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ROLE OF BIOTECHNOLOGY IN ACHIEVING SUSTAINABLE DEVELOPMENT

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ABSTRACT

Biotechnology is a dynamic and revolutionary force in the modern goal of global sustainability, providing creative solutions to difficult problems in a variety of industries. The convergence of applied science, technology, and biology makes biotechnology a crucial tool for accomplishing sustainable development objectives. In order to achieve sustainable development, biotechnology is essential since it stimulates favourable changes in the social, economic, and environmental spheres. Biotechnological developments have the power to fundamentally alter how we think about development, encouraging resilience, flexibility, and long-term well-being. These can range from improving healthcare and preserving the environment to revolutionising farming techniques and boosting resource efficiency. In addition to addressing pressing issues like food security, environmental degradation, and healthcare inequities, this diverse discipline lays the groundwork for a more peaceful and sustainable cohabitation between humans and the environment. Biotechnology plays a key part in this complex web of development, spurring innovation, encouraging prudent resource management, and providing a route forward for a more just and sustainable future for future generations. The goal of this review article is to discuss the several ways that biotechnology can be essential to the realisation of sustainable development.

Keywords: - Biotechnology, Sustainable Development Goals, SDGs, Environment Protection.

I. INTRODUCTION

Biotechnology, in its most basic form, is a biology-based technology. It leverages cellular and biomolecular processes to create goods and technologies that enhance both the quality of our lives and the state of the planet (Abioye, 2021). The UN Earth Summit in Rio de Janeiro in 1992 furthered the idea of sustainable development, which was first introduced by the World Commission on Environment and Development in the 1987 report Our Common Future. According to Agyeman et al. (2002), it is a type of development that satisfies current wants without jeopardising the capacity of future generations to satisfy their own. Microbes, plants, and animals that have undergone genetic modification have provided new insights. The foundation of "biotechnology," which is necessary to fulfil the 2030 Agenda's 17 sustainable development objectives, is the environmentally and financially responsible use of natural resources (Biermann et al., 2017). Future generations' prosperity depends on the SDGs being accomplished collectively. The bioeconomy depends on the long-term, sustainable use of biological resources that ultimately reduce waste and help to slow down global warming. This article will review the opportunities and problems involved in the application of biotechnology to sustainable development goals.

SDG 1: - No Poverty

Using biotechnology to improve living conditions in underdeveloped nations is the most effective strategy to combat poverty reduction. New technologies have the power to increase food nutritional value, boost agricultural yields by providing bio-pesticides and fertilisers, improve overall health conditions by making affordable medicines more accessible to the underprivileged, and make energy production more affordable by reducing reliance on fossil fuels (Evens & Kaitin, 2015; Awasthi et al., 2020). Through the use of biotechnological processes, biomass or biowaste may be converted into

biofuels through biorefineries, reducing reliance on fossil fuels and enhancing access to energy in underserved regions. The use of genetically modified crops and biotechnology-driven innovations can boost agricultural productivity, revenue, and climate change resilience (Cornell, 2018).

SDG 2: Zero Hunger

By employing methods like genetic engineering to make crops more productive and nutrient-dense, biotechnology allows us to contribute to the eradication of hunger. Furthermore, meals may be made even healthier by using biotechnology to include probiotics and prebiotics. Moreover, food safety may be improved by using biotechnology methods to identify poisons and other impurities in food (Atukunda et al., 2021). Crops that have undergone genetic modification (GM crops) have higher yields, improved nutritional value, and resistance to disease while using less pesticides. To combat hunger, biofortification produces crops that are high in nutrients. Animals with enhanced genetic makeup help produce more food. Food waste is decreased and shelf life is increased using biodegradable packaging. Aquaculture uses biotechnology to produce and conserve seafood. Aquatic animals are protected from illnesses using DNA vaccines (Medialdea et al., 2018; Dehghani et al. 2018).

SDG 3: Good Health and Wellbeing.

Using the enormous genetic potential that exists naturally in organisms, biopharmaceuticals and medical biotechnology are the two most important applied disciplines of contemporary biotechnology. For many years, these fields have helped with illness control, diagnosis, and prevention (Barzaeva et al., 2022). The development of medicinal drugs, diagnostic tools, and vaccinations made possible by biotechnology has enhanced public health and wellbeing. Thanks to developments in genetics and biotechnology, personalised medicine is now possible, allowing for more precise and effective healthcare by customising therapies based on each patient's unique genetic profile (Vorontsova et al., 2019). Food's utility and health advantages are improved by food and nutritional technology. Essential micronutrients are increased by genetic modification of food. Individual genetic markers are used by precision medicine to customise treatments. The detection of diseases is facilitated by advanced clinical diagnostics and imaging techniques (Hsieh & Ofori, 2007; Sarmidi&Enshasy, 2012).

