Research Article

Role of Microbial Biotechnology in Sustainable Agriculture and Environment

Sonia Kumari[1]*, A.K Jha[2], Rakesh Kumar[1] and Rajnikant[3]

[1]Department of Dairy Microbiology, SGIDT, BASU, Patna, India
[2]Department of Dairy Business Management, S.G. Institute of Dairy Technology, BASU, Patna, India
[3]Food Science and Technology Laboratory, Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, India

Abstract

Biotechnology is the science of using biological things into technology for the benefits of mans kind. It is a rapidly growing segment in biological sciences and has diversified applications in sustainable agriculture. Biotechnology uses many things such as plants, animals and Microbes. This review will use the application of microbes in technology such as applications in agriculture as bio fertilizers, bio-pesticides, bio-herbicides, bio insecticides, fungal based bio insecticides and viral based bio insecticides. They have also a role in cleaning the environment through biodegradation of waste and oil spills. This review will enlist the role of microbial biotechnology in all these application with few most advanced examples.

Keywords: Biotechnology, Microbial biotechnology, Genetic modified crops (GM), Bio fertilizer, Bio pesticides, Bioremediation

***Correspondence**
Author: Sonia Kumari
Email: sonia.sinhasgidt@gmail.com

Introduction

The population of world is increasing day by day with simultaneously leads to increase food demand as well. This poses a great challenge to traditional agricultural systems. Old farming equipment and practices are now exhausted and their effectiveness is decreasing to meet the agricultural productivity and their by the demand of the peoples. As countries develop these pressures are multiplied by reducing farmland, rising labour costs and shortage of farm workers. Biotechnology offers modern method to improve the sustainability of existing system to produce more and better quality of our agricultural products. There are numerous application of biotechnology that includes increased crop yield, reduced use of chemical pesticides, providing resistance to the disease and pest to the crop, Processing of foods turning them to more nutritious and easy to handle and transport. Agricultural technologies ensured a 'green revolution' in the middle of 20th century but causing high ecological cost and contributing global pollution, unfavorable climate change and loss of biodiversity [1].

Branch of biological science, which deals with the manipulation through genetic engineering of living organisms or their components to produce useful products for various applications in biological sciences, is known as Biotechnology. Biotechnology is the use of living systems and organisms to develop or make products, or "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use" (UN Convention on Biological Diversity, Art. The American Chemical Society defines biotechnology as the application of biological organisms, systems, or processes by various industries to learning about the science of life and the improvement of the value of materials and organisms such as pharmaceuticals, crops, and livestock. As per European Federation of Biotechnology, biotechnology is the integration of natural science and organisms, cells, parts there of, and molecular analogues for products and services. Development of biotechnology applications was initiated in 6000 BC, but development of genetic tools and cellular and tissue engineering gave the beginning in 1970s then after many the speed of biotechnological work gain momentum [2]. Use of microbes for the above purpose is known as Microbial Biotechnology. One of the most important contribution of biotechnology in agriculture is the development of genetically modified crops (GM) that has resistant to many pest and weeds and hence increased crop production [3]

Microbes and Biotechnology

Microorganisms are the group of tiny organism that are present everywhere in soil air and in water. Human being is exploiting microbes since ancient era. The science of producing curd, bread and alcohol was existed before modern

civilization. Early man used to decompose agricultural and kitchen waste by burying them in the soil and letting them for many months that now a day known as composting. Similarly the art of producing curd at home by putting small amount of curd are very well known to the early people. Similar is the case of alcohol and vinegar and pickles production. Now-a-days this art called as "Fermentation technology" which is being done at large scale and by this technology many more valuable products are being made at industrial level. At present day microbes are exploited in the biotechnology process known as Microbial biotechnology which is an important area that promotes for advances in food safety, food security, value-added products, human nutrition and functional foods, plant and animal protection, and overall fundamental research in the agricultural sciences. Microbial biotechnology, enabled by genome studies, will lead to breakthroughs such as improved vaccines and better disease-diagnostic tools, improved microbial agents for biological control of plant and animal pests, modifications of plant and animal pathogens for reduced virulence, development of new industrial catalysts and fermentation organisms, and development of new microbial agents for bioremediation of soil and water contaminated by agricultural runoff [4].This review is based on the exploitation of microbial biotechnology in the field of agriculture and environmental protection from pollutant pesticides.

