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ROLE OF GREEN BIOTECHNOLOGY IN SUSTAINABLE DEVELOPMENT

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Abstract: Green biotechnology is a type of biotechnology that uses biological techniques to improve agricultural processes and reduce environmental impact, tackle climate change issues, produce renewable energy and reduce greenhouse gas emission. It uses genetic engineering to develop more sustainable agricultural crops with high yield and nutritional content, insect resistance, longer self-life and various other traits like production of edible vaccine, monoclonal antibodies, phytoremediation and so on. Green 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 green biotechnology a crucial tool for accomplishing sustainable development objectives. In order to achieve sustainable development, green biotechnology is essential since it stimulates favourable changes in the social, economic, and environmental spheres. Green biotechnology plays a key role 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, Green Biotechnology, Sustainable Development Goals, Environment Protection.

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 [1]. Green biotechnology refers to biological techniques of plants with the target of improving the nutritional quality, quantity and production economics. Such as production of disease-resistant or UV-resistant plants, or plants that have superior qualities, by means of genetic modification. Other examples include production of biofuels, such as ethanol or methane, from crops such as corn, or even from marine algae grown at land-based production facilities. [2] The first genetically modified crops were cultivated in the USA in 1996. In 2009, 14 million farmers in 25 countries used Genetically Modified (GM) crops. The annual global acreage has increased to more than 134 million hectares worldwide. [3]GM seed tends to be more expensive but in return, it reduces expenses in other areas, such as the

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cost of pesticides, machines and labor [4] the three major contributions of green biotechnology to the mitigation of the impact of climate change are:

A. Greenhouse gas reduction

B. Crops adaptation

C. Protection and increase yield with less surface [5].

The population of the world is projected to increase by roughly 75 million people annually from now until the year 2030, reaching 8.1 billion. The majority of population growth will take place in emerging nations, which can ill-afford further population pressures [6]. 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 [7], 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 [8]. Future generations' prosperity depends on the SDGs being accomplished collectively. The bio economy depends on the long-term, sustainable use of biological resources that ultimately reduce waste and help to slow down global warming [9]. This article will review the opportunities and problems involved in the application of green biotechnology to sustainable development goals.

GREEN BIOTECHNOLOGY

Crop plants that have been genetically modified in laboratories by gene transfer technique through genetic engineering to enhance different traits (resistance to pesticides or improved nutritional content, bigger and better crops, improved taste and look, etc.) are called as transgenic crops or genetically modified (GM) crops. The ultimate goal of transgenic (involving introduction, integration, and expression of foreign genes) is to improve the crops, with the desired traits. Some beneficial GM Crops are ---

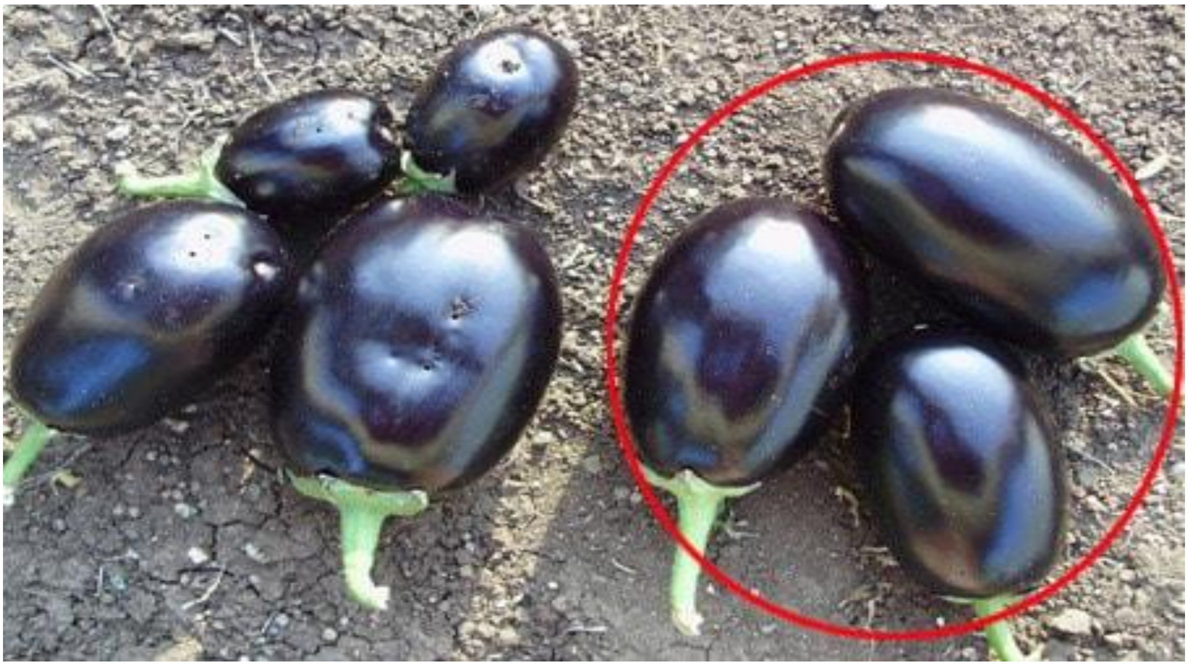
❖ Pest resistant plant ❖ Herbicide resistant plants ❖ Crops with increased self-life; ❖ Crops with increased nutrient contents; ❖ Viral disease resistant crops; ❖ Edible vaccines ❖ Biofuel producing crop