SDG 4: Quality Education

Investing in biotechnology may support the use of cutting-edge technologies in educational institutions and assist increase the number of excellent instructors. The creation of biotechnological tools for individualised learning experiences is one noteworthy use. Developments in genetic and neuroscientific research help us understand how each person thinks, which makes it possible to adapt instructional materials to the unique learning styles and capacities of each student. Real-time monitoring of students' involvement and comprehension is made possible by biometric technologies like facial recognition and eye tracking, which also provide important data for adaptive learning systems. In order to support the overriding objective of inclusive and equitable high-quality education for all, this involves the creation of sophisticated e-learning tools, adaptive algorithms, and educational applications that accommodate a variety of learning preferences (Sasidharakurup et al., 2015).

SDG 5: Gender Equality

Great female researchers, executives, and business owners work in biotechnology. An estimated 30% of women work in India's biotechnology sector, according to a survey published by the Association of Biotechnology Led Enterprises (ABLE). A Confederation of Indian Industry research states that women make up around 40% of the workforce in the biotechnology and pharmaceutical industries. Through addressing health disparities, empowering women in agriculture, and encouraging entrepreneurship, biotechnology has great promise for advancing gender equality. The World Health Organisation said that advances in biotechnology have improved family planning choices, decreased maternal death rates, and increased access to reproductive healthcare. Supporting female-led biotech firms can help close the gender gap in entrepreneurship, according to the Global Entrepreneurship Monitor.

SDG 6: Clean Water and Sanitation:

With agricultural practices and production methods that assist lower water demand, biotechnology contributes to the promotion of more sustainable water usage. By filtering wastewater and detecting pollutants, it also guarantees that water is available and clean. Water pollutants can be eliminated and

purified using microbes, microalgae, or cyanobacteria via the application of biotechnology. In order to purify water, bacteria are adsorbents in cellulosic fibres containing polyelectrolytes (Ottenhall et al., 2017). Water treatment involves the employment of oil-eating microorganisms. There are already around 30 species of known bacteria and fungi that degrade oil. Pathogens are eliminated with electrolyzed water that has antimicrobial qualities. Plant-based polymers called chitosan and chitin aid in the filtration of water. Nitrogen use efficient genetically modified crops reduce the environmental impact of fertilizers (Han et al., 2017; Samoila et al., 2019).

SDG 7: Affordable and Clean Energy.

Biotechnology provides substitutes for producing clean energy, guaranteeing more economical use of electricity, and recycling forestry and urban trash, as well as by-products from certain sectors, lessening their environmental effect. An increasing amount of clean, renewable energy is being produced by using biomass from other sources, such as forestry and agriculture. Microorganisms that have undergone genetic alteration are better able to convert biomass into bioenergy, which increases the production of bioenergy's total yield and financial sustainability. Furthermore, genetically modified crops created especially for the generation of bioenergy are now possible thanks to biotechnological developments, guaranteeing a steady and renewable supply of feedstocks. Utilising genetic engineering and bioprocessing, biofuels may be produced from feedstocks including algae, crops, and agricultural waste. Fuel may be replaced with low-carbon bioethanol made from sugarcane and other sources. Anaerobic digestion of biomass produces biogas, which reduces organic waste and offers cleaner energy for automobiles and cooking (Arora and Mishra, 2022; Lisboa et al., 2011; Rexen & Munck, 1984).

SDG 8: Decent work and economic growth

Biotechnology is helping in agricultural productivity and food security, industry boost, skills development, and improved healthcare; eventually upgrading global economy and fostering financial systems. GM crops have enabled increased yields for farmers and raised income for small farmers. Policies that encourage innovation attract investors and enhance product and service value. Microbial biotechnology offers opportunities in diverse fields like therapies, plant growth promotion, bio-catalysis, bioenergy, clean water provision, and more (Frey, 2017). According to a report by Grand View Research, the global biopharmaceuticals market size was valued at USD 338.5 billion in 2020 and is expected to grow at a compound annual growth rate (CAGR) of 7.6% from 2021 to 2028. This growth indicates the economic importance of biotechnology in the pharmaceutical sector, contributing to SDG 8.

SDG 9: Industry, Innovation and Infrastructure.

