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Prasanna S,

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No. 08, Arul Nagar, Seera Thoppu,

Maudhanda Kurichi, Srirangam,

Tiruchirappalli – 620102

Phone : +91 94896 71437 - info@iledu.in / Chairman@iledu.in

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BIOTECHNOLOGY IN AGRICULTURE

AUTHOR - M. ANNIE DEVADHARSHINI, LLM SCHOLAR AT DEPARTMENT OF HUMAN RIGHTS AND DUTIES EDUCATION. SCHOOL OF EXCELLENCE IN LAW, TAMILNADU DR.AMBEDKAR LAW UNIVERSTITY

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ABSTRACT

Bio-Technology has become a cornerstone in transforming agriculture, enhancing crop yields, resilience, and nutritional quality through Genetic Modification(GM) and other innovative techniques. This article examines both the positive and negative impacts of the biotechnology in agriculture. On the Positive side, biotechnology enhances food availability, decreases reliance on chemical inputs, and improve nutrition, particularly in regions with limited access to diverse diets and promote sustainable farming practices. As agriculture increasingly shifts towards a commercial industry, biotechnology also supports large-scale production, efficient resources use, and enhanced profitability. The negative impacts are, the widespread use of genetically modification crops has raised concerns about biodiversity loss and potential ecological risks. To address these, India enforces strict biodiversity guidelines under the National Biodiversity Act,2000. The patenting of biotech seeds by large corporations leads to dependency among small farmers who may struggle to afford the high costs of the GM seeds. The Protection of Plant Varieties and Farmers Rights Act,2001 offers some safeguards by protecting farmers rights to save and reuse seeds. Food Safety and Standards Authority of India (FSSAI) require extensive testing and labelling of GM foods to ensure safety of the human beings. This article address that how agricultural biotechnology being used, and its benefits, and its safety considerations and also address the risks and ethical concerns. Overall, while biotechnology has contributed significantly to India's agricultural growth, the government's regulatory framework is crucial to manage risks, ensure ethical practices, and protect the environment, carefully balanced to safeguard human rights, and ensuring that biotechnology benefits are distributed equitably across India's diverse farming landscape.

KEY WORDS: Biotechnology, Genetic Modification (GM), Agriculture Transformation, Crop Yields, Nutritional Quality, Food Security, Sustainable Practices, Chemical Inputs Reduction, Biodiversity Concerns, Ecological Risks.

INTRODUCTION:

Human influence on biotechnology in agriculture has led to profound advancements that have reshaped food production and crop management. By harnessing biotechnology, humans have developed genetically modified (GM) crops that are resistant to pests, diseases, and environmental stresses. These innovations have significantly boosted crop yields, ensuring a more stable food supply and helping to meet the demands of a growing global population. Additionally, biotechnology has been used to enhance the nutritional content of crops, like Golden Rice, which is enriched with Vitamin A to combat malnutrition. These biotechnological tools have made agriculture more resilient to climate change by producing crops that can better withstand drought, heat, and other stresses, making agriculture more adaptive in the face of global climate challenges.

However, the human impact on agricultural biotechnology also brings about ethical, environmental, and socio-economic challenges. The dominance of certain GM crops can reduce biodiversity, as traditional crop varieties are often neglected in favor of high-yield or pest-resistant strains. This can weaken ecosystems and make them more vulnerable to pest outbreaks and diseases. The rise of herbicide-resistant "superweeds" and pesticide-resistant pests is another unintended consequence of biotech crop reliance, potentially leading to increased chemical use. Furthermore, the intellectual property rights associated with biotech seeds can place financial strain on small-scale farmers, creating dependency on biotech companies and limiting traditional seed-saving practices. These issues highlight the need for careful consideration and responsible management of biotechnology in agriculture to balance its benefits with the potential long-term impacts on ecosystems, food security, and farmer livelihoods.

CONCEPT OF BIOTECHNOLOGY:

The term Biotechnology was first used in 1919 by the Hungarian engineer Karl Erky. Biotechnology is technology based on biology - biotechnology harnesses cellular and biomolecular processes to develop technologies and products that help improve our lives and the health of our planet[54]. Biotechnology is defined as a set of tools that uses living organisms (or part of organisms) to make or modify a product, improve plants, trees or animals, or develop microorganisms for specific uses. We have used the biological processes of microorganisms for more than 6,000 years to make useful food products, such as bread and cheese, and to preserve dairy products.

CONCEPT OF ARICULTURAL BIOTECHNOLOGY:

Biotechnology in agriculture, also known as agri-biotech, involves the application of scientific and engineering principles to modify and utilize biological systems, organisms, or derivatives to create or enhance agricultural products, processes, and practices. Agricultural biotechnology is the term used in crop and livestock improvement through biotechnology tools. This monograph will focus only on agricultural crop biotechnology. Biotechnology encompasses a number of tools and elements of conventional breeding techniques, bioinformatics, microbiology, molecular genetics, biochemistry, plant physiology, and molecular biology.[55]

The biotechnology tools that are important for agricultural biotechnology includes:

- Conservational plant breeding
- Tissues culture and micropropagation
- Molecular breeding or marker assisted selection
- Genetic engineering and GM crops
- Molecular diagnostic tools

In essence, agri-biotech aims to improve crop yields, enhance nutritional quality, protect against pests and diseases, and ensure sustainable farming practices. It leverages the power of modern biology to tackle agricultural challenges and innovate solutions for better productivity and environmental stewardship.

