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Review

Utilization of Microbes for Sustainable Agriculture: Review

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Abstract

Sustainable agriculture is a system of farming using a microbe that protects the environment, maintains natural resources, produces healthy foods, and minimizes the use of chemical pesticides or fertilizers. Soil microbes like bacteria and fungi play an essential role in maintaining soil fertility, decomposing organic matter, and recycling nutrients. The presence of microorganisms in soil depends on the soil properties like moisture, pH, temperature, oxygen, salinity, porosity. Rhizosphere microbial communities play important role in plant protection, growth promotion, and production of antibiotics. Soil horizon maintenance is also vital for soil health and quality. The soil environment consists of a variety of physical, chemical, and biological factors that directly affect the diversity of microbes. For sustainable agriculture, soil-microbial diversity is important for ensuring soil productivity, and increase in crop production. The microbial technologies, for instance, gene-editing system, RNAi mediated gene silencing, proteomics, Genetic engineering, Metagenomics, Metatranscriptomics, and microbial whole-genome sequencing are used for sustainable agriculture. In this review, we investigated magnitude of microbes in sustainable agricultural development.

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1. Introduction

Sustainable agriculture is an alternative integrated approach aiming at sustainably producing foods using microbes while maintaining soil productivity [1]. Meeting the demand for healthy food is a crucial challenge. A promising approach is to use microbes for healthy crop production. Conventional agriculture plays an important role in meeting the food demands of a growing population. However, the world population is increasing rapidly creating food insecurity problems. To solve them, agricultural sectors use chemical fertilizers to increases the crop yield but destroys the beneficial soil microflora affecting the environment and human health [2]. The microorganisms present in the soil improve agriculture productivity. The wide range of microorganisms plays essential roles in agricultural sustainability. The microorganisms such as bacteria, fungi, and algae have great contributions in agriculture through decomposition of organic matter, nutrient recycling, increasing soil fertility, and improving crop productivity. Beneficial microbes are alternative to chemical fertilizers and pesticides [3].

The rhizosphere is a rich source of microbial diversity and activity. The microbial diversity in the soil is important for the maintenance of soil health and quality. High microbial diversity is an indicator of healthy soil. Plant-microbes interaction is necessary for increasing crop productivity. Moreover, it is in the rhizosphere is important for plant health [4]. Besides, microbial technology plays a promising role in cost-effective and sustainable agriculture.

Microbial technology like gene-editing system, RNAi mediated gene silencing, proteomics, genetic engineering, metagenomics, metatranscriptomics, microbial whole-genome sequencing are useful in sustainable agricultural development. The CRISPR cas9 is the most advanced form of gene editing system, which is used to achieve precise genome editing of the plant genome to develop disease-resistance against pathogens. Genetic engineering manipulates the genomes of the organisms, and increases crop productivity. Genetically modified microbes are also used as biofertilizers. Microbial technology is the solution for increasing crop production sustainably [5]. In this review, we investigated importance of microbes in sustainable agricultural development.

2. Plant-Microbe Interactions:

Plant-microbe interactions include the study of interaction of microbes with plants (figure 1). Nitrogen-fixing symbiotic associations are the interactions between legumes plants and rhizobia [6]. This association benefits both partners. The plant provides sugar to microbes as a source of energy for nitrogen fixation and the microbes provide fixed nitrogen to the plant for its growth [7]. Nitrogen is an essential element for plant growth and development [8]. Beneficial microbes associated with plants help increasing crop yield and enhance resistance to pathogens [9].

Plant-microbes interactions help in promoting plant growth under stress conditions increasing crop productivity [10]. Arbuscular Mycorrhiza fungi (AMF) live within plant roots and help in the phosphate absorption from the soil [11]. Phyto-stimulation is the process in which removal of organic pollutants such as pesticides, and aromatics from the soil with the help of rhizosphere microbes occurs [12]. Quorum sensing is used for planting microbial interactions in understanding bacterial social behaviors, which play an important role in communication between bacterial communities and plants. That senses extracellular signals and causes a change in gene expression of the population and increases the multiple species communities [13].

