**Sustainable Agriculture: Application of Environmental Biotechnology in Crop production**

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**ABSTRACT**

This chapter discusses environmental biotechnology applications in crop productivity as well as sustainable agriculture. Through the use of genes granting resistance or tolerance to biotic and abiotic challenges, biotechnology contributes to sustainable agriculture by lowering dependence on agro-chemicals, notably pesticides. Through the use of tissue culture, molecular biology, and crop development, plant biotechnology is a crucial tool for improving agriculture. The degradation of soils, salinity, contamination with heavy metals and hydrocarbons, drought, desertification, and deforestation are just a few of the issues that agriculture is currently dealing with. 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. The use of microorganisms in technology will be discussed here, including applications in agriculture such as bio-fertilizers, bio-pesticides, bio-herbicides, bio-insecticides based on viruses, fungi. 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

**INTRODUCTION**

Biotechnology is described as "any technology application that uses biological systems, living organisms, or derivatives there from to make or modify products or processes for specific uses" by the Convention on Biological Diversity (CBD). In a broad sense, the definition includes a lot of the equipment and methods that have been traditionally employed in agriculture, food processing, and utilization. Agriculture, forestry, fisheries, as well as the food and other primary product-related businesses, are already supported by biotechnology. It has the potential to have a significant impact on the world's food security, the health of people and animals, the environment, and the overall standard of living (Serageldin, 1999).

By 2050, there will be a continuing rise in global population, from 6.7 billion to 9 billion. By 2030, agricultural production must increase by 50% in order to meet the rising demand for food (Royal Society, 2009). 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 new crops can be developed that are resistant to pathogens, insects, salinity, flooding, rising temperatures, and other environmental challenges (Gregory *et al*., 2009; Royal Society, 2009). The use of chemical pesticides and herbicides 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 improve the nutritional value of products by studying the 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 100 billion in 2020 and is expected to expand at a CAGR 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. The purpose of this chapter is to discuss the value and difficulty of using biotechnology as a sustainable agricultural resource.

**Sustainable Agriculture**

Since the end of World War II, agriculture has undergone significant development. Due to new technologies, mechanization, greater chemical use, specialization, and government policies that favored maximizing production and lowering food prices, food and fiber productivity have improved dramatically. Fewer farmers can now produce more food and fiber at cheaper prices because to these improvements. Despite the fact that these advancements have greatly decreased hazards in farming and had numerous positive benefits, they are still very expensive. Topsoil loss, contaminated groundwater, air pollution, greenhouse gas emissions, the decline of family farms, disregard for the living and working conditions of farm laborers, new dangers to public health and safety resulting from the spread of new pathogens, economic concentration in the food and agricultural industries, and the dissolution of rural communities are prominent among these.

Agroecology, biodynamics, ecology, organic supply, sensitivity to the environment, low input, and other terms may be included in the notion of sustainability in agricultural systems (McNeely and Scherr, 2003). According to Pretty (2008), some fundamental sustainability principles include:

a. The process of producing food primarily considers the nutrient cycle in plants, nitrogen fixation, soil regeneration and conservation, pathogens, predation, and parasitism;

b. To preserve the environment by using non-renewable resources as little as possible;

c. To use wisely what farmers know and the skills of them;

d. To use the knowledge and capacities of the people to solve the major issues of agriculture and natural resources, for example, plant pathogenesis.

Sustainability, in the context of agricultural systems, primarily refers to the application of technology to boost crop yield without endangering the environment, according to Dobbs and Pretty (2004) and MEA (2005). The maintenance of sustainable development must be the primary goal of agriculture in order to ensure food safety for the global population both now and in the future. It is essential to highlight 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 population, which is expected to reach nine billion people by the year 2050. Abiotic stress events including drought, floods, little rain, and salinity are also on the rise and will reduce food output. According to Hans and Colaco (2019), sustainable agriculture must prevent soil degradation, ensure the protection and maintenance of biodiversity, and promote social and economic prosperity.

