector.

India has become a global leader in biotech innovation, production, and research due to these government initiatives.

7. Biotech Applications in Indian Agriculture

GM crops

Research on genetically modified Bacillus thuringiensis (Bt) cotton in India has primarily examined short-term effects and neglected other significant developments in cotton production. This Perspective compares Bt adoption with yields and other inputs at national and state-specific scales across 20 years using multiple data sources. The adoption of Bt cotton is a weak indicator of yield trends but a good indicator of initial pesticide reductions. Increases in fertilizer and other inputs boost yield. Bt cotton effectively controls one important pest, however because to resistance and increased non-target pests, farmers now spend more on pesticides than before Bt. The situation is likely to worsen (Kranthi & Stone, 2020) [3].

Bt cotton (Bacillus thuringiensis cotton) is GM to resist bollworm, a common cotton pest. Bt cotton was India's first GM crop certified for commercial production in 2002. Its introduction has affected India's agriculture, economy, environment, and society. An outline of its impact follows:

Due to bollworm resistance, Bt cotton yields have increased. Fewer crop losses have increased productivity and income for farmers.

Bt cotton reduces pesticide use, a major benefit. Before Bt cotton, farmers used insecticides to combat bollworm, which was expensive and harmful. Bt cotton reduces pesticide use, saving farmers money and health.

Indian Bt cotton adoption is rapid. By 2019, Bt cotton dominated India's cotton agriculture. This widespread adoption shows farmers' perceived benefits.

Increased Farmer Income: Higher yields and lower pesticide costs have increased farmers' incomes. Especially small and marginal farmers have benefited from this economic boost.

One of the world's largest cotton growers and exporters is India. Bt cotton has increased India's cotton production and quality, strengthening its position in the global cotton market.

While Bt cotton offers economic benefits, its high seed cost relative to regular seeds is an issue. The cost of these seeds has caused some farmers financial concern.

Chemical Use: Bt cotton farming reduces pesticide use, improving the environment. It has reduced pesticide runoff into waterways, soil deterioration, and agricultural worker pesticide-related health issues.

Bt toxin resistance has been reported in bollworms. This raises questions regarding Bt cotton's long-term sustainability and the necessity for new pest management methods or GM cultivars.

The impact of Bt cotton on beneficial insects and soil microbes has been debated. While the total impact is being researched, biodiversity and ecological balance are concerns.

Farmer Suicides: Bt cotton's relation with Indian farmer suicides is contentious. Critics say farmer suicides have increased due to the high cost of Bt seeds and crop failures. Some argue that debt, poor monsoons, and lack of credit also contribute to this link.

The introduction of Bt cotton has emphasized the need for increased farmer education and knowledge of GM crops. Bt cotton seeds planted without pest management have caused problems in several locations.

The only GM crop permitted for commercial production in India is Bt cotton. Due to Bt cotton concerns, regulatory and popular opposition to other GM crops has been strong.

Legal and ethical issues: Bt cotton seeds have been litigated over intellectual property rights and seed monopolies. These challenges pose ethical questions regarding multinational firms controlling seed technology.

To address resistance difficulties, second-generation Bt cotton cultivars with numerous Bt genes have been created and introduced. These variants attempt to preserve Bt cotton in India from pests and maintain its sustainability.

Diversification: Bt cotton has been successful, but increasingly, farmers are seeing the need to diversify and lessen crop dependence. This is crucial given climate change and the need for adaptable farming systems.

Many Indian farmers now earn more from Bt cotton, which has cut pesticide use and increased cotton productivity. However, resistance development, high seed costs, and socio-economic impacts on particular farming groups remain concerns. Bt cotton has also shaped Indian policy and public perception on GM crops.