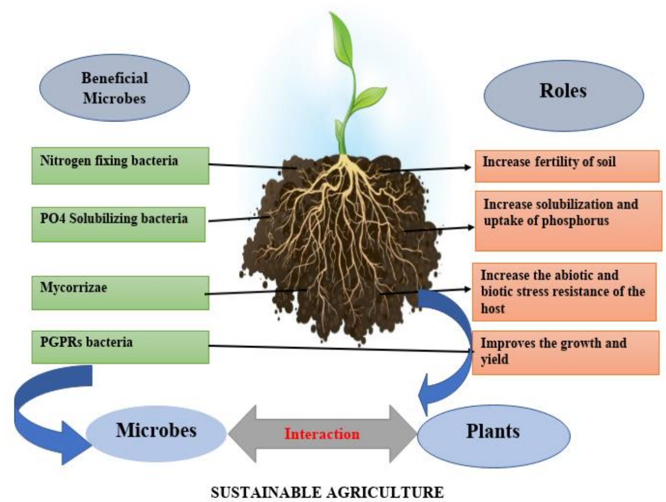

Figure 1: Plant-Microbe Interactions.

3. Soil microbe diversity:

Soil is necessary for the maintenance of the diversity of microbes [14]. Soil microbes play an essential role in maintaining soil health and crop productivity. Soil physical, chemical, and biological properties determine the soil quality, directly affecting microbial diversity [11]. Soil presents a variety of diverse organisms and has its unique optimal conditions for growth like pH and temperature. Microbial activity increases with temperature and becomes more active enhancing the rate of decomposition [15].

Enzyme activity is the most important activity of the soil. A high level of microbial diversity is required for healthy soil [16]. Microorganisms perform various kinds of functions like decomposition of organic matter, nutrient cycling, and phytohormone production [17]. Microbes in soil play important role in soil structure formation and decomposition of organic matter.

Healthy soil has a wide range of microbes like symbiotic nitrogen-fixing bacteria, mycorrhizal fungi, and Phosphate solubilizing bacteria (figure 1) that solubilize inorganic phosphate from insoluble compounds and managing phosphorus deficiency in agriculture soils having considerable contribution in plant growth promotion (figure 2) [18]. Soil microbial diversity is related to the soil-microbes-plant interactions. The effective management of microbial diversity is necessary for maintaining soil productivity [14].

4. Role of Microbes in sustainable agriculture:

Microbes have potential of excellence to support the plant growth (figure 2). Soil microorganisms such as bacteria, fungi, algae, and actinomycetes are crucial in maintaining agriculture sustainability [19,20]. The soil microbes are essential for breaking down organic matter, recycling nutrients, increasing mineral solubilization, fixing nitrogen [21]. Decomposition is a microbe-mediated process. Mainly Bacteria and fungi carry out the decomposition process in soil that degrades complex organic matter such as sugars, proteins, lipids into simpler substances that are made available to plants for their growth.

Actinomycetes are a specialized group of bacteria that have potential contribution in the cycling of organic matter, suppressing plant pathogens, and are used as plant growth-promoting agents [22]. Mycorrhizal fungi increase nutrient uptake; mainly phosphorus and produce growth-promoting substances [23]. Colonies of plant growth-promoting rhizobacteria (PGPR) surround plant roots (figure 1) [24].

The rhizosphere is the zone of maximum microbial diversity and activity (table 1). PGPR facilitates plant growth and is also used as biofertilizers. PGPR species such as *Azoarcus, Azospirillum* (table 1)*, Rhizobium, Azotobacter* (table 1)*, Clostridium, Enterobacter, Gluconoacetobacter, Pseudomonas Serratia* [25] are required by plants. PGPR directly or indirectly affects plant growth. In direct mechanism of PGPR involves the production of plant hormones, nitrogen fixation (figure 2), and phosphate solubilization with the help of Phosphate Solubilizing bacteria (PSB) [24]. On the other hand, indirect mechanisms involve antibiotic or antifungal metabolite production, siderophore production along with induced systemic resistance (ISR) to stimulate plant defense response against plant pathogens [26].

Plant growth-promoting fungi (PGPF) are responsible for synthesis of plant hormones, increase in nutrient uptake, solubilization of minerals producing volatile organic compounds, and inhibiting plant pathogens [27]. Arbuscular mycorrhizal fungi improve the growth, yield, and phosphorus acquisition of plants. Besides, these used as biofertilizers that are applied to improve soil fertility and are important for soil health and plant growth [28]. AMF plays an essential role in the absorptions of minerals such as phosphorous and other macro and micro elements [29].