**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.

* Hawaiian papaya plants that are employed in underdeveloped nations are resistant to the virus (Serageldin, 1999). Free-disease banana plants grown in Kenya by tissue culture aid in increasing output and defending farmers' earnings that are under risk due to the decline of commercial coffee crops. As a consequence of collaboration between the Ugandan National Agricultural Research Organization and the International Potato Centre in Peru, disease-free potato plants have been planted and are growing in Uganda (Wambugu, 2001).
* The function of *Arabidopsis* HOS15 in suppressing ABA signalling and drought stress tolerance was reviewed by Ali and Yun (2020). In order to increase crops' tolerance to salinity, Akyol *et al*. (2020) explored fresh insights on the root microbiome of halophytes.
* Dryland agriculture in China for sustainable productivity was examined by Li *et al*. in 2020. The use of biotechnology in rice molecular breeding in the Philippines was discussed by Manangkil *et al*. in 2020. Sukara *et al*. (2020) examined the state of Indonesian agriculture and cassava with added value. The forty endosperm mutants for dry-milling rice cultivars were reviewed by Mo and Jeung (2020).
* Low molecular weight antioxidants in sweet potatoes were metabolically engineered by Kim *et al*. (2020) to enable sustainable FNS. A review of the production and accumulation of flavonoids in buckwheat was done by Borovaya and Klykova (2020).
* While Demican *et al*. (2020) reported a mitochondrial alternative oxidase (AOX1a), which is necessary for the mitigation of arsenic-induced oxidative stress in *Arabidopsis*, Paeng *et al*. (2020) described the role of the molecular chaperone NPR1 in protecting *Arabidopsis* plants from heat stress.
* Over the course of three years, sugar beetroot, maize and canola fields in the United Kingdom (UK) were used to assess the potential environmental consequences of GM herbicide-tolerant crops.
* 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, but there were rises in the number of dicotyledonous weeds, weed seeds, and seed-feeding beetles. The prevalence of springtails, many of which feed on decomposing plant waste, rose for herbicide-tolerant beetroot and maize. There were noticeably less granivorous birds in the herbicide-tolerant maize fields, according to research on a subset of the FSE fields that looked at the impact of management on birds (Chamberlain *et al*., 2007).
* 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, including rice, wheat, maize (corn), and soybean, genetic engineering has been employed to produce drought resistance.
* Additionally, complementary biotechnology techniques are being applied to boost agricultural output effectiveness. By decreasing the amount of nitrogen applied to crops (and later leaching into groundwater), 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 vitamin A deficiency and save thousands of lives each year (Stein *et al*., 2006).
* 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. If maize, soybeans, or other crops are used to make biofuels, then switching to biologically based fuels (biofuels), such as ethanol or biodiesel, may help protect farmers from price spikes or price instability and give an extra source of income.
* Using GM yeasts and bacteria, biotechnology is being used to more efficiently manufacture ethanol from cellulose. Similar to this, genetic engineering is assisting in the development of plants that produce more energy than currently existing types.
* Applications of biotechnology may also enable the production of fuels from agricultural byproducts that would otherwise be regarded as waste. Non-food crops, such as native perennial grasses, may provide the same advantages as soy- or maize-based biofuels while also using less energy, fertilizer, and pesticides and reducing carbon dioxide emissions.
