

SUSTAINABLE AGRICULTURE: APPLICATION OF ENVIRONMENTAL BIOTECHNOLOGY IN CROP PRODUCTION

Abstract

This chapter discusses environmental biotechnology applications in crop productivity as well as sustainable agriculture. Biotechnology supports sustainable agriculture by reducing reliance on agrochemicals, particularly pesticides, by using genes that confer resistance or tolerance to biotic and abiotic challenges. Plant biotechnology, which uses tissue culture, molecular biology and crop development, is a vital technique for enhancing agriculture. A few of the problems that agriculture is currently facing include soil erosion, salinity, contamination with heavy metals and hydrocarbons, drought, desertification and deforestation. One option is biotechnology. The science of utilizing biological elements in technology for the betterment of humankind is known as biotechnology. It has variety of uses in sustainable agriculture and is a fast expanding field within biological sciences. This article will explore the use of microorganisms in technology, including applications in agriculture such as bio-fertilizers, bio-pesticides, bio-herbicides and bio-insecticides based on viruses and fungal materials. They contribute to environmental cleanup by allowing garbage and oil spills to biodegrade. With a handful of the most cutting-edge examples, this paper will outline the function of microbial biotechnology in each of these applications.

Keywords: Agriculture, Biotechnology, Crop Production, Environment and Sustainable

Authors

Uma Devi S

Assistant Professor
Department of Botany
Sree Ayyappa College for Women
Nagercoil, Tamil Nadu, India.
umapradeep80@gmail.com

Rekha G S

Assistant Professor
Department of Botany
Rani Anna Government College for Women
Tirunelveli, Tamil Nadu, India

I. INTRODUCTION

The Convention on Biological Diversity defines biotechnology as any technological application that uses biological systems, living beings or their derivatives to create or modify goods or procedures for particular uses. Broadly speaking, the definition entails a lot of equipments and methods that have been traditionally employed in utilization and processing of food and agriculture. Biotechnology already supports the food and other primary product-related industries, as well as forestry, agriculture and fisheries. It could have a significant effect on the global food security, health of people and animals, the environment, and the overall standard of living (35).

By 2050, there will be a continuing rise in global population, from 6.7 billion to 9 billion. By 2030, agriculture must improve its output by 50% and should supply more food to satisfy growing need (33). Additionally, it is critical to recognize that the amount of arable land is restricted due to urbanization and abiotic pressures including salinization, desertification, and drought. Crop genetic modification is one way to address these issues, as fresh crops can be developed that are opposed to pathogens, insects, salinity, flooding, rising temperatures, and other environmental challenges (13, 33). Chemical pesticides and herbicides use is one way that biotechnology contributes to the preservation and protection of the environment.

Agriculture is strongly dependent on biotech research since it offers priceless insights into the genetic and physiological properties of crops. Researchers can create novel varieties and bio-inputs that raise crop tolerance to environmental stressors, increase yields, and enhance the nutritional value of products by studying genetics and biochemistry of crops. Furthermore, biological research is essential for creating sustainable agricultural methods since it reveals the complex interactions between organisms and their environment.

According to estimates, the market for agricultural biotechnology will be worth USD(United States Dollar) 100 billion in 2020 and is expected to expand at a CAGR (Compound Annual Growth Rate) of 8% during the next five years. By enabling novel breeding methods, the growing acceptance and development of new biotechnology instruments will spur industry expansion. The adoption of biotechnology technologies that generate or alter attributes of species, including plants, animals, and microbes, to improve traits like color, yield, or size would strengthen the worldwide agricultural biotechnology business. This chapter's purpose is to quote about the benefits and challenges of employing biotechnology as a sustainable agricultural resource.

II. SUSTAINABLE AGRICULTURE

A greater amount of development has occurred in agriculture since the end of World War II. Food and fiber productivity have increased significantly as a result of new technology, mechanization, increased chemical use, specialization and government policies that promoted production and reducing food prices. These advancements allow fewer farmers to produce more food and fiber at lower costs. These innovations have considerably reduced the risks associated with farming and have had many positive effects, but they are still quite expensive. Among these are topsoil loss, tainted ground water, air pollution, greenhouse gas emissions, the decline of family farms, indifference to the living and working conditions of

farm laborers, new risks to public health and safety brought on by the spread of new pathogens, economic concentration in the food and agricultural industries, and the dissolution of rural communities.