Table1-Microorganisms Reported to Be Involved In Crop Improvement [30]

Microbes Name	Role in crop improvement
Cyanobacteria -	Use as a biofertilizer [31]
Rhiophagus clarus-	Improve nitrogen and phosphorus uptake [10]
Klebsiella-	Enhanced plant productivity [32]
Bacillus-	Phosphate solubilizing bacteria [32]
Azospirillum-	Free-living N2- fixing bacteria [33]
Azotobacter-	Play a crucial role in nitrogen cycling and capacity to produce vitamins [34]
Penicillium aspergillus-	Used as a bio-decomposers [35]

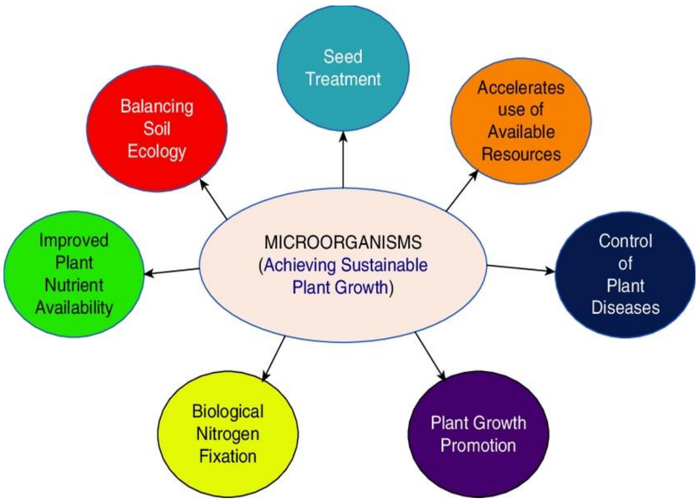

Figure 2: Role of microorganisms in plant growth [36]

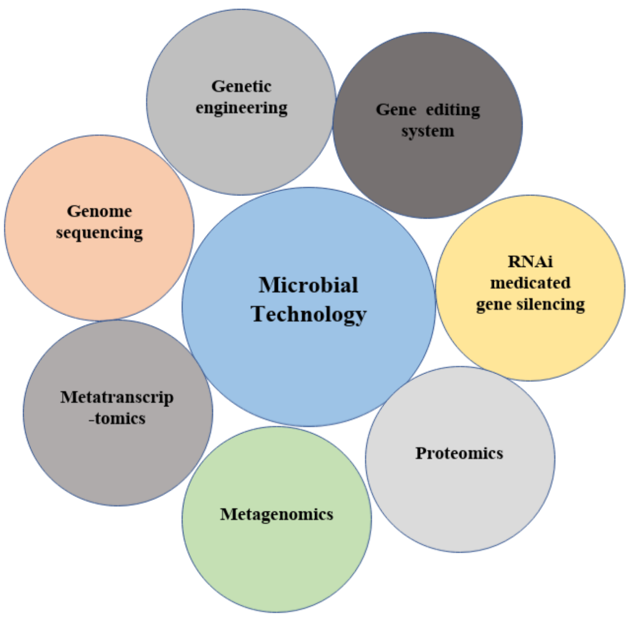

Figure 3: The Microbial technology for sustainable agriculture [5]

5. Microbial Technology for Sustainable Agriculture:

Microbial technology has valuable credit in reducing the dependence on agrochemicals in sustainable agriculture (table 1). The various microbial technologies, for example, gene editing systems, RNAi-mediated gene silencing, proteomics, genetic engineering, metagenomics, metatranscriptomics, and microbial whole-genome sequencing (figure 3) are being implemented. The gene-editing system can manipulate DNA. CRISPR is an auspicious gene-editing system. CRISPR-based genome editing involves precise genetic modifications and, on this basis, the plant-microbe interactions can be understood [37], and is used to increase crop productivity and disease resistance [38]. RNAi-mediated gene silencing can be used by the plant to increase bacterial and fungal disease resistance by changing gene expression against pathogens and by silencing any undesired plant gene that greatly affects the crop yield [39].

Proteomics technology is an area in which several proteins assist in plant growth and development [40]. Genetic engineering is used to alter the genetic makeup of organisms and improves microbial activity. The metagenomics technique is used to access the complete soil microbial diversity [41]. Microbial communities are important for ecosystem functioning. Many microorganisms are present in the natural environment but are not cultivable and their roles are unclear. Metagenomics is used for the identification of microbes present within a community (figure 3) [42]. Metatranscriptomics studies the gene expression of microbes and is applied for plant-microbe interactions (figure 3) [43]. Microbial whole-genome sequencing is important for mapping genomes of novel organisms and is useful for microbial identification (figure 3) [44].

6. Conclusion:

The use of beneficial microorganisms in the agriculture field is safe, cost-effective, and eco-friendly. Exploiting the interaction between plants and microbes is recommended to increase crop yield. The use of microbes offers new and more sustainable practices that will play a promising role in sustainable agriculture.

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