HISTORY OF BIOTECHNOLOGY IN AGRICULTURE:

Traditional biotechnologies have been used for thousands of years, including the utilisation of yeast to produce wine and bread. Understanding the fundamentals of heredity has given framers new methods of breeding crops and animals ever since the late 19th century. They created hybrid crops by choosing certain organisms that had advantaged traits.

Since the 1954 discovery of the DNA structure, new techniques have been created. For instance, it is possible to modify plant genetics to make them resistant to pests or disease, and microorganisms may be employed to create medications.

By creating medications and other remedies for illnesses, boosting food yields,

[54] www.bio.org/what-biotechnology

[55] John Smith, "Advances in Agricultural Biotechnology," GreenTech Publications, 2022, p. 45.

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lowering environmental pollution, etc., modern biotechnology continues to have a significant positive influence on prolonging human longevity and improving quality of life. Plant and crops may be modified through biotechnology to survive external stressors like spatial constrains or extreme weather.

A range of scientific techniques are used in agricultural biotechnology to enhance plants, animals, and microbes. On the basis of their understanding of DNA scientists have created methods to increase agricultural output. Based on their capacity to recognise genes that are advantageous to certain crops and their ability to precisely control these features, breeders are better able to improve crops and livestock. The improvements possible through biotechnology are not possible with simple traditional close-breeding.

About 6000 years ago, humans began using microbial biological processes to make bread, alcoholic beverages, cheese and preserve dairy products.

1. **EARLY DOMESTICATION (CIRCA 10,000 B.C.):** Early humans began domesticating wild plants and animals, selecting for desirable traits such as larger seeds, better taste, and easier cultivation. This was the earliest form of agricultural biotechnology[56].
2. **SELECTIVE BREEDING:** Over centuries, farmers continued to select and breed plants and animals to enhance specific traits, leading to improved crop varieties and livestock.
3. **GREEN REVOLUTION (1930s-1960s):** The introduction of agrochemicals like fertilizers and pesticides significantly boosted agricultural productivity[57]. This period also saw the development of high-yield crop varieties.
4. **MOLECULAR BIOLOGY ERA (1970s-1980s):** Advances in molecular biology and genetic engineering allowed scientists to directly modify the genetic material of organisms. This led to the development of genetically modified (GM) crops with traits such as pest resistance and herbicide tolerance.
5. **COMMERCIALIZATION (1990S-PRESENT):** The first GM food product was commercialized in 1990. Since then, biotechnology has become a cornerstone of modern agriculture, with millions of farmers worldwide adopting GM crops.
6. **CURRENT TRENDS:** Today, biotechnology continues to evolve with new techniques like CRISPR gene editing, which allows for precise modifications in the genome. The focus is on sustainability, climate resilience, and improving nutritional content.

Biotechnology has transformed agriculture from its early days of simple domestication to a sophisticated science that addresses global food security and environmental challenges.

INTERNATIONAL CONVENTIONS RELATED TO AGRICULTURAL BIOTECHNOLOGY:

The International Convention for Agricultural Biotechnology primarily refers to various international agreements and protocols that address the use of biotechnology in agriculture.

1.CONVENTION ON BIOLOGICAL DIVERSITY 1992:

The Convention on Biological Diversity (CBD) is a international treaty that was adopted on June 5, 1992, during the Earth Summit in Rio de Janeiro, Brazil. The CBD aims to conserve the world's biological diversity, promote sustainable use of its components, and ensure fair and equitable sharing of benefits arising from the utilization of genetic resources. The convention recognizes that biological diversity is essential for sustaining the planet's ecosystems and providing resources necessary for human survival and well-being.

56 https://www.nature.com
57 https://www.embibe.com

Three Main Goals:

1. **Conservation of Biological Diversity**: Protecting ecosystems, species, and genetic diversity to maintain the health of the planet.
2. **Sustainable Use of Its Components**: Ensuring that the use of biological resources does not lead to their long-term decline, thereby maintaining ecosystem services.
3. **Fair and Equitable Sharing of Benefits**: Ensuring that the benefits derived from genetic resources (e.g., in agriculture, pharmaceuticals) are shared fairly, particularly with the countries where these resources originate.

Article 15 - Access to genetic resources:

It establishes the framework for access to genetic resources and the fair and equitable sharing of benefits arising from their utilization. It highlights the importance of access to genetic resources for biotechnology applications in agriculture.

Article 16 - Access to and Transfer of Technology:

It emphasizes the need to promote access to and transfer of technologies, including biotechnology, that are relevant to the conservation and sustainable use of biological diversity. It encourages the sharing of biotechnological innovations that can help improve agricultural practices.