Agroecology, biodynamics, ecology, organic supply, environmental sensitivity, minimal input, and other terms may be included in the notion of sustainability in agricultural systems (24). According to (29), some fundamental sustainability principles include:

- The cycle of nutrients in plants, nitrogen fixation, soil regeneration and conservation, diseases, predation and parasitism are the main factors taken into account during the production of food.
- To protect the environment by using non-renewable resources as little as possible;
- To employ wisely the knowledge and abilities of farmers;
- To use the knowledge and skills of human to address the major concerns relating to agriculture and the environment, such as plant pathogenesis.

Sustainability, with regard to agricultural systems, primarily relates to the application of technology to boost crop yields without damaging the environment (10, 25). The maintenance of sustainable development must be the primary goal of agriculture to be able to ensure food safety for the global population in the present and in the future. It is crucial to emphasize sustainable agricultural development activities for the maintenance and preservation of natural resources. However, these resources must also increase for future generations, taking into account the rise in food demand as well as the world's population, which is expected to reach nine billion people by the year 2050. Anthropogenic stressors including floods, drought, little rain, and salinity are also on the rise and will reduce food output. According to (14), in order to maintain and protect biodiversity, prevent soil degradation and advance social and economic well-being, sustainable agriculture must to practiced.

III. APPLICATIONS OF ENVIRONMENTAL BIOTECHNOLOGY IN CROP PRODUCTION

All biotechnology-based research, technological development, and product development are based on genetic resources found in plants, animals, and microorganisms. By locating, isolating, cloning, and transferring desirable genes from one species to another, from microbe to man, the molecular tools of biotechnology have sped precision breeding, making the idea of a Mendelian population obsolete. Biotechnology has had a significant impact on all aspects of genetic resource management, including collection, conservation, evaluation, and use.

1. Hawaiian papaya plants that are employed in underdeveloped nations are resistant to the virus (35). Free-disease banana plants grown in Kenya by tissue culture aid in increasing output and defending farmers' earnings that are under risk because commercial coffee crops are declining. In Uganda, disease-free potato plants have been planted and are currently flourishing as a result of cooperation between the Ugandan National Agricultural Research Organization and the International Potato Centre in Peru (39).

2. The function of *Arabidopsis* HOS15 in suppressing ABA signalling and drought stress tolerance was reviewed by (2). In order to increase crops' tolerance to salinity, in 2020 (1), investigated novel findings on the halophytes' root microbiota.
3. Dryland agriculture in China for sustainable productivity was examined by (22). Philippines' molecular breeding of rice with biotechnology was discussed by (23). The situation of Indonesian agriculture and *Cassava* with added value was examined by (38). (26) reviewed forty endosperm mutants for dry-milling rice cultivars.
4. Sweet potatoes with low-molecular weight antioxidants were metabolically engineered by (20) to enable sustainable FNS (Food and Nutritional Service). (3) reviewed the production and accumulation of flavonoids in buckwheat.
5. While (8) demonstrated the existence of a mitochondrial alternative oxidase (AOX1a), which is essential for *Arabidopsis* to reduce arsenic-induced oxidative stress. According to (27) the molecular chaperone plays a crucial function in protecting *Arabidopsis* plants from heat stress.
6. In United Kingdom, sugar, beetroot, maize and canola fields were utilized over the course of three years to evaluate the possible environmental effects of Genetically Modified herbicide-tolerant crops.
7. Sugar, beetroot and canola grown with herbicide tolerance resulted in fewer butterflies, bees (only sugar beetroot), weeds, weed seeds and seed-feeding beetles. No appreciable drops in the number of bees or butterflies were observed in herbicide-tolerant maize, however, the quantity of dicotyledonous weeds, weed seeds, and seed-eating insects increased. Springtails are common, and many of which feed on decomposing plant waste, rose for herbicide-tolerant beetroot and maize. According to studies on a subset of the FSE (Field Scale Evaluations) fields that looked at the impact of management on birds, there were much less granivorous birds in the herbicide-tolerant maize fields (6).
8. The biggest challenges to agricultural productivity and profitability are shortages or oversupplies of the essential resources that plants and animals need to survive (such as water, heat, and nutrients). The creation of crops with greater drought tolerance is one strategy to boost yields during drought conditions and maybe minimize water use. For several important crops, such as rice, wheat, maize (corn), and soybean, genetic engineering has been employed to produce drought resistance.
9. Additionally, complementary biotechnology techniques are being applied to boost agricultural output effectiveness. By decreasing the quantity of nitrogen applied to crops (and then leaching into underground water), increasing crops' ability to absorb nitrogen efficiently will save fertilizer expenditures in industrialized nations and aid in maintaining water quality. The nutritional content of agricultural goods is one of the other biotechnology uses. The Golden Rice with added beta-carotene may be the most well-known instance; it has the potential to eliminate the deficiency of vitamin A and save many lives each year (36).