Microbial biotechnology and its applications in Agriculture

Soil is diverse in microbial flora and fauna. There are many indigenous microorganisms which benefits plants in one and in another way. The group of microorganisms that directly or indirectly benefits the crop. Directly they made nutrient present in soil into available form while indirectly they secretes many hormones and organic acid that that have role in chelating many micronutrient and make them unavailable to the pathogens and their by suppressing their growth and acts as bio control agents. The group of responsible for that above activity comes under PGPR (Plant growth promoting rhizobacteria).Some example of PGPR are as follow:

Bio fertilizers

Bio fertilizer are preparation of live or latent cell of efficient strain of nitrogen fixing, phosphate solubilizing or cellulolytic microorganism used for application of soil, or seed or mixed with compost to accelerate the process of mobilization of nutrient from the soil and thereby making them more available to the growing crops or plants [5]. Bio fertilizers are known to play a number of vital roles in soil fertility, crop productivity and production in agriculture as they are eco friendly and can replace chemical fertilizers that are indispensable for getting maximum crop yields. Some of the important functions or roles of Bio fertilizers in agriculture are:

- They supplement chemical fertilizers for meeting the integrated nutrient demand of the crops.
- They can add 20-200 kg N/ha year (eg. *Rhizobium sp* 50-100 kg N/ha year; *Azospirillum Azotobacter* : 20-40 kg N/ha /yr; Azolla : 40-80 kg N/ha; BGA :20-30 kg N/ha) under optimum soil conditions and thereby increases 15-25 percent of total crop yield.
- They can at best minimize the use of chemical fertilizers.
- Application of Bio fertilizers results in increased mineral and water uptake, root development, vegetative growth and nitrogen fixation.
- Some Biofertilizers *(eg, Rhizobium BGA, Azotobacter* sp) stimulate production of growth promoting substance like vitamin-B complex, Indole acetic acid (IAA) and Gibberellic acids etc.
- Phosphate mobilizing or phosphorus solubilizing bio fertilizers / microorganisms (bacteria, fungi, mycorrhiza etc.) converts insoluble soil phosphate into soluble forms by secreting several organic acids and under optimum conditions they can solubilize / mobilize about 30-50 kg P2O5/ha due to which crop yield may increase by 10 to 20%.
- Mycorrhiza or VA-mycorrhiza (VAM fungi) when used as Biofertilizers enhance uptake of P, Zn, S and water, leading to uniform crop growth and increased yield and also enhance resistance to root diseases and improve hardiness of transplant stock.
- They liberate growth promoting substances and vitamins and help to maintain soil fertility.
- They act as antagonists and suppress the incidence of soil borne plant pathogens and thus, help in the bio-control of diseases.
- Nitrogen fixing, phosphate mobilizing and cellulolytic microorganisms in bio-fertilizer enhance the availability of plant nutrients in the soil and thus, sustain the agricultural production and farming system.
- They are cheaper, pollution free and renewable energy sources
- They improve physical properties of soil, soil tilth and soil health in general.

- They improve soil fertility and soil productivity.
- Blue green algae like *Nostoc, Anabaena, and Scytonema* are often employed in the reclamation of alkaline soils.
- Bio-inoculants containing cellulolytic and lignolytic microorganisms enhance the degradation/ decomposition of organic matter in soil, as well as enhance the rate of decomposition in compost pit.
- BGA plays a vital role in the nitrogen economy of rice fields in tropical regions.
- *Azotobacter* inoculants when applied to many non-leguminous crop plants, promote seed germination and initial vigor of plants by producing growth promoting substances.
- *Azolla-Anabaena* grows profusely as a floating plant in the flooded rice fields and can fix 100-150 kg N/ha /year in approximately 40-60 tones of biomass produced.
- Plays important role in the recycling of plant nutrients.

Bio-pesticides

The term biopesticide is used for all kind of bio control agents like microbial pesticides, microbial herbicides, while the microbes used for insect control of often called bioinsecticides and use of microbes or its secretion to kill the weeds is microbial herbicides [6]. Not all microorganisms found in the soil are friendly to plants. Some of them are pathogens can cause disease or damage the plant. Scientists developed biological "tools," which use these disease-causing microbes to control weeds and pests naturally. Bio pesticides being a living organisms (natural enemies) or products there of pose less threat to the environment and to human health, hence can be used for the management of pests. One of the most widely used microbial biopesticides is *Bacillus thuringiensis,* popularly known as Bt. A list of bio pesticides given in **Table 1**.