Innovations in biotechnology improve industrial processes' sustainability and efficiency, encouraging ethical production and consumption. Industries may minimise waste creation, optimise resource utilisation, and adopt environmentally friendly manufacturing methods by utilising biotechnology. Furthermore, biotechnology promotes a paradigm shift towards greener and more sustainable solutions by enabling the development of novel materials, fuels, and products. Innovations in biotechnology also aid in the construction of strong, resilient infrastructure, which increases system flexibility to deal with changing problems. Innovation is accelerated when academic institutions and business collaborate. R&D spaces and startup help are offered by biotechnology parks and incubation centres. According to Denoncourt (2019), investing in biotechnology promotes technological transfer and economic growth.

SDG 10: Reduce Inequalities.

Biotechnological applications contribute to addressing health disparities, enhancing agricultural productivity, and providing innovative solutions for economic and social inclusivity. In the healthcare sector, biotechnology enables the development of affordable and accessible medical treatments, diagnostics, and vaccines, thereby reducing health inequalities across different populations (Barzaeva et al., 2022). Through biotechnological interventions in agriculture, such as genetically modified crops with improved nutritional content and resistance to pests, marginalized communities can benefit from increased food security and improved livelihoods. Additionally, biotechnology supports the development of sustainable and inclusive business models, fostering economic opportunities for underprivileged populations (Dehghani et al. 2018).

SDG 11: Sustainable Cities and Communities.

Biotechnology aids in the development of eco-friendly and energy-efficient solutions for urban infrastructure, ranging from waste management to water treatment. Advanced biotechnological processes facilitate the conversion of organic waste into biofuels or compost, reducing the environmental impact of urban areas (Alper, 1992). Bioremediation technologies utilize microorganisms to detoxify polluted environments, revitalizing contaminated sites and improving overall environmental quality. Biotechnological advancements also support the creation of "smart cities" through the integration of biosensors and data analytics, enabling efficient resource management and enhancing overall urban sustainability. Furthermore, biotechnology plays a crucial role in sustainable construction materials, reducing the ecological footprint of urban development. Bio-based materials, such as bioplastics and bio-concrete, offer environmentally friendly alternatives to traditional construction materials (Vasil, 1998; Wollenberger, 1993).

SDG 12: Responsible Consumption and Production.

Biotechnological innovations contribute significantly to achieving SDG 12 objectives by providing sustainable alternatives and solutions across various sectors. Biotechnology facilitates precision agriculture, enabling farmers to optimize resource use and minimize environmental impact through targeted applications of fertilizers and pesticides (Yanni & Hegazy, 1990). Within the industrial landscape, biotechnology offers eco-friendly manufacturing processes and the production of bio-based materials. This includes the development of biodegradable plastics, enzymes for more efficient industrial processes, and the use of microorganisms to clean up pollutants. These advancements contribute to reducing the ecological footprint of industries, aligning with the sustainable production targets of SDG 12 (Rexen & Munck, 1984). Biotechnology aids in the decomposition and recycling of organic waste, turning it into valuable resources like bioenergy or compost. This approach supports a circular economy by minimizing the reliance on finite resources and reducing the environmental burden associated with traditional waste disposal methods. Biotechnological advancements in recycling and waste treatment contribute to minimizing landfill usage and decreasing the environmental impact of waste disposal. Bioplastics made from polyhydroxyalkanoates (PHAs) are eco-friendly alternatives to chemical plastics. They are synthesized by rich biomass concentration of microorganisms by the process of activated sludge (a system where microorganisms metabolize and consume organic matter in a tank). These biologically manufactured plastics have vast usage in food packaging, 3D painting, therapeutics and agriculture, and they are biodegradable (Abd et al., 2020).

SDG 13: Climate Action

Climatic deviations have reached to critical thresholds, impacting our planet, ecosystems, and human well-being. These climate extremes call for urgent actions to reduce greenhouse gas emissions, mitigate climate risks, and lessen significant threats to sustainable development. Biotechnology helps mitigate the effects of climate change by replacing materials based on fossil fuels with biological ones, such as bioplastics or biopesticides, with the resulting reduction in CO2 emissions (Adenle et al., 2012).

Genetically modified crops designed for increased drought resistance or enhanced photosynthetic efficiency can bolster food security in the face of changing climatic patterns. Biotechnology also holds promise in the realm of carbon capture and storage. Engineered microorganisms and plants can sequester carbon dioxide from the atmosphere, contributing to efforts to reduce greenhouse gas emissions. Biotechnological processes, such as the use of algae for carbon capture, offer innovative and sustainable alternatives to conventional methods (Campbell et al., 2018). Furthermore, biotechnology supports the development of bioenergy as a renewable and low-carbon alternative to fossil fuels. Biodegradation processes facilitated by microorganism's help convert organic waste into valuable resources, minimizing the release of potent greenhouse gases (Arora and Mishra, 2022).

