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Mini Review

Microbial Contribution to Agricultural Development and Environmental Conservation

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Abstract

Alternatives are required to solve challenges encountered in the food security sector with the increasing global population due to ecological instability and changes observed in climate. Abiotic stress including high salinity and drought caused the degradation of soil thereby making it not fittable for agricultural practices to reveal the problem encountered. However, microbial communities including bacteria, fungi, and archaea have been proven to contribute to soil health, plant growth promotion, induce systemic resistance against diseases, and overall promote abundant production of agricultural products. These microbes also have the potential to control biotic and abiotic stresses and they are associated with improving climate-resilient soils. This review reveals the green and sustainable methods employed to combat soils encountering the problem posed by the change in climate and further reveals the potential of the microbes to stimulate the production of nutrients or elements required for agricultural sustainability, and also the beneficial value they add to the environment via biogeochemical cycle.

Keywords: Biogeochemical cycle, Bioremediation, Biotic and abiotic factor, Food security, Microbial functions, Plant protection, Soil health, Sustainable agriculture

Abbreviations: CO_2: Carbondioxide; PGPB: Plant Growth Promoting Bacteria; PGPF: Plant Growth-Promoting Fungi

Introduction

As the human population is increasing all around the world, there has been the problem of food production that can serve the whole populace which is alarming resulting in hunger and untimely death [1]. Agricultural practices have been the major source of food materials to manufacture finished products or consume raw depending on the nature of agricultural products and how they can be processed before consumption. Nevertheless, aside from the increment in the number of people globally, there are other challenges resulting from climatic condition impacts that are triggered by carbondioxide (CO_2) and other greenhouse gas emissions [2], loss of soil fertility [3], and high consumption of water [4]. When agricultural land loses its fertility, it prompts farmers to find another land for the cultivation of crops which requires clearing the new site. Clearing the land exposes the land to greenhouse condition making it release greenhouse gases that contribute to global warming and eventually result in climate change [5].

Chemical fertilizers have been utilized by farmers to improve soil fertility and promote the production of abundant harvest, but this method has caused more harm than benefit it provides to man, animal, and the environment [6]. The challenge encountered are building of heavy metals in the soil which is toxic to humans and animals [7], some of the chemicals can be washed down into the nearby river, stream killing the aquatic life as a result of their toxic metals thereby causing water pollution [8], another challenge is environmental pollution when applied to farmland, it create some unfriendly odors, they are very expensive [9].

Reduction of soil degradation levels or making an effort to improve the fertility of the soil that has been lost is important for sustaining small-scale farming and also disallowing greenhouse gas emissions that may lead to climate change which ends up crumbling global economies. During the period of the International Decade of Soil that came up between 2015 to 2024, the Scientist of the

Union believed that the soil house and protect beneficial organisms which include some microbial communities that contribute to the sustainable form and resilience of soil [1,10]. Among the potential of these microbes is to promote soil health and improve the growth of plants thereby creating conditions for abundant production of crops which is why they are referred to as Plant Growth-Promoting Bacteria (PGPB) and -fungi (PGPF) [11-13]. They also confer resistance against biotic (pest and diseases) and abiotic (high temperature, drought, pH, salinity, etc) factors that can affect the development of plants [14]. This review reveals how the beneficial microbial communities including bacteria, fungi, and archaea can improve the fertility of the soil, prevent abiotic stress, and endeavor a biogeochimal cycle in other to return nutrients into the soil by utilizing carbon substrates obtained from organic remains or products of plant and animals. The review accentuates the utilization of green technology to regulate climate change affecting the soil, activate the potential of the microbes to mobilize major elements required for plant growth and abundant yield, and the biological activities of the microbes to promote soil features.

Concept of Soil Microbiome in Soil Protection

Microbial communities confer protection on the soil for agricultural sustainability by producing some functions in the agroecosystems to improve the production of crops, tolerate biotic and abiotic stresses, and improve soil fertility [15]. *Wu*, et al., [16] reported how the microbes are associated with the soil structure including accumulation and linkage with the soil pores in other to regulate the flow of water molecules, oxygen concentration, and required nutrients via the soil. The microbes dwelling in the soil perform important tasks in soil protection and functional diversity in the agroecosystem which include the following.

Nutrient cycling: Microbial communities contribute to the decomposition of organic materials for certain nutrients to be produced and returned to the soil (Figure 1) which is added to the soil and utilized by plants. The microbial function hitherto is to decompose the organic material into simple utilizable forms for developing plants which improve soil fertility [17].

Inhibition of diseases: Some microbes have the potential to biologically control the invasion of phytopathogens by producing metabolites that can antagonize the phytopathogens thereby reducing or absolutely eradicating the invasion of spoilage organisms [18].