PEST RESISTANT TRANSGENICS

Bt Cotton ❖ It is a Genetically modified variety of cotton that has a foreign gene, Bt toxin gene/ Cry gene (in particular Cry1A(a), Cry1A(b) and Cry1A(c)), from the bacterium Bacillus thuringiensis, integrated in its genome. It produces an insecticidal crystalline protein (ICP) called cry protein that provides protection against bollworms. India is the largest producer of cotton, and GM cotton, as of 2014.

Bt cotton

Bt Brinjal is a transgenic brinjal created by inserting a gene cry1Ac from the soil bacterium Bacillus thuringiensis into Brinjal. This genetically modified brinjal gives resistance against insects such as the Brinjal Fruit and Shoot Borer (Leucinodes orbonalis). Those in favour of BT Brinjal say: The use of Pesticides and costs will go down. The yield of brinjal will increase. Farmers will therefore earn more. India's food security will benefit. But protesters argue: The impact on human health and environment is not clear. Introducing BT Brinjal will open floodgates for other genetically-modified crops.



Bt Brinjal

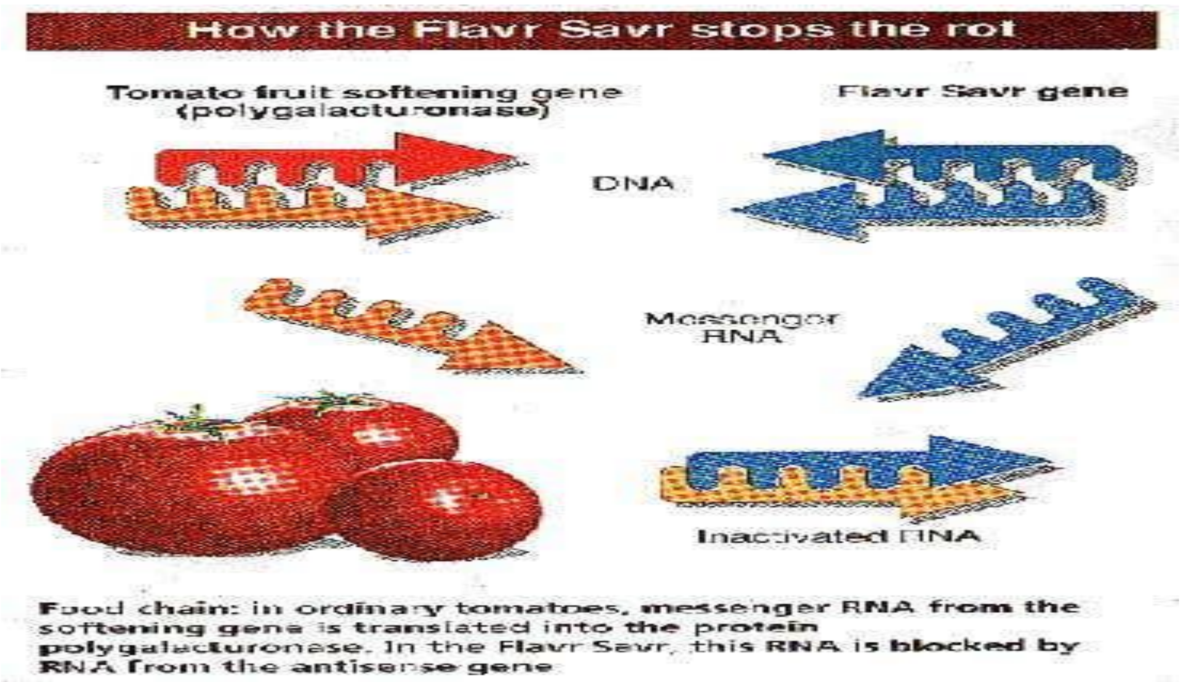
HERBICIDE RESISTANCE TRANSGENICS

Round Up ready soybeans (resistant to the herbicide Roundup) ❖ Roundup Ready crops are crops genetically modified to be resistant to the herbicide Roundup. Roundup is the brand-name of a herbicide (with active ingredient glyphosate) produced by Monsanto. ❖ RoundUp Ready crop seeds have notoriously been referred to as "terminator seeds." This is because the crops produced from Roundup Ready seeds are sterile. Each year, farmers must purchase the most recent strain of seed from Monsanto. This means that farmers cannot reuse their best seed.

Round up ready soyabean