Article 19 - Handling of Biotechnology and Distribution of its Benefits:

It specifically addresses the need for the handling of biotechnology in a way that benefits all parties involved. It acknowledges the importance of ensuring that biotechnology applications do not adversely impact biological diversity and that benefits derived from such applications are shared fairly.

2. CARTAGENA PROTOCOL ON BIOSAFETY 2000:

The Cartagena Protocol on Biosafety is a supplementary agreement to the Convention on Biological Diversity (CBD), adopted in 2000 and entered into force on September 11, 2003. Its primary focus is on the safe handling, transport, and use of living modified organisms (LMOs) resulting from modern biotechnology that may have adverse effects on biological diversity, taking also into account risks to human health.

The emphasis on **risk assessment in Article 10** is particularly relevant to agricultural biotechnology because it addresses concerns regarding the potential impacts of genetically modified organisms (GMOs) on crops, soil health, pest and disease management, and overall ecosystem integrity. This article helps to ensure that agricultural practices utilizing biotechnological innovations are conducted safely and sustainably, minimizing risks to biodiversity and human health.

By ensuring rigorous risk assessments, the Cartagena Protocol supports the responsible use of biotechnology in agriculture, promoting food security and sustainable agricultural practices while protecting the environment.

3.INTERNATIONAL TREATY ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE (ITPGRFA) 2001:

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), adopted in 2001, includes several provisions that are directly related to biotechnology in agriculture. These provisions emphasize the conservation and sustainable use of plant genetic resources and the fair and equitable sharing of benefits arising from their use, particularly in the context of modern biotechnological advancements. Here are some relevant aspects:

Article 5 - Conservation, Exploration, Collection, Characterization, Evaluation, and Documentation of Plant Genetic Resources for Food and Agriculture:

Promotes the conservation of plant genetic resources, including through modern biotechnological methods.

Encourages countries to take measures to ensure that plant genetic resources are sustainably used and conserved.

Article 6 - Sustainable Use of Plant Genetic Resources:

Advocates for the development and promotion of a diverse range of plant varieties, including those enhanced through biotechnology, to foster food security and sustainable agriculture.

Encourages the use of biotechnology to improve the conservation and utilization of plant genetic resources.

Article 7 - National Commitments, International Cooperation, and Technical Assistance:

Highlights the importance of international cooperation and technical assistance in the sustainable use of plant genetic resources, including the sharing of biotechnological advancements and expertise.

Article 9 - Farmers' Rights:

Recognizes the rights of farmers to save, use, exchange, and sell farm-saved seed/propagating material, which is crucial for maintaining agricultural biodiversity and can be supported through biotechnology.

Article 13 - Benefit-sharing in the Multilateral System:

Ensures the fair and equitable sharing of benefits arising from the use of plant genetic resources, including those derived from biotechnology, through mechanisms such as exchange of information, access to and transfer of technology, capacity-building, and sharing of monetary and other benefits.

These articles collectively emphasize the role of biotechnology in enhancing the conservation and sustainable use of plant genetic resources. The treaty recognizes the importance of modern biotechnological tools in improving crop varieties and ensuring food security while promoting the equitable sharing of benefits among all stakeholders.

4.FOOD AND AGRICULTURE ORGANIZATION 1945:

The Food and Agriculture Organization (FAO) has established several guidelines to address biotechnology and food safety, particularly concerning the assessment and regulation of genetically modified organisms (GMOs) in agriculture. These guidelines are essential for ensuring that biotechnological innovations are safe for human consumption and environmentally sustainable.

- **Overview of FAO Guidelines on Biotechnology and Food Safety:**

The FAO guidelines provide comprehensive recommendations for the risk assessment and management of GMOs, helping countries establish regulatory frameworks that ensure the safety and efficacy of biotechnological applications in food production. These guidelines are aimed at facilitating international trade while protecting human health and the environment.

- **FAO/WHO Guidelines for the Risk Assessment of Foods Derived from Recombinant-DNA Plants:**

These guidelines provide a framework for assessing the safety of foods derived from plants modified through recombinant-DNA technology. They serve as a reference for national authorities involved in food safety assessments.

- **FAO's Technical Guidelines on the Biosafety of Transgenic Plants:**

These technical guidelines focus on the biosafety assessment of transgenic (genetically modified) plants, providing recommendations for risk assessment and management practices that ensure environmental protection.

5.FOOD SAFETY AND STANDARDS ACT, 2006:

The **Food Safety and Standards Authority of India (FSSAI)** is a regulatory body has been established under **Food Safety and**

Standards, 2006 which consolidates various acts & orders that have hitherto handled food related issues in various Ministries and Departments. The FSSAI collaborates with other governmental bodies, such as the **Ministry of Agriculture and Farmers' Welfare** and the **Genetic Engineering Appraisal Committee (GEAC)**, to assess and regulate GMOs, ensuring that food safety standards are upheld.