10. One of the most well-known biotechnology initiatives is the creation of fuels that can replace petroleum-based ones. Currently, the majority of farmers rely on diesel and petrol to power their agricultural machinery. As a result, they become dependent on a resource that is (1) not renewable, (2) harmful to the environment, and (3) prone to price swings that may be controlled by nations that export petroleum. Switching to biologically based fuels, such as ethanol or biodiesel, may help shield farmers from price spikes or instability and provide an additional source of income if maize, soybeans or other crops are used to manufacture biofuels.
11. Using Genetically Modified yeasts and bacteria, biotechnology is being used to produce ethanol from cellulose more effectively. Similar to this, genetic engineering is assisting in the development of plants that produce more energy than currently existing types.
12. Applications of biotechnology may also enable the production of fuels from agricultural byproducts that would otherwise be regarded as waste. Native perennial grasses that are not food crops could supply the same advantages as soy- or maize-based biofuels while also using less energy, fertilizer, and pesticides and reducing carbon dioxide emissions.
13. Transgenic crop pest management has been the most economically successful use of agricultural biotechnology, even though pest control is just one of many aspects of agriculture, just as genetic engineering is just one tool in biotechnology. Alfalfa, beets, cotton, soybeans, canola, maize, rice and squash all currently exhibit traits for herbicide tolerance, insect resistance and virus resistance.
14. Transgenic maize cultivars that express insect-active toxins produced by soil bacterium *Bacillus thuringiensis* (Bt) are the greatest example of the sometimes-complex economics of biotechnology in the United States. The European maize borer (*Ostrinia nubilalis*) was the main target of the initial Bt maize cultivars. Low European corn borer numbers and low maize prices during 1998 and 1999 made it unprofitable to grow Bt maize (4). However, the economic climate in 1998 and 1999 was especially unfavourable for growing Bt maize; analysis taking into account conditions that are more common in the USA (34) reveals higher revenue for Bt-maize producers.
15. In Spain, farmers may benefit from utilizing transgenic insect control, according to studies on lepidopteran-active Bt maize (9). As new hybrids express more Bt toxins, the overall economic gains from decreased insect damage and costs connected with insecticidal control (scouting, pesticide, application) are altering. Maize is protected from European corn borers as well as corn root worms (*Diabrotica spp.*) by "stacks," which include the addition of Cry3Bb1 or Cry34/35Ab1 toxins (32). By making Bt maize more toxic to larger groups of lepidopteran maize pests, the application of two or more complementary Bt toxins in "pyramids" should raise the economic worth of Bt maize. Future adoption rates for various pests will also rely on how much technological costs rise.
16. Lepidopteran pest control is also economically advantageous when using Bt cotton, the other extensively used transgenic insect-resistant crop. As demonstrated for Argentina's farmer (30), China (28), India (18), and the USA (5), gains may be created by significant

decrease in pest damage (resulting in greater yield) or expenses associated with insecticide applications.