GM CROP WITH EXTENDED SELF LIFE: **FLAVR SAVR TOMATO**

❖ It is a tomato plant, genetically engineered via antisense RNA approach to turn off the gene for polygalacturonase (PG) enzyme which is involved in rotting and softening of the fruit is largely due to degradation of the cell wall (pectin) . ❖ It is the first commercially available genetically modified food with a longer shelf life and is the first genetically engineered crop granted license for human consumption. ❖ It was Produced by Californian company Calgene (1994) ❖ Calgene introduced a gene in plant which synthesize a complementary mRNA to PG gene and inhibiting the synthesis of PG enzyme.



Flavr savr tomato

BIOFORTIFICATION

GOLDEN RICE:

❖ Golden rice is a variety of Oryza sativa rice produced through genetic engineering to biosynthesize beta-carotene, a precursor of vitamin A, in the edible parts (endosperm) of rice. ❖ The transgenic rice 'golden rice' contains good quantities of β- carotene, which gives the grain a golden colour as an indicator of β-carotene concentration ❖ Golden rice-1 was created by transforming rice with three β-carotene biosynthesis genes: psy (Phytoene synthase) and lcy (lycopene β-cyclase) from daffodil (Narcissus pseudonarcissus) and crtI (Carotene desaturase) from the soil bacterium Erwinia uredovora ❖ Originial Golden Rice (GR1) does not produce enough ß-carotene (Provitamin A); it produces "only 1.6 µg/gm of carotenoids; a child would have to eat more than 10kg/day to get sufficient dose". ❖ In 2005, Syngenta biotech company produced a variety of golden rice called "Golden Rice 2" using the phytoene synthase (psy) gene from maize and carotene desaturase (crt1) from *Erwinia uredovora.* It produces 23 times more carotenoids than golden rice1