How biotechnology help to develop these Biopesticides

Bio-herbicides are the microbes possess invasive genes that can attack the defense genes of the weeds, thereby killing it. Bio herbicides can survive in the environment long enough for the next growing season [7]. It is cheaper than synthetic pesticides so reduce farming expenses if managed properly. In addition, it is not harmful to the environment as chemical herbicides and not affect non-target organism. Bio-technology also helps in developing alternative controls to synthetic insecticides to fight against insect pests. Micro-organisms in the soil that will attack fungi, viruses or bacteria which cause root diseases. Formulas for coatings on the seed (inoculants) which carry these beneficial organisms can be developed to protect the plant during the critical seedling stage. Bio insecticides do not persist long in the environment and have shorter shelf lives; they are effective in small quantities, safer to humans and animals compared to synthetic insecticides; they are very specific, often affecting only a single species of insect and have a very specific mode of action; slow in action and the timing of their application is relatively critical [8]. Likewise for the production of fungal insecticides, fermentation technology is used for mass production of fungi. Spores are harvested and packaged so these are applied to the fields where insects came. When the spores are applied, the enzymes of fungi break the outer surface of the insects' bodies. Once inside, they begin to grow and eventually cause death of the insects [9**]**. Baculoviruses Virus based insecticides are known to regulate many insect populations in nature. Their host-specificity is very high, usually restricted to a single or a few closely related insect species. They are amongst the safest pesticides, with no or negligible effects on non-target organisms, including beneficial insects, vertebrates and plants. Baculovirus-based pesticides are compatible with integrated pest management strategies and the expansion of their application will significantly reduce the risks associated with the use of synthetic chemical insecticides [10].

Microbial Biotechnology and Environmental Health

According to the international Society for environmental Biotechnology the "environmental Biotechnology is defined as an environment that helps to develop, efficiently use and regulate the biological systems and prevent the environment from pollution or from contamination of land, air and water have work efficiently to sustain an environment friendly Society. Applications of environmental biotechnology:
There are five major different types of Applications of Environmental Biotechnology. They are as follows

Biomarker

This type of Application of environmental Biotechnology gives response to a chemical that helps to measure the level

of damage caused or the exposure of the toxic or the pollution effect caused. In other word, Biomarker can also be called as the Biological markers. Human bio monitoring provides an efficient and cost-effective way to identify and quantify exposure to chemical substances, including those having deleterious effects on human beings. The usefulness and the limitations of these biomarkers in bio monitoring studies of populations exposed to pesticides, with regard to the main routes of uptake and different matrices, which can be used to monitor risk assessment in occupational settings [11].

Table 1 List of Important Bio Pesticides

Bio control agent	Suppressed agent	Crop	Disease /Host/Remarks
Bacteria			
Pseudomonas fluorescens	*Phytophthora infestans*	Potato	Fireblight
Erwinia herbicola	*Erwinia amylovara*	Pear, apple and other rosaceous plants	
B. subtilis	*Uromyces sp.*	Bean	Bean rust
S. griseoviridis	*Agrobacterium brasicicola*	Cruiciferae	Damping off of crucifers
P. fluorescens	*Rhizoctotnia solani P. ultimum*	Cotton	Damping off of cotton
P. fluorescens	*Pythium ultimum*	Mushroom	Brown blotch of Mushrooms
A.Radiobacter	*Agrobacterium tumefaciens*	Several crops	Crown gall
Bacillus thuringiensis	Heliothis and other Lepidoptera and Coleopteran	-	Cotton, chickpea, maize, tomato, groundnut etc.
Fungi			
Hirsutella thompsonii	Citrus mites	Citrus fruits	
Verticillium lecanii	Aphids, white, Lies		Citrus fruit
Trichoderma viride	*Macrophomina phaseolina*	Groundnut, chickpea	
Rhizoctonia solani	*Pythium ultimum*	Cotton legume	Damping off of cotton
T. viride	*F. solani*	Sisam	Sisam wilt
Viruses			
Nucleopoyhedrosis virus	Rice borer	Rice	Asiatic rice borer
Nucleopoyhedrosis virus	Cotton leaf worm	Cotton	Cotton leaf worm
Chilo Granulosis virus	*Chilo infuscatellus*	Sugarcane	
Nucleopoyhedrosis virus (NPV)	Asiatic rice borer, cabbage looper	Cotton, rice Cabbage	Commercially used in USA
Granulosis viruses (GV)	Codling moth, tuber worm rice borer	Potato, rice	
Bioherbicides			
Phytophthora citrophora	Milk weed	-	-
Colletrotrichum gloecosproioides	*Aeschynomene verginica*	-	-
Protozoa	-	-	-
Malameba locustae	Grass hoper, Lepidoptera	-	-