* Transgenic crop pest management has been the most economically successful use of agricultural biotechnology, even though pest management is only one of many facets of agriculture and genetic engineering is only one of many instruments of biotechnology. Currently, characteristics for herbicide tolerance, insect resistance, and viral resistance are present in alfalfa, beets, cotton, soybeans, canola (oilseed rape), maize, cotton, rice, and squash.
* The sometimes-complex economics of biotechnology are best shown in the USA by transgenic maize cultivars that express insect-active toxins generated from the soil bacterium *Bacillus thuringiensis* (Bt). 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 (Carpenter & Gianessi, 2001). However, the economic climate in 1998 and 1999 was especially unfavourable for growing Bt maize; analysis taking into account conditions that are more typical for the USA (Sankula, 2006) reveals higher profitability for Bt-maize producers.
* Farmers may benefit from utilizing transgenic insect control, according to studies on lepidopteran-active Bt maize in Spain (Demont & Tollens, 2004) and the Philippines (Yorobe & Quicoy, 2006). As new hybrids express more Bt toxins, the overall economic benefits from reduced insect damage and costs connected with insecticidal control (scouting, pesticide, application) are altering. Maize is protected from both European corn borers and corn root worms (Diabrotica spp.) by "stacks," which include the addition of Cry3Bb1 or Cry34/35Ab1 toxins (Rice, 2004). 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 value of Bt maize. Future adoption rates for various pests will also rely on how much technological costs rise.
* Lepidopteran pest control is also economically advantageous when using Bt cotton, the other extensively used transgenic insect-resistant crop. As demonstrated for farmers in Argentina (Qaim & de Janvry, 2005), China (Pray *et al*., 2002), India (Kambhampati *et al*., 2006), and the USA (Cattaneo *et al*., 2006), gains may be created by significant reductions in pest damage (resulting in greater yield) or expenses associated with insecticide applications.
* 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 (James, 2006). Economic benefits have been demonstrated for soybean, the most frequently cultivated herbicide-tolerant crop, in the USA (Heatherly *et al*., 2002) and Argentina (Qaim & Traxler, 2005).
* The benefits of higher production, quality, and the possibility to lower herbicide costs were also highlighted in an economic analysis of transgenic glyphosate-resistant sugar beets grown in the USA (Kniss *et al*., 2004).
* In Canada, herbicide-tolerant canola also seems to offer farmers a general economic advantage (Stringam *et al*., 2003). However, some have argued that the widespread and quick farmer acceptance of herbicide-tolerant crops may be best understood by the concept of convenience (Economic Research Service, 2002; Stringam *et al*., 2003). According to Kambhampati *et al*. (2006), it's also likely that grower surveys utilized in some studies of biotech crops don't accurately capture some forms of economic benefits (such as decreased labour) associated with cultivating herbicide-tolerant crops.
* Another use of biotechnology in agriculture that affects sustainability is biofortification. In order to increase the nutritional value of the staple foods, particularly in poor nations, this approach is based on the application of micronutrients to crops including beans, rice (*Oryza sativa* L.), and wheat utilizing conventional plant breeding and biotechnology (Khush, 2008).