Golden rice

RESISTANCE AGAINST VIRAL INFECTION

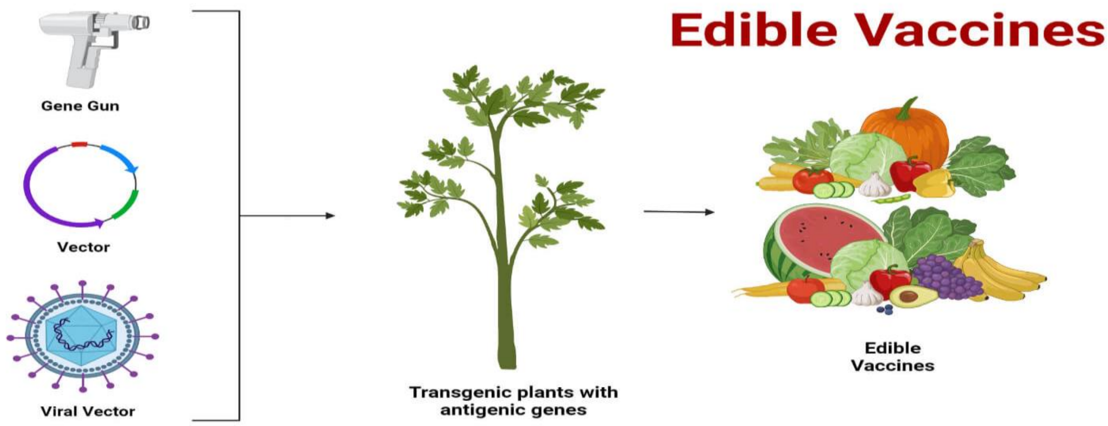
❖ Coat protein gene from tobacco mosaic virus (TMV), classified as a positive strand RNA virus, has been transferred to tobacco and in the transgenic plants. Expression of coat proteins CP, was observed ❖ further when inoculated with TMV, the infection in the transgenic plants was very low and delayed relative to control plants that were not transferred. This provides to a new approach for producing virus resistant plants, coat protein gene should be constitutively expressed and may thus have effects on the nutritional value of plants ❖ Subsequently this approach has been applied to a range of crops (tomato ,alfalfa , tobacco , potato , melons ,rice) for developing resistance against a broad spectrum of positive RNA strand plant virus ❖ DNA coding for a component of TMV replicase enzyme , was also transferred to tobacco plants , conferring resistant to TMV. Viral and Fungal Disease Resistance Banana ❖The most important viral disease of banana is the Banana Bunchy Top Virus (BBTV). The "bunched" appearance is due to the stunted growth of the banana leaves and the infected plant usually does not bear fruit. Another disease is the Banana Bract Mosaic Virus (BBrMV) characterized by inter-veinal discoloration of the leaves. ❖Coat protein or replicase genes of the virus are incorporated into banana cultivars to produce QCAV-4 banana that is resistance to the disease ❖ A genetically modified banana cultivar that is resistant to a fungus that is fatal to the Cavendish banana.

RESISTANCE AGAINST TMV INFECTIONS ON LEAF

EDIBLE VACCINES

❖ A protein which acts as the vaccine, present in food and consumed as the internal composition of food is known as edible vaccine. ❖ The phrase edible vaccines was first used by Charles Arntzen in 1990 and refers to any foods (typically plants) that produce vitamins, proteins or other nourishment that act as a vaccine against a certain disease. ❖ Edible vaccines are genetically modified crops that contain added "immunity" for specific diseases. Future potential ❖ Plant-based vaccines are a novel class of vaccines that have great potential to treat diseases. Though the development procedure has advanced considerably, there remains a need for more suitable gene delivery methods to achieve efficient and optimum vaccine production.

❖ Several bioethical concerns surrounding the production of plant-based vaccines, such as the risk of transferring allergens from transgenic plants to humans and animals, are also important to consider. Additionally, various technical challenges, such as the development of regulatory requirements, must be addressed before these vaccines can be produced on a large scale.



EDIBLE VACCINES

BIOREMEDIATION

Use of microorganisms to detoxify or decontaminate the environment by removing or degrading the pollutants is called as Bioremediation

❖Bioremediation is a cost effective and nature friendly biotechnology that is powered by microbial enzymes.

❖The species belonging to genera*Alcanivorax, Pseudomonas, Acinetobacter etc*. metabolise oil as the sole source of carbon. They do so by the process of*"*bioremediation*"*.