17. Equally intriguing is the uptake and economic viability of herbicide-tolerant crops. Nevertheless, three times as much land as Bt maize and cotton is planted with transgenic herbicide-tolerant crops (17). Economic benefits have been demonstrated for soybean, the most frequently cultivated herbicide-tolerant crop, in the USA (15) and Argentina (31).
18. The benefits of higher production, quality, and the possibility to lower herbicide costs were also highlighted in an economic examination of transgenic glyphosate-resistant sugar beets grown in the USA (21).
19. In Canada, herbicide-tolerant canola seems to offer farmers a general economic advantage (37). However, some have argued that the widespread and quick farmer acceptance of herbicide-tolerant crops may be best understood by the concept of convenience (11; 37). According to (18), additionally, it's possible that some studies on biotech crops will use grower surveys which don't accurately capture some forms of economic benefits (such as decreased labour) associated with cultivating herbicide-tolerant crops.
20. Another biotechnology use in agriculture that affects sustainability is biofortification. In order to boost the nutritional worth of the staple foods, particularly in poor nations, this approach is centered on the use of micronutrients to crops including beans, rice, and wheat using conventional plant breeding and biotechnology (19).

The outcomes of biotechnology should be broadly applied in poor nations. In many nations, biotechnology is a catalyst for social and economic advancement (7) and provides credit-based access to technology, particularly for underprivileged rural farmers (16). Molecular crop breeding to increase resistance to abiotic conditions like drought, salinity, and oxidative stress is a common topic in articles on plant science. For sustained food security, articles about plant biotechnology concentrate on rice, sweet potatoes, cassava and buckwheat.

IV. CONCLUSION

Numerous issues brought on by a growing population and few or damaged resources could be made less severe via biotechnology. With the help of modern technologies, agriculture may be able to produce an adequate amount of more nutrient-dense meals and biofuels that require less land and resources. In terms of pest management, biotechnology can offer better pest control, typically with less strain on adjacent agricultural and environmental systems. Even though biotechnology has amazing possibilities, it shouldn't be viewed as the solution to sustainability.

Benefits of biotechnology for the private sector are undoubtedly limited to some extent by the need to maximize earnings. Furthermore, it is possible to apply biotechnology's tools in ways that reduce sustainability. High expectations had been raised regarding the ability of the new biotechnology as a crucial instrument for feeding a population that is always growing even before the first goods emerged on the market. A new revolution that can increase production by lowering costs, promoting the usage of more eco- friendly agricultural

practices, and acting as a development apparatus for underdeveloped nations has been dubbed agricultural genetic engineering. Currently, both the employment of conventional methods and cutting-edge methods to accomplish sustainable agriculture are taken into consideration.

The successful integration of new technologies into programs for sustainable development, is necessary for an effective agroecological approach. Biotechnology-derived goods must serve to overcome various issues, including diseases, pests, and constraints on the environment on plant production. The main advantages of biotechnology are that it makes it possible to grow crops without using as many pesticides, herbicides, or chemical fertilizers. Additionally, it maintains a clean and healthy environment for future generations to use. It assists both creatures and engineers in figuring out practical strategies for adapting to environmental changes and maintaining a clean, green environment.

The benefits of environmental biotechnology help us to avoid using harmful wastes and pollutants that deplete our environment and natural resources. The advancement of civilization ought to be carried out in a manner that both advances and protects the environment. The elimination of the contaminants is aided by environmental biotechnology. Additionally, biotransformation opens the door to the production of numerous beneficial industrial enzymes and goods without endangering the environment. Biotechnology and bacteria work together in this way to serve humankind.

The future of biotechnology will be significantly impacted by how these worries and misgivings about the use of biotechnology to provide a safe environment and agriculture are addressed. Since the overall objective is to achieve a safe environment and increased agricultural productivity, a thorough review of both the benefits and drawbacks would be helpful in guiding the future of environmental and agricultural biotechnology.

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