SDG 14: Life Below Water

Sea water constitutes the largest ecosystem of the world but faces many challenges, such as pollution and climate change. SDG 14 primarily focuses on protecting and sustainably utilizing oceans for sustainable development (Gulseven, 2020). Blue biotechnology is helping to conserve valuable marine species to avoid overfishing, known as 'blue revolution'. Techniques, like genomics and recombinant DNA technology, have been utilized to grow genetically modified salmon, trout, and tilapia in fish tanks to lessen overfishing and protect marine species. Biosensors have been deployed in oceans to screen marine environments and detect for the presence of pollutants, nutrients, sediments, oil, and invasive micro-organisms in cost-effective manner. Filamentous algae have the ability to rapidly

absorb nitrogen (N) and phosphorus (P) (discharged by agricultural runoff) from the water above and incorporate them into their biomass. Through microalgal biotech approaches, filamentous microalgae are cultivated in a controlled flow-way, to allow the microalgae absorb the nutrients (Sutherland et al., 2021).

SDG 15: Life on land

Biotechnology is significantly contributing to preserving life on land. Agricultural innovations, and development of genetically modified crops which are the benchmarks of modern biotechnology, that are the supporters of land conservation efforts (Krauss, 2022). Biotechnology products are helping preserve life on earth and slow the loss of biodiversity. In fact, according to data from the ISAAA, 231 million hectares of land have been saved in recent decades thanks to biotechnology crops and the environmental impact quotient has dropped by 18.4%.Engineered organisms, such as genetically modified insects or microorganisms, can be deployed to control invasive species, protecting native flora and fauna. Additionally, biotechnological tools contribute to soil health and fertility through the development and application of microbial biofertilizers, promoting sustainable land use practices.in the context of habitat restoration, biotechnology supports the identification and manipulation of microorganisms to aid in soil remediation and the rehabilitation of degraded ecosystems. These microbial technologies enhance nutrient cycling, reduce soil erosion, and contribute to the restoration of terrestrial habitats (Brister & Newhouse, 2020).

SDG 16: Peace, Justice and Strong Institutions.

At a molecular level, biotechnological tools are employed in forensic genetics, aiding in the identification and verification of individuals in legal contexts. DNA profiling techniques, including polymerase chain reaction (PCR) and DNA sequencing, are crucial for criminal investigations and the establishment of justice systems. Advancements in genetic fingerprinting contribute to the development of reliable and secure identification systems. This has applications in law enforcement, border control, and the establishment of robust identity verification mechanisms, reinforcing the foundation of strong and accountable institutions (Drobnic, 2021).

Diagnostic technologies based on biotechnological principles, such as the PCR and nucleic acid sequencing, are pivotal for disease surveillance, pandemic monitoring, and forensic epidemiology. These applications aid in the prevention and investigation of crimes related to public health, contributing to the overall goal of building resilient and accountable institutions. Furthermore, biotechnological tools are employed in the development of advanced surveillance systems, such as pathogen detection in environmental samples. The rapid and accurate identification of biological threats supports early intervention and crisis management, reinforcing the institutional capacity for maintaining peace and security (Schmid & Drexler, 2004).

SDG 17: Partnership For The Goals.

The Sustainable Development Goals necessitate intricate solutions, therefore forming coalitions with other system stakeholders is crucial. Maintaining a resilient global society requires partnerships between the public and private sectors to generate innovation and meet sustainable development goals, as well as knowledge exchange and capacity building, technology transfer, health and disease management, and environmental concerns. Through training initiatives, biotechnology may help developing countries strengthen their capacity by equipping local populations with the know-how to implement biotechnological solutions for sustainable development. For many years, biotechnology has had a significant social, environmental, and economic influence thanks to public-private partnerships and global goals (Franco & Abe, 2020).

II. CONCLUSION

Ultimately, biotechnology plays a significant and diverse role in attaining sustainable development, encompassing several domains and tackling the complex issues delineated by the Sustainable Development Goals (SDGs) of the United Nations. Biotechnological advancements have revolutionised agriculture, industry, healthcare, and environmental conservation, making them potent tools for bringing in a more just and sustainable future. The revolutionary impact of biotechnology is apparent

as we stand at the nexus of technical development and the goal of a sustainable future. Biotechnology may, in fact, play a key role in creating a society that is robust to environmental threats, socially inclusive, and economically successful with sustained research, appropriate use, and international collaboration.

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