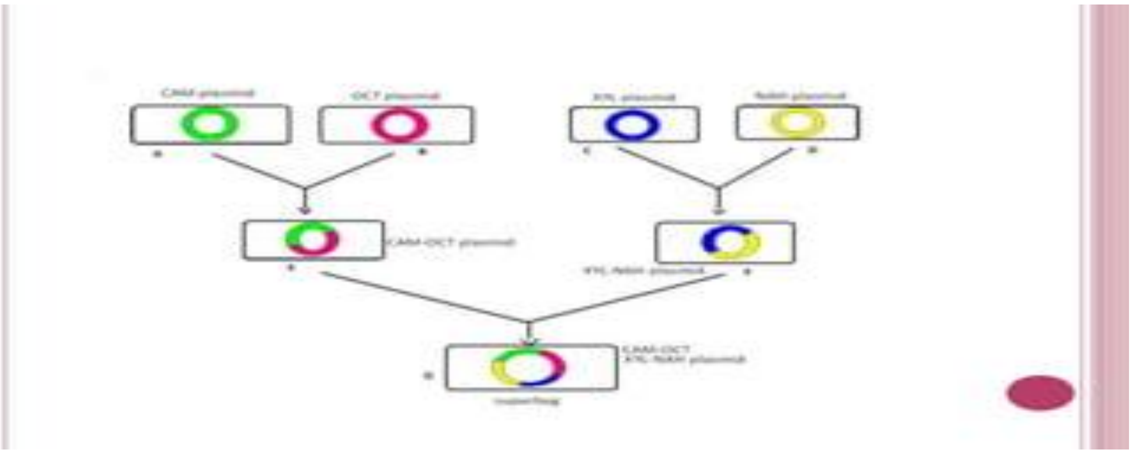
❖*Alcanivorax* is one such bacterium that was instrumental in cleaning up 2010 oil spill in the Gulf of Mexico

❖*Alcanivorax borkumensis* is an oil degrading gram negative rod shaped bacterium. It by aggregation forms a biofilm over the oil surface. This biofilm secretes surfactants that emulsify the oil after which the oil is degraded by bacteria.

In 1971,Prof. AnandaMohan Chakraborty ("Father of Patent Microbiology") *et al.* used four strains of*Pseudomonas* that independently degrade the chemical compound octane, camphor, xylene, and naphthalene and then fused all four strain's plasmids to create the superbug, *Pseudomonas putida* that can degrade petroleum (camphor, octane, xylene and naphthalene). This was patented in 1980. The American Government, in 1990, allowed to use the superbug to clean up oil spills in the water of Texas State.

❖Chakraborty called it a*"multi-plasmid hydrocarbon-degrading Pseudomonas"*which is capable of digesting nearly all types of hydrocarbon found in typical oil spills at a faster pace than previously known existing strains of oil-eating microbes

❖The genetically modified bacteria are also capable of tolerating high salinity, extreme temperature, adapting to the sudden fluctuations in the surroundings and can withstand the highly toxic chemicals present in the oil spills.



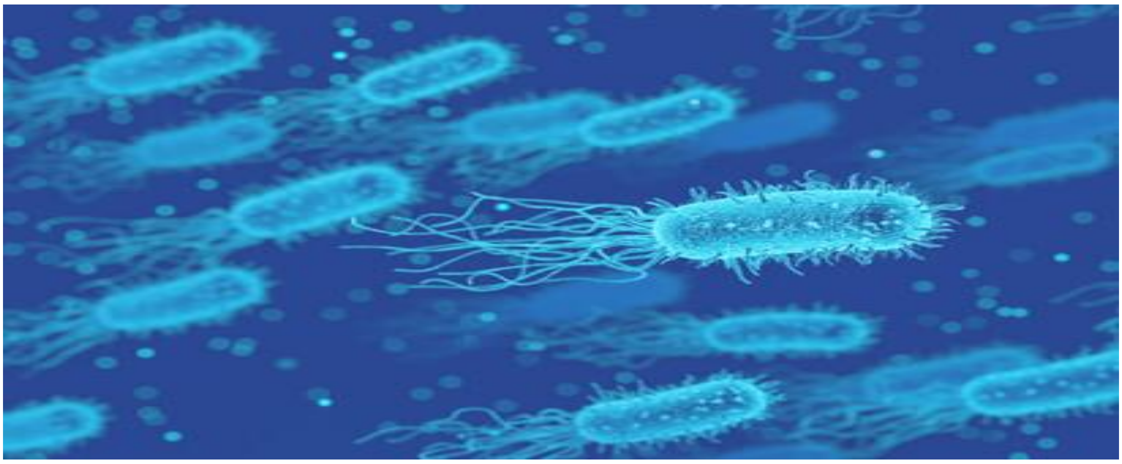
BIOREMEDIATION BY SUPERBUG

MICROBES CLEANING RADIOACTIVE WASTE

Many bacteria reduce the radioactive metals from an oxidized soluble form to a reduced insoluble form.