Bio energy

Biogas, biomass, fuels, and hydrogen are collectively called as the Bio energy. The use of this application of Environment Biotechnology is in the industrial, domestic and space sectors. As per the recent need it is concluded that the need of clean energy out of these fuels and alternative ways of finding clean energy is the need of the hour. There are many substrates that can be used for biogas production. Spent oyster mushroom substrate can be utilized effectively for biogas production [12]. Similarly paddy straw has been utilized to produce bio ethanol [13] production

Bioremediation

A variety of industrial organic chemicals are released into the environment that serves as a raw material for microbial enzymes [14]. The process of cleaning up the hazardous substances into non-toxic compounds is called the Bioremediation. Depending on their behavior in the environment, organic compounds are often classified as

biodegradable, persistent or recalcitrant. A biodegradable organic compound is one that undergoes a biological transformation [15, 16]. A persistent organic compound does not undergo biodegradation in certain environments; and a recalcitrant compound resists biodegradation in a wide variety of environments. Mineralization is a parallel term to biodegradation, referring to complete degradation to the end products of CO2, water and other inorganic compounds [17]. Microorganisms has the ability to degrade a wide variety of compounds, like benzene, phenol, naphthalene, nitroaromatics, biphenyls, polychlorinated biphenyls (PCBs) and chlorobenzoates [18]. Although simple aromatic compounds are biodegradable by a variety of degradative pathways, halogenated counterparts are more resistant to bacterial attacks and often necessitate the evolution of novel pathways [19]. Biotechnology has the answer for the bioremediation of this bio hazardous chemical pollutant by cloning of different genes isolated from the diverse bacterium and assembled them on a single bacterial plasmid. Genetically modified strain of *P.fluroscences* strain HK44 was able to sense environmental pollution signaling through bioluminescence and able to bioremediate the environment [20].

Biotransformation

Biotransformation can be clarified as the specific modification of a definite compound to a distinct product with structural similarity, by the use of biological catalysts including microorganisms like fungi [21] The biological catalyst can be described as an enzyme, or a whole, inactivated microorganism that contains an enzyme or several enzymes produced in it. There is only slight difference between a biotransformation and a bioconversion [22]. A bio conversion utilizes the catalytic activity of living organisms and hence can involve several chemical reaction steps and hence is quite unstable for used substrates. The properties of bio transformations and bioconversions are very similar and in many cases the terms are cited as interchangeable [23].

Advantages of Microbial Transformation

- Microbial transformation has the ability to operate at near neutral pH, ambient temperatures and atmospheric pressures [24]. In contrast to the normal chemical reaction this operated at extremes of these conditions that are not environment friendly and industrially undesirable.
- Microorganisms are capable to multiply in a shorter time period so it can produce a great variety of enzymes in a short period of time.
- Cultivation of microorganisms is easy that under extreme environments such as low or high temperatures and/or acidic or alkali conditions.
- Feasible reactions that are not likely to be carried out by traditional synthetic procedures can be carried out by microbial transformation.

Conclusion

The major benefits of biotechnology are many more it helps to produce crop without much application of chemical fertilizers, pesticides, herbicides etc. It also keep our environment safe and clean for the use of the future generations. It helps the organisms and the engineers to find useful ways of getting adapted to the changes in the environment and keep the environment clean and green. The benefit of environmental biotechnology helps us to avoid the use of hazardous pollutants and wastes that affect the natural resources and the environment. The development of the society should be done in such a way that it helps to protect our environment and also helps us to development it. The environmental biotechnology has a role to play in the removal of the pollutants. Also biotransformation makes possibility of producing many useful industrial enzymes and product without causing any hazardous to the natural environment. In this way microbes and biotechnology go side by side to benefits the man kinds.

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