The outcomes of biotechnology should be broadly applied in poor nations. In many nations, biotechnology is a catalyst for social and economic advancement (DaSilva, 1998) and provides credit-based access to technology, particularly for underprivileged rural farmers (Holaday, 1999). Molecular breeding of crops to increase tolerance to abiotic conditions like drought, salinity, and oxidative stress is a common topic in articles on plant science. For sustained food security, articles in the field of plant biotechnology concentrate on rice, sweet potatoes, cassava and buckwheat.

**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 hopes had been raised regarding the potential of the new biotechnology as a crucial tool in the provision of food to a continuously expanding human population even before the first goods emerged on the market. A new revolution that can increase production by lowering costs, promoting the adoption of more ecologically friendly agricultural practices, and acting as a development engine 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 effective application of new technologies, which can be adapted in sustainable development programmes, is necessary for an effective agroecological approach. Products obtained from biotechnology must serve to overcome various issues, including diseases, pests, and environmental restrictions 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 advantage of environmental biotechnology aids us in avoiding the usage of dangerous wastes and pollutants that harm the 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.

**REFERENCES**

1. Akyol TY, Sato S & Turkan I (2020) Deploying root microbiome of halophytes to improve salinity tolerance of crops. Plant Biotechnol Rep. <https://doi.org/10.1007/s11816-020-00594-w> Plant Biotechnology Reports (2020) 14:139–141 141
2. Ali A & Yun DJ (2020) Arabidopsis HOS15 is a multifunctional protein that negatively regulate ABA-signaling and drought stress. Plant Biotechnol Rep. https://doi.org/10.1007/s11816-020-00600-1
3. Borovayaa SA & Klykova AG (2020) Some aspects of biosynthesis and accumulation of favonoids in buckwheat. Plant Biotechnol Rep. https://doi.org/10.1007/s11816-020-00614-9
4. Carpenter JE & Gianessi LP (2001) Agricultural Biotechnology: Updated Benefit Estimates. Washington, DC: National Center for Food and Agricultural Policy. Available at www.ncfap.org/reports/biotech/updatedbenefits.pdf.
5. Cattaneo MG, Yafuso C & Schmidt, C (2006) Farmscale evaluation of the impacts of transgenic cotton on biodiversity, pesticide use, and yield. Proceedings of the National Academy of Sciences of the USA, 103, 7571–7576.
6. Chamberlain DE, Freeman SN & Vickery JA (2007) The effects of GMHT crops on bird abundance in arable fields in the UK. Agriculture, Ecosystems and Environment, 118, 350–356.
7. DaSilva EJ (1998) Biotechnology, developing countries and globalization. World J Microbiol Biotechnol 14:463–486
8. Demican N, Cucun G & Uzilday B (2020) Mitochondrial alternative oxidase (AOX1a) is required for mitigation of arsenic induced oxidative stress in Arabidopsis thaliana. Plant Biotechnol Rep. https://doi.org/10.1007/s11816-020-00595-9
9. Demont M & Tollens E (2004) First impact of biotechnology in the EU: Bt maize adoption in Spain. Annals of Applied Biology, 145, 197–207.
10. Dobbs T & Pretty JN (2004) Agri-environmental stewardship schemes and multifunctionality. Rev Agric Econ 26:220–237
11. Economic Research Service (2002) Adoption of Bioengineered Crops, Agricultural Economic Report No. 810. Washington, DC: US Department of Agriculture. Available at www.ers.usda.gov/publications/aer810/aer810.pdf.
12. FAO (2001) Action against undernutrition and poverty. Redirecting food assistance to those who need it most. In: The state of food insecurity in the world. http://www.fao.org/docrep/003/y1500e/y1500e05.htm#P0\_0
13. Gregory PJ, Johnson SN, Newton AC & Ingram JSI (2009) Integrating pests and pathogens into the climate change/ food security debate. J Exp Bot 60:2827–2838
14. Hans BV & Colaco VM (2019) Sustainable agriculture and economic growth. JETIR 6(1):483–512
15. Heatherly LG, Elmore CD & Spurlock SR (2002) Weed management systems for conventional and glyphosate-resistant soybean with and without irrigation. Agronomy Journal, 94, 1419–1428.