❖Gemma Reguera, a microbiologist discovered that *Geobacter* traps or immobilizes the uranium with the help of its protein like nanowires and thus prevents the spreading of harmful radioactive waste.

❖According to the findings of U.S. National Science Foundation (published in the Journal of Applied and Environmental Microbiology) the bacterium *Geobacter sulfurreducens* has a lipopolysaccharide coat (on its cell surface) that absorbs uranium like a sponge.

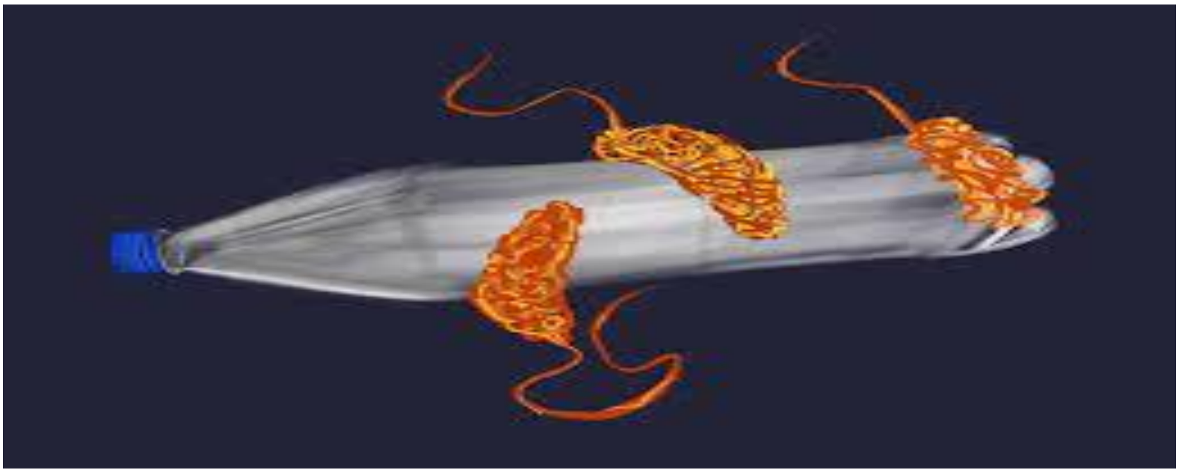


URANIUM EATING BACTERIA

PLASTIC EATING MICROBES

According to Royal Netherlands Institute for Sea Research, *Rhodococcus ruber,* a gram positive aerobic bacterium can digest plastic and convert them into Carbon dioxide and other harmless substance. Another gram negative aerobic rod shaped bacterium *Ideonella sakaiensis* can digest a particular type of plastic called Polyethylene terephthalate (PET) by converting the long chain PET to short chain terephthalic acid and ethylene glycol with the help of its digestive enzyme, PETase. The researchers then break down this terephthalic acid in to vanillin through a series of chemical reactions.

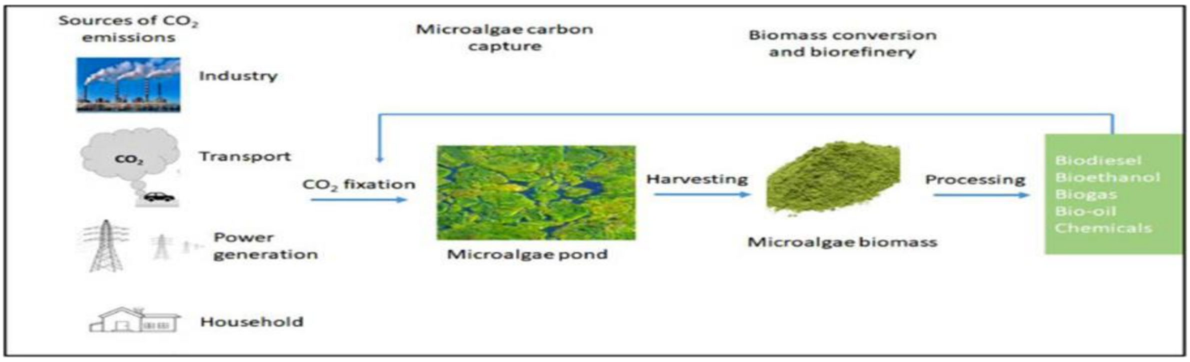
According to The Journal "Proceedings of the National Academy of Science of the United States of America (PANS)", Researchers at the University of Portsmouth re-engineered PETase to create a cocktail enzyme, by combining PETase and MHETase (Monohydroxyethyl terephthalate hydrolase) that digests plastic six times faster than the normal. This super enzyme can also digest polyethylene furanoate (PEF), a sugar-based bioplastic. Researchers at University of Edinburgh, use *E. coli* bacteria to convert plastic into vanillin.