The FSSAI plays a vital role in regulating biotechnology in agriculture through the Food Safety and Standards Act, 2006. By establishing safety standards and guidelines for GM foods, the FSSAI ensures that biotechnological innovations are safe for consumers while promoting public confidence in the food supply. The sections of the FSSAI Act relevant to biotechnology highlight the authority's commitment to ensuring food safety and protecting public health in the context of agricultural biotechnology.

HOW IS AGRICULTURAL BIOTECHNOLOGY BEING USED?

Biotechnology provides farmers with tools that can make production very cheaper and manageable. For example, biotechnology crops can be engineered to tolerate specific herbicides, which make weed control simpler and more efficient. These crop production options could help countries keep pace with demands for food while reducing production costs.

Many other types of plants are now in the research and development stages. Though it is not possible to know exactly which will come to fruition, certainly biotechnology will have highly varied uses for agriculture in the future. Developers are using biotechnology to try to reduce saturated fats in cooking oils, reduce allergens in foods, and also increase disease-fighting nutrients in foods. They are researching was to use genetically engineered crops in the production of new medicines, which may lead to a new plant-made pharmaceutical industry that can reduce the costs of production using a sustainable resource.

Though, genetically engineered plants are being developed for a purpose known as phytoremediation in which the plants detoxify pollutants in the soil or absorb and accumulate polluting substances out of the soil so that the plants can be harvested and disposed of safety. In case the result is improved soil quality at a polluted site. To produce hardier crops that will flourish in even the harshest environments and that will need less fuel, labor, fertilizer, and water helping to decrease the pressures on land and wildlife habitats.

IMPORTANCE OF AGRICULTURAL BIOTECHNOLOGY:

Biotechnology can be a boon to Indian agriculture in several ways. Crop damage can be minimized through disease and pest resistant varieties through reducing the use of chemical. The Indian pepper crop is now ravaged by the dieback disease, as the banana is being ambushed by the bunchy top disease, sorghum eroded by downy mildew, and the coconut is crippled by the wilt problem. Conventional plant breeding has little ammunition to deal with these problems expediently and efficiently. India has serious problems of the blast in rice, rust in wheat, leaf rust in coffee, viruses in tomato and chillies and leaf spot in groundnut across the country. These problems can be minimized in an ecologically-friendly manner with the development of genetically reprogrammed seeds designed to resist these disease attacks while minimizing or even eliminating costly and hazardous pesticide sprays.

The strategic integration of agricultural biotechnology tools into India agricultural system can revolutionize Indian farming and usher in a new era in the countryside. Comparing to the "green revolution", the "gene revolution" scales neutral, benefiting big and small farmers alike. It is environmentally friendly. Therefore, it can be of great help to the smallest farmer with limited resources, in increasing farm productivity through the availability of improved but powerful seed. It can reduce his dependency on chemical inputs such as pesticides and fertilizer. India unequivocally needs the help of technologies to march into the next century with a vision for economic upliftment and prosperity for its two-thirds of populace dependent on farming.

The Government of India's Department of biotechnology and other scientific agencies have done admirable work to deal with the safety issues of GM crops by developing a strong, reliable, and trustworthy regulatory mechanism. The existing biosafety framework now requires that all genetically modified organisms should undergo a rigorous review and safety assessment before their import, field testing, or release. The government should enhance its legal system by instituting penalties for those who do not follow the regulations, strengthen and enforce its anti-trust laws to prevent monopolies, and impose product-liability laws to force corporate responsibility.

APPLICATION OF BIOTECHNOLOGY IN AGRICULTURE:

The application of biotechnology in agriculture mainly involves scientific techniques such as Genetically Modified Organisms, Bt Cotton, and Pest Resistant Plants. It helps in modifying plants, animals, and microorganisms and improves their agricultural productivity. Techniques like vaccines, tissue culture, and genetic engineering are also used.

Genetically Modified Organism- Biotechnology has both Genetically modified and Non-Genetically modified applications in agriculture. It has made the plant breeding procedure more precise and quick. The Non-genetically modified application involves tools like Marker Assisted Selection, Tissue Culture, and Mutation breeding, etc. The Genetically modified technology is being used in world agriculture. It has applications such as insect control, weed management, water use efficiency, nitrogen use efficiency, and salinity tolerance, etc which help us to grow our crops with less pesticide and under difficult abiotic stress conditions. Genetically Modified technology can help in conserving soil and the environment through reduced tilling and pesticide use.

Genetically modified organisms are plants, animals, bacteria, or fungi whose genes have been modified by genetic manipulation. Genetically modified crops are used in the following ways:

- They are more tolerant of stresses such as drought, cold and heat, etc.
- They are pest-resistant and so less dependent on chemical pesticides.
- Genetically modified crops help to reduce post-harvest losses.
- They also help to increase the mineral usage by plants, thereby preventing early exhaustion of soil fertility.
- Genetically modified plants have enhanced nutritional value. An example is Vitamin A enriched rice.