16. Holaday JW (1999) Competing in the new millennium: challenges facing small biotechnology firms. Congressional Testimony -Subcommittee on Technology, 27 October, 1999. http:www.house.gov/science/holaday-102799.htm
17. James C (2006) Global Status of Commercialized Biotech/GM Crops: 2006, ISAAA Brief No. 35. Ithaca, NY: International Service for the Acquisition of Agri-Biotech Applications.
18. Kambhampati U, Morse S, Bennett R & Ismael Y (2006) Farm-level performance of genetically modified cotton: A frontier analysis of cotton productionin Maharashtra. Outlook on Agriculture, 35, 291–297.
19. Khush GS (2008) Biofortification of crops for reducing malnutrition. Proc Indian Natl Sci Acad 74 (1):21–25
20. Kim HS, Wang W, Kang L, Kim SE, Lee CJ, Park SC, Park WS, Ahn MJ & Kwak SS (2020) Metabolic engineering of low molecular weight antioxidants in sweetpotao. Plant Biotechnol Rep. https://link.springer.com/article/10.1007/s11816-020-00621-w
21. Kniss AR, Wilson RG, Martin AR, Burgener PA & Feuz DM (2004) Economic evaluation of glyphosate- resistant and conventional sugar beet. Weed Technology, 18, 388–396.
22. Li GX, Xu BC, Yin LN, Wang SW, Zhang SQ, Shan L, Kwak SS, Ke Q & Deng XP (2020) Dryland agricultural environment and sustainable productivity. Plant Biotechnol Rep. https://doi.org/10.1007/s11816-020-00613-w
23. Manangkil OE, Abdula SE & Quilang EJP (2020) Role of biotechnology in rice breeding strategy of the Philippines. Plant Biotechnol Rep. https://doi.org/10.1007/s11816-020-00618-5
24. McNeely JA & Scherr SJ (2003) Ecoagriculture. Island Press, Washington, DC, p 319
25. MEA (2005) Ecosystems and human well-being. Island Press, Washington, DC, p 155
26. Mo Y & Jeung JU (2020) The use of foury endosperm mutants to develop rice cultivars suitable for dry milling. Plant Biotechnol Rep. https://doi.org/10.1007/s11816-020-00604-x
27. Paeng SK, Chi YH, Kang CH, Chae HB, Lee ES, Park JH, Wi SD, Bae SB, Phan KAT & Lee SY (2020) Chaperone function of Arabidopsis NPR1. Plant Biotechnol Rep. https://doi.org/10.1007/s11816-020-00609-6
28. Pray CE, Huang J, Hu R & Rozelle S (2002) Five years of Bt cotton in China: the benefits continue. Plant Journal, 31, 423–430.
29. Pretty J (2008) Social capital and the collective management of resources. Science 302:1912–1915
30. Qaim M & de Janvry A (2005) Bt cotton and pesticide use in Argentina: economic and environmental effects. Environment and Development Economics, 10, 179–200.
31. Qaim M & Traxler G (2005) Roundup Ready soybeans in Argentina: farm level and aggregate welfare effects. Agricultural Economics, 32, 73–86.
32. Rice ME (2004) Transgenic rootworm corn: assessing potential agronomic, economic, and environmental benefits. Plant Health Progress doi:10.1094/PHP-2004–0301-01-RV, available at [www.plantmanagementnetwork.org/pub/php/review/](http://www.plantmanagementnetwork.org/pub/php/review/) 2004/rootworm/.
33. Royal Society (2009) Reaping the benefits: science and the sustainable intensification of global agriculture. The Royal Society, London, p 86
34. Sankula S (2006) A 2006 Update of Impacts on US Agriculture of Biotechnology-Derived Crops Planted in 2005: Executive Summary. Washington, DC: National Center for Food and Agricultural Policy. Available at www.ncfap.org/whatwedo/pdf/2005biotechExecSummary.pdf/.
35. Serageldin I (1999) Biotechnology and food security in the 21st century. Science 285:387–389
36. Stein AJ, Sachdev HPS & Qaim M (2006) Potential impact and cost-effectiveness of Golden Rice. Nature Biotechnology, 24, 1200–1201.
37. Stringam GR, Ripley VL, Love HK & Mitchell A (2003) Transgenic herbicide tolerant canola: the Canadian experience. Crop Science, 43, 1590–1593.
38. Sukara E, Hartati S & Ragamustari SK (2020) State of the art of Indonesian agriculture and the introduction of innovation for added value of cassava. Plant Biotechnol Rep. https://doi.org/10.1007/s11816-020-00605-w
39. Wambugu F (2001) Modifying Africa: how biotechnology can benefit the poor and hungry, a case study from Kenya. In: Action against undernutrition and poverty, Nairobi, Kenya, p 76
40. Yorobe JM & Quicoy CB (2006) Economic impact of Bt corn in the Philippines. Philippine Agricultural Scientist, 89, 258–267.