PLASTIC EATING BACTERIA

CARBON SEQUESTRATION

The process of removing atmospheric carbon dioxide and storing it in in solid or liquid form is known as carbon sequestration. About 45% of Carbon dioxide released by human is sequestered in ocean. Phytoplanktons are thought to be responsible for contributing 50-85% of the oxygen on earth through photosynthesis. Researchers estimate that *Prochlorococcus* and *Synechococcus* remove about 10 billion tons of carbon from the air each year; this is about two-thirds of the total carbon fixation that occurs in the oceans. Scientists have deciphered the genomes of these two microbes. With this knowledge scientists hope to understand why these two microbes carry out photosynthesis so successfully.



THE 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 ([14],[6]).

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 [5]. 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 [22]; [11].

SDG 3: Good Health and Wellbeing: For many years, these fields have helped with illness control, diagnosis, and prevention [4]. The development of medicinal drugs, diagnostic tools, and vaccinations made possible by biotechnology has enhanced public health and wellbeing. 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 [29]. Individual genetic markers are used by precision medicine to customise treatments. The detection of diseases is facilitated by advanced clinical diagnostics and imaging techniques ([7]. [24]

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 [25].

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. The World Health Organisation said that advances in biotechnology have improved family planning choices, decreased maternal death rates, and increased access to reproductive healthcare.

SDG 6: Clean water sanitation: water pollutants can be eliminated and purified microbes by the application of biotechnology. In order to purify water bacteria are absorbent in cellulosic fibres containing polyelectrolytes [23].

SDG 7: Affordable and clean energy: Biotechnology provides substitute for producing clean energy. Utilising genetic engineering and bioprocessing, biofuel may be produced from feedstock including algae crop and agricultural waste. Fuel may be replaced with low carbon bioethanol made from sugarcane and other resources. Anaerobic digestion of biomass produces biogas which reduce organic waste and offer cleaner energy for automobile and cooking. ([4], [21])

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. [16]. 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.

SDG 9: Industry, Innovation and Infrastructure: 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. Industries may minimise waste creation, optimise resource utilisation, and adopt environmentally friendly manufacturing methods by utilising biotechnology. According to [12], 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 [7].

SDG 11: Sustainable Cities and Communities: 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 [28]; [30]).

SDG 12: Responsible Consumption and Production: Biotechnology facilitates precision agriculture, enabling farmers to optimize resource use and minimize environmental impact through targeted applications of fertilizers and pesticides (Yanni & Hegazy, 1990). 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. These biologically manufactured plastics have vast usage in food packaging, 3D painting, therapeutics and agriculture, and they are biodegradable [1].

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 [3]. 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 [10]. 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 [4].

SDG: 14 Life below water: primarily focuses on protecting and sustainably utilizing oceans for sustainable development [15]. 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 [25].

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 [21]. 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 [9]

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 [13]. Diagnostic technologies based on biotechnological principles, such as the PCR and nucleic acid sequencing, are pivotal for disease surveillance, pandemic monitoring, and forensic epidemiology. ([26]

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 [15].

CONCLUSION

Last but not the least the application of biotechnology in the field of agriculture (green biotechnology) is immense. The green biotechnology helps to reduce or solve the problems related to the environment as well as to agriculture. It cleans the ecosystem for living organisms and helps in having a sustainably healthy life. Because of industrialization, urbanization and anthropogenic activities, the environment is facing different issues like depletion of natural resources, pollution of natural bodies, etc.; by exploiting the applications of green biotechnology, these problems can be effectively and efficiently solved. Similarly in agricultural sector food security including quality nutrition and health care can be achieved by the help of biotechnology. 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.

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