AGRICULTURAL BIOTECHNOLOGY PRODUCTS:

(i) VACCINES BENEITS OF AGRICULTURAL BIOTECHNOLOGY:

New vaccines employing green biotechnology innovation are changing the processes of preventing illnesses, mainly in developing countries. Genetically modified crops have a significant contribution to the development of vaccines. Foods that are fruits, grains, and vegetables are engineered to carry antigenic proteins that are extracted from pathogens. When injected into the body and these antigens trigger an immune response and boost the resistance of the body against the pathogens. An example is an anti-lymphoma vaccine that's obtained from tobacco.

(ii) PLANT AND ANIMAL REPRODUCTION BENEFITS OF AGRICULTURAL BIOTECHNOLOGY:

The use of traditional methods such as cross-pollination, grafting, and cross-breeding to enhance the behavioural patterns of plants and animals is time-consuming. Artificial insemination, embryo transfer, and associated technologies are used in managing the reproductive functions of an animals and influencing the traits of the resultant offspring. Then, these improvements have increased agricultural productivity in developing countries and enhanced their capabilities to sustain the growing population.

(iii) ANTIBIOTICS:

Agricultural biotechnology is applied in the production of antibiotics for humans and animals. Animal antibiotics formed through this technology are low cost but equally as efficient as traditionally manufactured antibiotics. While these antibiotics are obtained from plants, a large quality of the product can be obtained at a time. Also, there is the ease of purification and the risk of contamination is minimized as compared to the use of mammalian cells and culture media in antibiotics production.

(iv) NUTRITIONAL BENEFITS OF AGRICULTURAL BIOTECHNOLOGY:

In a bid to promote better human health, scientists have come up with ways to create genetically modified foods with nutrients that can help fight disease. A great example of such foods is the golden rice which has beta carotene, a major source of Vitamin A in the body.

The name of the rice comes from the color of the transgenic grain made from three genes they are two from daffodils and one from the bacterium. The genes are cloned to create the rice "golden". People who eat this rice supplement their diet with the vitamin and other nutrients that may not be getting from other foods.

Scientists are creating genetically altered foods that contain nutrients known to help fight disease or malnourishment, to improve human health, mainly in underdeveloped countries. An example of this is Golden Rice, which has beta-carotene, the precursor for Vitamin A production in our bodies.

(v) PESTICIDE RESISTANT CROP BENEFITS OF AGRICULTURAL BIOTECHNOLOGY:

Biotechnology in agriculture has led to the engineering of plants that are resistant to pesticides. This allows framers to selectively kill weeds without harming their crops. The technology was first introduced in genetically modified soybeans, making them resistant to the herbicide glyphosate. The herbicide can be applied in copious amounts to elimination of weeds saves farmers' valuable time as compared to the traditional process of weeding.

For many years, a microbe called Bacillus thuringiensis (Bt) has been used to dust crops by producing toxic proteins against pests. Scientists have come up with a way to eliminate the use of Bacillus thuringiensis by introducing pest-resistant crops. These are called Bt crops as the gene that's introduced in the crop was originally identified in Bacillus thuringiensis. Examples if pest-resistant plants today are Bt maize, potato, and corn. This toxic protein is harmful to pests but is safe for humans. And it has saved farmers from dealing with expensive pest infestations in crops.

(vi) FLOWERS:

Biotechnology is not just about developing genetically modified foods and crops it has some aesthetic application as well. There is more biotechnology than just fighting disease or improving foods quality. An example of this is the use of gene identification and transfer techniques to improve the color, size, and other features of flowers. Also, biotech has been used to make improvements to other common ornamental plants, in particular, shrubs and trees. Some of these changes are similar to those made to plants, such as enhancing the cold resistance of a breed of the tropical plant so that it can be grown in gardens.

IS CROP BIOTECHNOLOGY SAFE?

Biotechnology is safe, effective and widely used by more than 18 million farmers around the world biotechnology is a proven tools that has successfully improved crop productivity for growers, resulting in an abundant and affordable food supply. Different studies have shown the safety of technology to human being, animals, and the environment.

BENEFITS OF AGRICULTURAL BIOTECHNOLOGY:

1. INCREASED CROP YIELDS:

Biotechnology has greatly improved the amount of food we can grow. By using genetic engineering, scientists have developed crops that produce more food per plant. For example, genetically modified (GM) crops like Bt cotton and Roundup Ready soybeans are designed to be more productive. Bt cotton contains a protein that protects it from pests, which means farmers can get higher yields without needing as many pesticides.

Research shows that these GM crops can increase yields by 10-20%. This boost is crucial as we work to feed a growing global population. Higher crop yields help ensure that we can produce enough food while using fewer resources, making farming more efficient and effective.

2. PEST AND DISEASE RESISTANCE:

Another major advantage of biotechnology is the development of crops that resist pests and diseases. Traditional farming often relies on chemical pesticides to protect crops, but biotechnology offers a different approach. By engineering crops to be naturally resistant to insects and diseases, we can reduce the need for harmful chemicals.

For instance, scientists have created rice varieties that are resistant to the rice blast fungus, which can otherwise cause significant crop losses. These disease-resistant crops not only help protect food supplies but also reduce the environmental impact of pesticide use, making farming practices more sustainable.