Other GM crops coming

Eggplant Bt Brinjal

DMH-11 (GM Mustard)

Bt Rice

GM corn

Chickpea GM

GM Potato

Gold Rice

GM Soy

GM Sorghum

GM Banana

GM Groundnut

GM Sugarcane

8. Mistakes and lessons learned

According to Kumar and Mallick (2019) [5], there is no unanimity among scientific groups on the use of GM technology in rice biotechnology research in India. The first Indian Golden Rice experiment failed. Multiple inconsistencies in the Golden Rice experiment cast doubt on the scientific and technological reliability of GM technology. Overall, it casts question on Golden Rice's safety and predictability in India. The policy framework for GM technology, notably technical regulations, has design flaws and operator failures. The Intellectual Property Rights regime hinders rice biotechnology R&D in various ways. Rice biotechnology researchers reject such institutional frameworks by following Mertonian science.

The biotechnology business, which was $4 billion in 2011, aimed to reach $100 billion by 2025 (IFC, 2019) [4].

While biotechnology has improved agriculture, it has also failed and caused controversy. Future lessons can be learned from these issues. Here are some Indian agricultural biotechnology failures and controversies and their lessons:

Conclusions

Key points summary

1. Accepted Applications

Bt Cotton: Increased yields and lower pesticide use, although pest resistance in some places requires integrated pest management.

Drought-Tolerant Crops: Increased water resistance boosting productivity in drought-prone areas.

Golden Rice and Biofortified Crops: Improved public health and nutrition by addressing vitamin and nutrient deficits.

Tissue Culture: Improved banana yield and health by propagating crops disease-free.

Biofertilizers and Biopesticides: Improved soil health and reduced synthetic chemical use for sustainable farming.

2. Disputes and Failed

Due to safety and environmental concerns, Bt Brinjal faced popular opposition and regulatory delays, underlining the necessity for honest communication and risk assessments.

Failure of Some Biopesticides and Biofertilizers: Stressed the need for thorough testing and farmer feedback to assure efficacy and reliability.

The controversy over gene editing technology highlights the need for clear regulations and public education.

Seed Monopoly: Requested equitable pricing and farmer support to address seed affordability and access.

3. New Technologies

CRISPR-Cas9: Precise gene editing for crop traits, but regulatory and public acceptance issues.

Data-driven management and automation improve precision farming efficiency and sustainability.

Real-time data and predicted insights from IoT and AI improve farm management and efficiency.

Blockchain technology improves food safety and trust by tracing supply networks.

4. Sustainable Agriculture Roadmap

ssessment and Planning: Assess practices, define goals, and include stakeholders.

R&D: Sustainable crop types, insect resistance, soil health.

Launch trial initiatives, teach farmers, and scale successful techniques.

Regulation: Create supportive policies, assure safety and compliance, and promote public acceptability.

Assess impact, adapt strategy, and communicate outcomes.

Innovation and Future Directions: Promote holistic sustainability, innovation, and trend adaptation.

5. Lessons learned

Public engagement and transparency: Key to biotechnology innovation adoption and trust.

Integrated Management: Biotechnology and conventional methods improve efficiency and sustainability.

New technologies need rigorous testing and monitoring to assure reliability and safety.

Support and Education: Training and support aid new practice and technology adoption.

Ethics and Social Considerations: Sustainable growth requires ethical and equitable access.

References

1. Raghuram N. (February 2002). Indian plant adopts biotechnology. Trends in Plant Science, 7(2), 92-94.
2. National Human Rights Commission (April 2022). Indian agricultural productivity and innovation. Retrieved 2 3/10/2024 from https://nhrc.nic.in/sites/default/files/Group%205%20April_compressed.pdf.
3. Kranthi, K.R., Stone, G.D. Long-term effects of Bt cotton in India.Nat. Plants 6, 188-196 (2020). https://doi.org/10.1038/s41477-020-0615-5
4. IFC (2019). Indian Biotech Landscape. An international view. Retrieved 23/10/2024 from https://birac.nic.in/webcontent/1574377200_Bio_Technology_Report.pdf.
5. Kumar, A., Mallick, S. (2019). GMO Controversies: Socio-political Constructal of Rice Biotechnology Research Innovations in India. Asian Journal of Social Science, 47(4-5), 607-630.Asian Journal of Social Science.

Citation: Dr. V. Basil Hans. "Biotechnology in Indian Agriculture – Need for a Balanced Innovation". NL Journal of Agriculture and Biotechnology 1.2 (2024): 12-22.