Environmental stress resilience: Another important task soil microbes perform is intensifying soil resilience to various stresses posed by the environment where the plant is growing. Such stresses are abiotic stresses (salinity, pH, drought, extreme temperature, etc) and biotic stress (pest attack, insects, animals, birds, etc). Microbes can accomplish this by producing certain chemical substances that protect the crops from invaders [19].

Soil stability and structure: The structure of soil is maintained by the aid of microorganisms when they are produced. Microbes produce sticky polysaccharide materials that bind together the soil particles in order to stabilize and aggregate the soil. The aggregation of soil promotes moisture content of the soil, water retention, and prevents washing away of the topsoil (erosion) [20].

Detoxification and bioremediation: Furthermore, microbial communities inhabiting the soil have the potential to degrade pollutants or contaminants that are found in the soil. They can bioremediate chemical substances like chemical fertilizers, fungicides, pesticides, herbicides, and hydrocarbons and decompose them into simple utilizable forms and non-toxic to plants, animals, and the environment. So, these microorganisms are known for clean-up activities and soil protection [21,22].

Microbial Communities and their Impact on the Environment

Living organisms carry out their activities by depending on essential materials from the soil. The soil contains various major nutrients or elements including nitrogen (N), phosphorus (P), carbon (C), oxygen (O), hydrogen (H), sulfur (S), iron (Fe), calcium (Ca) [23] and minor elements including manganese (Mn), zinc (Zn), cobalt (Co), manganese (Mn), molybdenum (Mo), copper (Cu), etc [24]. Furthermore, microorganisms were responsible for recycling the elements to prevent them from being used up without replacement. They are required in the transformation of organic substances into new products which can be utilized by other organisms. As a result, the enzymes produced by microbes take part in biogeochemical processes which are defined as the transformation of chemical materials that takes place between living organisms, the earth (Soil), and the atmosphere [25,26].

The organic carbon found in the earth's crust is influenced by the equilibrium between respiration and photosynthesis (Figure 1). Carbon can find its way into the soil from the atmosphere through the fixation of carbon conducted by certain organisms that can utilize simple organism molecules like plants (autotrophs) and some microbes like cyanobacteria, and microalgae (chemotrophs) [27,28]. They do so via the process of photosynthesis utilizing CO_2 water, and chlorophyll to trap sunlight to produce glucose and oxygen gas that is expelled into the atmosphere as by-products [29].

$$6CO_{2(g)} + 6H_2O_{(1)} \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_{2(g)}$$

The fixed carbon is reverted into the atmosphere through some biological routes that involve microbial respiration either heterotrophically or autotrophically (Figure 1). These pathways constitute the decomposition of organic molecules like dead animals and decayed plants by microbial communities residing in the soil acting on the organic materials. The microbes sequestrate the organic carbon substrates as a product of metabolism thereby assimilating some carbon substrates [30] and liberating the others as byproducts such as CO_2 gas or as a metabolite.

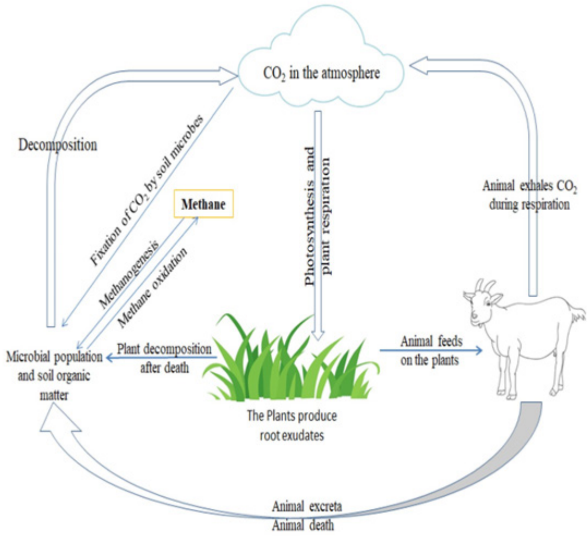

Figure 1: Soil microbial communities mediate carbon cycle.

Soil often exists in unsaturated form worldwide and due to this, CO_2 is regarded as the major respiratory rate. In highly moisture soil like peatland and or rice paddies, the CO_2 level is lower by the activity of extremophiles (archaea) in the process known as Methanogenesis. During this process, the amount of methane gas evolved counts on the potential of the methanogens against the potential of methanotroph-aerobic methane-oxidizing bacteria that inhabit the top layer of the wetland soil and likewise anaerobic condition of methane in hypoxia bed (Figure 1).

Conclusion

The mini review revealed the activity of microorganisms toward agricultural sustainability from soil health to abundant crop production. Moreover, the soil microbes are involved in other beneficial functions including the biogeochemical cycle, control of biotic and abiotic stresses, and bioremediation of toxic chemical derivatives. Based on these objectives using microorganisms is the best method of improving agriculture due to their beneficial traits with no side effects and other reported features.

Acknowledgement

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Conflict of Interest

None.

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