3. ENHANCED NUTRITIONAL VALUE:

Biotechnology also helps improve the nutritional quality of our food. Through a process called biofortification, scientists can increase the levels of important vitamins and minerals in crops. One well-known example is Golden Rice, which has been modified to provide higher amounts of Vitamin A.

Vitamin A deficiency is a serious health issue in many developing countries, and Golden Rice offers a way to combat this problem. By enhancing the nutritional content of staple foods, biotechnology can help address malnutrition and improve public health.

4. SUSTAINABLE AGRICULTURAL PRACTICES:

Sustainability is a key focus of modern agriculture, and biotechnology contributes significantly to this goal. Biotech innovations help reduce the environmental impact of farming by making it possible to use fewer resources like water, fertilizers, and pesticides. For example, some biotech crops require less water and fewer chemicals, which helps conserve natural resources and reduces pollution.

In addition to conserving resources, these practices support soil health and biodiversity. By minimizing chemical use, biotechnology helps maintain healthy soil and supports a diverse range of organisms that are crucial for a balanced ecosystem.

5. EFFICIENT RESOURCE UTILIZATION:

Biotechnology also improves how efficiently resources are used in farming. Advanced technologies, like precision agriculture, use data to help farmers apply resources more effectively. This means that water, fertilizers, and other inputs are used more precisely, which reduces waste and boosts crop productivity.

Farmers benefit from these advancements through higher yields and lower costs. Efficient resource use not only helps increase profits but also promotes long-term sustainability by ensuring that resources are managed carefully and responsibly.

6. CLIMATE CHANGE ADAPTATION:

As climate change affects weather patterns and growing conditions, biotechnology offers solutions to help crops adapt. Scientists are developing crops that can handle extreme weather conditions, such as droughts and floods. These resilient crops are designed to use water more efficiently and survive in challenging conditions.

Drought-resistant crops, for example, help maintain food production even during periods of water scarcity. These advancements are essential for securing food supplies in a changing climate and will continue to be important as we face future environmental challenges.

AGRICULTURE IN COMMERCIAL INDUSTRY:

Agriculture in the commercial industry involves large-scale production and distribution of agricultural products aimed at sale, emphasizing efficiency, productivity, and profitability. It include large farms and agribusinesses that utilize advanced technologies, such as precision agriculture and automated equipment, to maximize output. The sector is market-oriented, integrating into global supply chains while responding to consumer demands for organic and sustainably sourced products. Financially, commercial farmers have better access to capital and employ risk management strategies to navigate market fluctuations.

ARTIFICIAL INTELLIGENCE IN AGRICULTURE:

AI will have significant global impact on agricultural productivity at all levels of the value chain. According to CB Insights, agricultural tech startups have raised over USD800million in the last 5 years. Deals for startups using robotics and machine learning to solve problems in agriculture started gaining momentum in 2014, in line with the rising interest in AI across multiple industries like healthcare, finance, and commerce. From analysing millions of satellite images to finding healthy strains of plant microbiome, these startups have raised over USD500 million to bring AI and robotics to agriculture.

In 2016, approximately 50 Indian agricultural, technology based startups ('AgTech') raised USD313 million17. For the first time, this sector is seeing widespread participation by startups. Intello Labs, for example, uses image-recognition software to monitor crops and predict farm yields. Aibono uses agri data science and AI to provide solutions to stabilise crop yields. Trithi Robotics uses drone technology to allow farmers to monitor crops in real time and provide precise analysis of their soil. SatSure, a startup with roots in India, uses ML techniques to assess images of farms and predict economic value of their future yield.

Use of AI and related technologies have the potential to impact productivity and efficiency at all of the above stages of the agricultural value chain.

- **Soil health monitoring and restoration:** Image recognition and deep learning models have enabled distributed soil health monitoring without the need of laboratory testing infrastructure. AI solutions integrated with data signals from remote satellites, as well as local image capture in the farm, have made it possible for farmers to take immediate actions to restore soil health.
- **Crop health monitoring and providing real time action advisories to farmers:** The Indian agriculture sector is vulnerable to climate change due to being rain dependent. Varying weather patterns such as increase in temperature, changes in precipitation levels, and ground water density, can affect farmers especially in the rainfed areas of the country. AI can be used to predict advisories for sowing, pest control, input control can help in ensuring increased income and providing stability for the agricultural community. For example, many

agronomic factors (such as vegetation health and soil moisture) can be monitored up to the farm level through remote sensing. Using remote sensed data, high resolution weather data, AI technologies, and AI platform, it is possible to monitor crops holistically and provide additional insights to the extension workers/farmers for their farms as & when required.

- **Increasing efficiency of farm mechanisation:** Image classification tools combined with remote and local sensed data can bring a revolutionary change in utilisation and efficiency of farm machinery, in areas of weed removal, early disease identification, produce harvesting and grading. Horticultural practices require a lot of monitoring at all levels of plant growth and AI tools provide round the clock monitoring of these high value products.

