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The Microbial Keystone: Harnessing Microbes for Agricultural Sustainability

Prasanna Kumar*

Fermentation and Bioprocess Associate, Syngenta Biologicals, 1,2,3,16,17&18, Phase-II, IDA Pashamylaram (V), Patancheru (M), Sangareddy Dist. Hyderabad. Telangana, India

***Corresponding Author:** Prasanna Kumar, Fermentation and Bioprocess Associate, Syngenta Biologicals, 1,2,3,16,17&18, Phase-II, IDA Pashamylaram (V), Patancheru (M), Sangareddy Dist. Hyderabad. Telangana, India.

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Climate change poses a significant threat to global agriculture, with rising temperatures, extreme weather events, and altered precipitation patterns disrupting food production. As we seek sustainable solutions, the role of microbial communities emerges as a promising avenue for mitigating climate change's impact on agriculture. This paper explores the multifaceted contributions of microbes to agricultural sustainability, focusing on their ability to enhance carbon sequestration, reduce greenhouse gas emissions and improve soil health.

Introduction

Microorganisms and biogeochemical cycles are the two sides of the same coin. It takes place inside oceans, soil, open and closed environment. Both are facilitating the way of making and using greenhouse gases. Microorganisms provide long and short-term encouragement and discouragement feedback responses to global warming as well as climate change [12]. Microbes play an important role as either generators or users of these gases in the environment as they can recycle and transform the essential elements such as carbon and nitrogen that makeup cells [6].

Climate change and its underlying causes

Climate is defined as general or average weather conditions of a certain region, including temperature, rainfall and wind. The earth's atmosphere traps solar radiation and is mediated by the presence in the atmosphere of gases such as carbon dioxide, water vapor and methane that allow incoming sunlight to pass through, but absorb the heat radiated back from the earth's surface. This provides a blanketing effect in the lower strata of the earth's atmosphere and this blanketing effect is being enhanced because of human activities like the burning of fossil fuels [9].

Mechanisms to Address Climate Change

Microorganisms regulate terrestrial greenhouse gas flux. This involves consideration of the complex interactions that occur between microorganisms and other biotic and abiotic factors. The potential to mitigate climate change by reducing greenhouse gas emissions through managing terrestrial microbial processes is a tantalizing prospect for the future. It is widely accepted that microorganisms have played a key part in determining the atmospheric concentrations of greenhouse gases [14]. The major feedback response mechanism for climate change by changing their microbial community structure and composition solve this kind of environmental problem, simply using nutrient cycling processes and stimulating their functional genetic material for degrading and eliminating chemicals or gasses which lead to global warming [13]. When microbial communities and biogeochemical cycles are linked together act as a good mechanism to solve climate change. Microorganisms are particularly important to use greenhouse gases as energy sources and build their cell [1].

Microbial Genetics in a Dynamic Environment

Proper understanding of microbial function could give us lots of insight, and we could exploit it in managing climate change-related situations. A lot of microbes have a short generation time to produce new variants that other eukaryotic and large organisms are unable to do [3]. Phenotypic plasticity or change in an organism's behavior develops on them in the changing environment with a change in certain morphological and physiological traits. Bacterial species are found to display extensive phenotypic variability/heterogeneity [11].

Improves Plant Stress Tolerance by Rhizosphere Microbes

The plant rhizosphere is occupied with various microbes such as plant growth-promoting bacteria (PGPB) and plant growth promoting fungi (PGPF). Mycorrhizae supply phosphate and nitrate to plants and rhizobacteria play a role in fixing atmospheric nitrogen. Some beneficial microbes can provide resistance to environmental stress factors. Growth of crops under abiotic stress conditions can be improved by different bacterial families [5]. Co-inoculation of *Rhizobium/Pseudomonas* with *Zea mays* can increase its salt tolerance due to decreased electrolyte leakage and balance of leaf water contents [4]. Various microorganisms produce plant growth hormones such as indole acetic acid and gibberellic acid, which promote root growth.

Microorganisms and their Impact on Carbon Emission Control

Carbon sequestration by microbial processes is yet to be explored. Two important sinks of carbon are soil and the ocean can play a major role to mitigate anthropogenic carbon emission [8]. There is a huge potential of the carbon sequestration process which can be modified by microbial community engineering, i.e., a shift in land use from arable land to grassland entails an average 18 % higher carbon sequestration, with a yearly carbon input of 0.75 tonnes C/ha/year [7]. A limited degree of soil manipulation could bring a higher degree of microbial homeostasis for sequestration. The addition of charcoal or biochar to the soil as a long-term carbon source improves soil quality and adsorption of nutrients to increase their bioavailability to the plants [10].

Conclusion

The role of microbes is least known among the scientific community. Various promising aspects of microbes have been discovered to cope with the changing environment due to climate change. Climate change is a real thing, and it is already marking its harmful impact on Earth. The future of climate change will be more harmful, and we need to act immediately. Among various adaptation methods on climate change, microbial mitigation and adaptation are the latest additions here. Microorganism genetic resources for agriculture carry out many of the vital functions that underpin the ecosystem services that sustain life. Their role is vital to nutrient cycling, supporting the soil food web, imparting resilience, transforming and protecting food from spoilage, and controlling pests, diseases and weeds.

Generally, microorganisms through nutrient cycling act as a break down organic matter release greenhouse gases and speed up global climate change. On another side, it minimizes or compromises the emission of different gases and slows down or prevents climate change by converting to an organic form usable for themselves and others. In ecological processes, microbes have significant value in the consumption/transformation and production of gases. Biological mechanisms are regulating carbon and nitrogen exchanges between the land, water and atmosphere. Microbial ecology to assess the terrestrial carbon cycle plays an important role in balance the ecosystem and stabilizes the atmospheric condition.

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