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Popular Article

Potential Application of Microbial Biotechnology in Agricultural Development

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Overview

Microbes are tiny organism present everywhere in water, air and soil. Employment of biotechnological approaches with microorganism offer a broad field of research in agriculture and sustainable development. Harnessing the potential application of microbial biotechnology in agriculture is considered as a most fruitful and long-term solution to promote quality crop production, food safety, food security, value-added products, human nutrition and functional foods, plant and animal protection. Several microorganisms have been identified which gave benefit to plants through protection against insects, pests, disease and abiotic threats. Microbial–technology applicable in the production of biofertilizers, bio-pesticides, bio-herbicides, bio-insecticides etc. Microbial–assisted breeding is emerging research area which provide strength to the sustainable crop improvement in the era of climate change. One of the notable contributions of microorganism in genetic engineering is to manipulate plants for the development of genetically modified plants. Recently, several microbes have been identified which are involved in the genome editing studies in alteration of plant genome for useful traits. Therefore, effective utilization of microbial biotechnology helpful in promoting sustainable agriculture development that accomplishes with safe environment, which in turn manifests positively on human health.

1. Introduction

Traditional farming practices are now exhausted and their effectiveness is shrinking to meet the food demand of increasing population across the world in the era of climate change. In last few decades, agricultural practices are based on the exhaustive use of mineral fertilizers, agrochemicals, and water to meet global food demand (Malhi, et al., 2021). The excess use of agrochemicals has resulted as devastating environmental threats. Current crop production and agricultural sustainability needs novel approach of crop production. One of these approaches are incorporation of beneficial microbes into agricultural practices to retain agricultural sustainability with maximizing yield potential of the crop cultivars (Koskey, et al., 2021). The aggregate of microorganism has huge diversity in the environment and emerge as vital components along with biotechnological research and development in the present past. Some beneficial microbes perform multidimensional activities in promoting growth and development of agriculturally important crops are emerging field of biotechnological research to exploit agricultural development (Schlaeppi and Bulgarelli, 2015). Agriculturally important microbes with Fe- and Zn-solubilizing attributes can be used for the biofortification of micronutrients in different cereal crop species employing biotechnological approaches. Microbial–assisted biotechnology using genetic engineering tools and techniques will leads to advancement in the modification of plants for desirable traits like disease resistance, stress tolerance bioremediation and biofortification (Ardanov, et al., 2016). Several biotechnological tools have augmented in crop breeding by distinguishing, DNA isolation, gene cloning, and transferring of genes desired from one species to another species. Furthermore, the microbial biotechnology helps to develop crop cultivars for sustainable crop production without much application of chemical fertilizers, pesticides, herbicides, etc. Microbial biotechnology also reduces the use of hazardous pollutants (Noble, et al., 2010).

2. Microbial role in biotechnological research

In agricultural sector, microbial biotechnology offers research area of quality crop production, crop improvement and sustainable development. Agricultural microbiology now introduced as interesting research area employing biotechnological approaches (Anderson, et al., 2016). Recently genomic assisted breeding, genome editing and genetic manipulation of crop plants for useful traits is the interesting area of research. Development of genetically modified

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organism (GMO) and transgenic crops employing microbes play a vital role in the creation of agricultural sustainability. Moreover, strategic biotechnological inventions pay attention in the identification of beneficial microbiome (Barea, 2015). Genetic material sequencing is one of the important biotechnological platform used for the detection of microbes in the microbiomes of different agro-ecologies, which makes it easy to identify microbiome in every feasible environment bypassing the necessity to isolate and culture microbes. Hence, exploitation of genome sequencing approaches is greatly worthwhile to develop approaches in the manipulation of the microbiomes for the higher acquisition of nutrients and enhanced biotic and abiotic stress tolerances causing better productivity of crops (Prasad, et al., 2018). Next generation sequencing now being used to precise the microbial genomic data has a huge potential to provide sufficient information about the detection of microbial composition and diversity, novel genes, microbial pathways, and interactions. Knowledge of the complete genome sequence of agriculturally important microbes and their alteration in sustainable crop production with the help of biotechnological tools like genetic transformation, microbial–assisted breeding and genome editing would be helpful for development of climate resilient agriculture. Furthermore, Microbial–assisted crop biofortification is getting attention to increase the nutritional profile of the major food crops. Biofortification of the micronutrients like iron, zinc, essential amino acids and vitamins in the promising crop species such as maize, oats, rice, and wheat, has been shown to improve bioavailability of nutrition to the humans (Bouis and Saltzman, 2017). Major use of microorganism in biotechnological research and development are follows:

2.1. Microbes in genome sequencing: Microbial whole–genome sequencing imparting the genome of novel organism and comparing genome sequences in diverse samples. Complete genome sequencing of microbes generates reference genome for microbial identification and comparative genome studies to identify novel nucleotide sequences governing useful traits. Additionally, the next–generation genome sequencing able to identify low-frequency variants and genome rearrangements that may be missed using other methods of genome sequencing. Furthermore, the whole–genome sequencing of the beneficial microbes such as bacteria, viruses, fungus etc. provide novel reference sequence while comparing to others (Samuel, et al., 2010).

2.2. Microbes in genetic engineering: Microorganisms have been used extensively in genetic engineering research and development since last five decades. Variety of microorganism have been demonstrated to existence of genetic engineering studies in the cleavage of DNA, insertion of

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desired DNA fragments into vector and their transformation to develop genetically modified organism. In 1973, Herbert Boyer and Stanley Cohen showed for the first time that two short pieces of bacterial DNA could be 'cut and pasted' together and returned to E. coli. They went on to show that DNA from other species, such as frogs, could also be introduced in E. coli. Additionally, Scientists have employed Agrobacteria to deliver genomic ability to provide resistance to insects or pathogens in higher crop plants. Therefore, the potential applications of genetically engineered microbes are even more diverse as they have tremendous natural diversity with respect to metabolism, extreme environment tolerance, and substrate utilization (Afkhami-Poostchi, et al.,2020).

2.3. Microbes in genome editing: Genome editing techniques have been extensively used in microorganism. Multiplex genome editing employing Cas–9 based CRISPR tools was first time reported in the microbe (*Streptococcus pneumonia*). Genome editing tools offers repairing of genomic DBs by homology-directed repair (HDR), non-homologous end joining repair (NHEJ) employing microbial – mediated end joining (MMEJ). These tools have been potentially used in the genome editing of plant species for useful traits to sustainable agriculture development (Yao, et al., 2017). The broad role of microbial biotechnology is illustrated in the given figure.

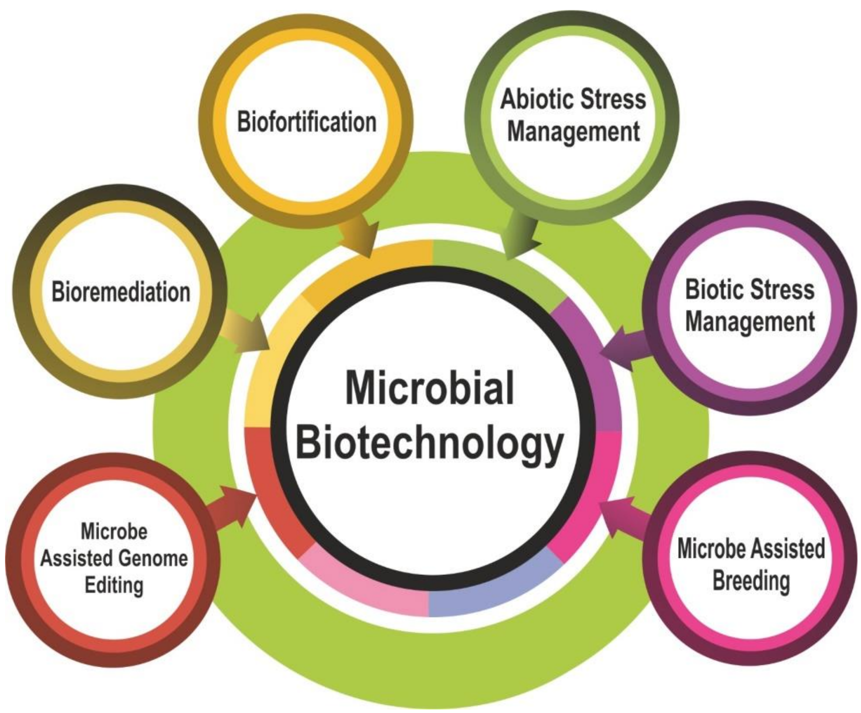

Figure: Microbial biotechnology in sustainable agriculture development

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3. Application of microbial biotechnology in agriculture