THE POSSIBLE RISKS ASSOCIATED WITH USING TRANSGENIC CROPS IN AGRICULTURE:

Some consumers and environmentalists feel that inadequate effort has been made to understand the dangers in the use of transgenic crops, including their potential long-term impacts. Some consumer-advocate and environmental groups have demanded the abandonment of genetic engineering research and development. Many individuals, when confronted with conflicting and con fusing statements about the effect of genetic engineer ing on our environment and food supply, experience a "dread fear" that inspires great anxiety. This fear can be aroused by only a minimal amount of information or, in some cases, misinformation. With people thus concerned for their health and the well-being of our planetary ecology, the issues related to their concerns need to be addressed. These issues and fears can be divided into three groups: health, environmental, and social.

HEALTH-RELATED ISSUES:

Allergens and toxins:

People with food allergies have an unusual immune re action when they are exposed to specific proteins, called allergens, in food. About 2% of the population has food allergies, which occur when the immune system reacts to specific proteins called allergens. While most foods are safe for the majority, individuals with allergies typically react to one or a few allergens in specific foods. The genetic engineering is the potential introduction of new allergens or toxins. The FDA monitors allergen levels in transgenic foods to ensure they remain within normal ranges, and transgenic technology is being explored to remove allergens from high-risk foods like peanuts.

Antibiotic resistance:

Antibiotic resistance genes are often used as markers during genetic modification to confirm successful gene transfer. However, this practice raises fears about the emergence of antibiotic-resistant bacterial strains. Although the risk of gene transfer from plants to bacteria is much lower than natural bacterial gene transfer, the FDA advises caution. It recommends that developers avoid using antibiotic resistance markers that confer resistance to clinically important antibiotics to protect public health while ensuring the safety of genetically modified foods.

ENVIRONMENTAL AND ECOLOGICAL ISSUES:

Potential gene escape and superweeds:

There is a belief among some opponents of genetic engineering technology that transgenic crops might cross pollinate with related weeds, possibly resulting in "superweeds" that become more difficult to control. One concern is that pollen transfer from glyphosate-resistant crops to related weeds can confer resistance to glyphosate. While the chance of this happening, although extremely small, is not inconceivable, resistance to a specific herbicide does not mean that the plant is resistant to other herbicides, so affected weeds could still be controlled with other products.

Some people are worried that genetic engineering could conceivably improve a plant's ability to "escape" into the wild and produce ecological imbalances or disasters. Most crop plants have significant limitations in their growth and seed dispersal habits that prevent them from surviving long without constant nurture by humans, and they are thus unlikely to thrive in the wild as weeds.

Impacts on "nontarget" species:

Some environmentalists maintain that once transgenic crops have been released into the environment, they could have unforeseen and undesirable effects. Although transgenic crops are rigorously tested before being made commercially available, not every potential impact can be foreseen. Bt corn, for instance, produces a very specific pesticide intended to kill only pests that feed on the corn. In 1999, however, researchers at Cornell University found that pollen from Bt corn could kill cater pillars of the harmless Monarch butterfly. When they fed Monarch caterpillars milkweed dusted with Bt corn pollen in the laboratory, half of the larvae died. But follow-up field studies showed that under real-life conditions Monarch butterfly caterpillars are highly unlikely to come into contact with pollen from Bt corn that has drifted onto milkweed leaves—or to eat enough of it to harm them.

Insecticide resistance:

Another concern related to the potential impact of agricultural biotechnology on the environment involves the question of whether insect pests could develop resistance to crop-protection features of transgenic crops. There is fear that large-scale adoption of Bt crops will result in rapid build-up of resistance in pest populations. Insects possess a remarkable capacity to adapt to selective pressures, but to date, despite widespread planting of Bt crops, no Bt tolerance in targeted insect pests has been detected.

Loss of biodiversity:

Many environmentalists, including farmers, are very concerned about the loss of biodiversity in our natural environment. Increased adoption of conventionally bred crops raised similar concerns in the past century, which led to extensive efforts to collect and store seeds of as many varieties as possible of all major crops. These "heritage" collections in the USA and elsewhere are maintained and used by plant breeders. Modern biotechnology has dramatically increased our knowledge of how genes express themselves and highlighted the importance of preserving genetic material, and agricultural bio technologists also want to make sure that we maintain the pool of genetic diversity of crop plants needed for the future. While transgenic crops help ensure a reliable supply of basic foodstuffs, U.S. markets for specialty crop varieties and locally grown produce appear to be expanding rather than diminishing. Thus the use of genetically modified crops is unlikely to negatively impact biodiversity.

SOCIAL ISSUES:

Labelling:

Some consumer groups argue that foods derived from genetically engineered crops should carry a special label. In the USA, these foods currently must be labelled only if they are nutritionally different from a conventional food.

"TERMINATOR" TECHNOLOGY:

Most farmers in the USA and elsewhere buy fresh seeds each season, particularly of such crops as corn, green peppers, and tomatoes. Anyone growing hybrid varieties must buy new seeds annually, because seeds from last year's hybrids grown on the farm will not produce plants identical to the parent. For this same reason—to avoid random genetic diversity due to open pollination—farmers do not plant mango, avocado, or macadamia from seed; instead, they clone individual plants of known quality through techniques such as grafting.