Microbial biotechnology played crucial role in sustainable agriculture development through development of ecofriendly microbial products. Microbial biotechnology reduce the use of agrochemicals for management of abiotic and biotic stresses by increasing the use of microbial derived products such as biofertilizer, bio-pesticide and bio-insecticide. Some soil microbes like *Pseudomonas, Streptomyces, Bacillus, Paenibacillus, Enterobacter, Pantoea, Burkholderia,* and *Paraburkholderia* have been identified and characterized in the manufacturing of microorganism-based products. These microbial products are useful in the crop production and development of environmental sustainability. Some important products of microbial biotechnology and their application in sustainable agriculture development are as follows:

3.1. Biofertilizers: Biofertilizers are preparation of microorganism used in crop production. They are directly or indirectly promoting plant growth by supplying nutrients (Fasusi, et al., 2021). Generally, microorganism present is the soil mobilizes the nutrients from soil and converts them **to** usable forms through biological processes such as nitrogen fixation, phosphorus solubilization, zinc solubilization, siderophores production, and producing plant growth-promoting substances. Biofertilizers are additionally applied in the soil to mobilize the nutrients to target plants that remarkably improved the soil fertility and sooner increase the crop health and production Singh, et al., 2022).

3.2. Microbial Bio-pesticides: Bio-pesticides are naturally occurring agents obtained from living microbes. They are generally used to control agricultural pests and pathogens damaging crops. Additionally, the microbial products like genes or metabolites from these biocontrol agents can be used to prevent crop damage from pests and pathogens (EPA, 2021). Microbial bio-pesticides are prepared by using microbial species and strains of bacterial and fungi. Major bacterial straits or species used in the preparation of bio-pesticides are *Pseudomonas*, *Yersinia*, *Chromobacterium* and some fungal species are also utilized in the manufacturing of bio-pesticides such as *Beauveria*, *Metarhizium*, *Verticillium*, *Lecanicillium*, *Hirsutella*, *Paecilomyes* *(*Sporleder and Lacey, 2021).

3.3. Bio-energy: Bio-energy is the renewable energy generated from plants, animals and microbes and used as fuel. Bio-energy is generally produced from fermentation and anaerobic digestion using suitable microbial systems and agricultural raw materials. Microbial biotechnology is an

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important strategy for sustainable bioprocesses in which microorganisms and their enzymes are used for the conversion of carbohydrates, lignins, glycerol into various renewable resources like bioenergy production. Several microbes are used in the bio-fuel production. Ethanol is produced from lignocellulose, a mixture of cellulose, hemicellulose, and lignin, which make up the plant cell wall. Natural metabolic pathways play an important role in the bio-fuel production. In context to bio-fuel production, saccharomyces cerevisiae, which can produce bioethanol through the fermentation of nonfood lignocellulose wastes like rice husks, wheat straw, or corn Stover (Sonia, et al., 2013)?

3.4. Bioremediations: The industrial wastes and several organic chemicals released in the environment are used to decompose by microbial enzymes. These hazardous chemicals are converted in to non-toxic substances through release of enzymes in the environment by the microbial organism. Such type of conversion of hazardous substances in to non-toxic substances are comes under bioremediation. Therefore, microbes play crucial role in the bioremediation (Ripp, et al., 2020).

3.5. Bio-markers: Applied microbial biotechnology used to measure the level of damage caused by pollutants with the help of some indicator microbes are considerably known as bio-markers. Bio-markers have broad future in the era of increasing pollution across the world. Several attempts have been made by the researchers to develop bio-markers to monitor risk assessment caused by toxic substances in the environment (Kapka-Skrzypczak, et al., 2011).

Conclusion

The abundance of microorganism in the soil and their characterization may improve the agricultural productivity and sustainability. Addition of meta–genomic analysis in microbial biotechnology has a huge potential to provide sufficient information about detection of microbial composition, microbial diversity, and mining of novel genes. Use of microbial biotechnology would be useful ecological and sustainable agriculture development. It helps to produce a crop without much application of chemical fertilizers, pesticides, herbicides, etc. It also keeps our environment safe and clean for the use of future generations. The benefit of microbial biotechnology helps us to avoid the use of hazardous pollutants and wastes that affect natural resources and the environment.

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