In developing countries, many farmers who are not growing hybrids save harvested seeds for replanting the next year's crop. A technology has been developed that might be used to prevent purchasers of transgenic crop seeds from saving and replanting them. Such "termina tor" seeds are genetically engineered, along with other improvements more acceptable to farmers, to produce plants with seeds that have poor germination. This forces farmers who otherwise save seed to purchase it if they wish to use these improved commercial varieties. And, in the USA, the crops engineered with various characters are sold alongside non-transgenic alternatives for which growers also typically purchase seeds annually.

Despite these mitigating circumstances, this is serious issue among organic growers and in developing countries, where the practice of saving seeds is the norm for farmers who are not growing hybrid crops. Inclusion of "terminator" genes means that these farmers cannot take advantage of improvements brought about by genetic engineering without being brought into the eco nomic cycle that profits the seed companies. Without profit incentive, however, these companies are unlikely to invest in improving crops. This issue is analogous to that faced by pharmaceutical companies developing new medications against human diseases. Clearly, it is a difficult and divisive social issue.

JUDICIAL DECISIONS:

1.The "Roundup Ready" Patent Controversy:

The legal battles surrounding Monsanto's "Roundup Ready" crops have been significant. Farmers have faced lawsuits for using patented seeds without permission, often after inadvertently obtaining them through cross-pollination. The case of **Monsanto Co. v. Bowman (2013)** reached the U.S. Supreme Court, which ruled that a farmer could not use seeds from a patented crop for replanting without paying royalties to Monsanto. This ruling reinforced the enforcement of patent rights in biotechnology and raised discussions about the implications for farmers and seed sovereignty.

2.Starlink Corn Incident (2000):

Starlink corn was a genetically modified variety developed by Aventis (now part of Bayer) designed to be resistant to pests. However, it was approved only for animal feed and not for human consumption due to concerns that it might cause allergic reactions in some individuals.

In 2000, traces of Starlink corn were discovered in taco shells and other human food products, leading to widespread consumer fear and recall of affected products. The incident raised significant concerns about the regulatory processes in place for GMOs and the potential health risks associated with unintended human exposure to genetically engineered crops.

The incident highlighted gaps in the regulatory framework regarding GMOs and emphasized the importance of rigorous safety assessments for genetically engineered foods intended for human consumption.

3.Monsanto v. Geertson Seed Farms (2009):

While this case primarily focused on environmental concerns regarding the deregulation of genetically engineered alfalfa, it also had implications for human health. The plaintiffs raised concerns about the potential for cross-contamination of organic crops with genetically engineered varieties, which could affect food quality and safety.

The potential contamination of organic alfalfa with genetically engineered traits could impact those with allergies or sensitivities, raising questions about labeling and consumer choice.

SUGGESTION:

To manage human risks in agricultural biotechnology, here are some suggestions:

- Implement comprehensive risk assessments for genetically modified (GM) crops, focusing on potential allergenicity, toxicity, and other health impacts. This should be done on a case-by-case basis
- Ensure clear and accurate labeling of GM foods to inform consumers about the presence of genetically modified ingredients. This helps individuals with allergies or dietary restrictions make informed choices.
- Increase public awareness and education about the benefits and risks of agricultural biotechnology. This can help dispel myths and provide a balanced understanding of the technology.
- Develop and enforce robust regulatory frameworks to oversee the development, testing, and commercialization of GM crops. This includes monitoring for potential long-term health effects.
- Conduct ongoing research and monitoring to identify and address any emerging health risks associated with GM crops. This includes studying the impact of GM foods on human health over time.
- Foster international collaboration to share knowledge, best practices, and regulatory standards. This can help ensure that biotechnology is used safely and responsibly worldwide.
- Address ethical concerns by engaging with stakeholders, including farmers, consumers, and environmental groups, to ensure that biotechnology is developed and used in a socially responsible manner.

By implementing these suggestions, we can better manage human risks associated with agricultural biotechnology and ensure that the benefits of this technology are realized while minimizing potential harms.

CONCLUSION:

Agricultural biotechnology holds immense potential to address global challenges in food security, environmental sustainability, and agricultural productivity. By harnessing the power of genetic engineering, molecular breeding, and other biotechnological advancements, we can develop crops that are more resilient to climate change, have higher nutritional value, and require fewer chemical inputs.

However, it is essential to balance the benefits with the potential risks, such as environmental impact, health concerns, and socio-economic issues. This necessitates robust regulatory frameworks, transparent risk assessments, ongoing research, and public awareness to ensure the safe and responsible use of biotechnological innovations.

Ultimately, the integration of biotechnology in agriculture must be guided by principles of sustainability, equity, and ethical considerations, fostering a future where both humanity and the environment can thrive harmoniously. By doing so, we can fully realize the transformative power of biotechnology to create a more sustainable and food-secure world.