Biofertilizers as Sustainable Solution in Enhancing Food Security

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Abstract

Agricultural sector contributes to about one third share in global gross domestic products. However, the increasing trend in human population is leading to high food demand. Soil quality, availability of nutrients, environmental conditions as well as the biological health of the soil are important criteria for improving crop yield per unit area for achieving the targeted goal of food security, Intensive use of Chemical fertilizers despite the high nutrients contents and ability to grow crops faster have also been proven to have a harmful effect on soil quality, soil nutrient, water, the environment, and, ultimately, plants and human health. The alternative to these, biofertilizers arose today due to their attributes such as being eco-friendly, cost-effective, and easy to apply in the agricultural field. Biofertilizers are a batch of diverse microorganisms, which can induce plant growth along with soil health, even under abiotic stress conditions. All these led to them gaining importance in sustainable agriculture. In most agricultural systems, nitrogen is most often the limiting nutrient that dictates crop production; that is why a broad canvas of biofertilizers that enhance nitrogen and those that enhance phosphorus nutrition were discussed from several perspectives. This study aims to explore the potentials and prospects of microorganism-based biofertilizer usage in agriculture and the overall solution to food security.

Keywords: Biofertilizer, Chemical fertilizer, soil quality, Sustainable solution, food security.

INTRODUCTION

Modern intensive agricultural practices face numerous challenges that pose major threats to global food security (Kumar et al.,2022). According to FAO *et al.*(2022), at the beginning of 2022 global food security was already in a state of deterioration as a result of the measures adopted to contain the COVID-19 pandemic, new or pre-existing conflicts, weather shocks and global economic slowdown. Up to 828 million people were hungry in 2021. The number of people affected by chronic hunger had grown by about 150 million since the outbreak of the COVID-19 pandemic. After remaining relatively unchanged since 2015, the prevalence of undernourishment in the world jumped from 8.0 in 2019 to 9.3 percent in 2020 and rose at a slower pace in 2021 to 9.8 percent.At the same time, a confluence of factors led to increasing food prices in 2020 and 2021. As demand started to recover in mid-2020 from the dramatic decrease in economic activity at the beginning of the pandemic, agricultural commodity prices rebounded from a 10-year low in May 2020. Increasing fuel and transportation costs added momentum to the surge in food prices. On the supply side, weather-related production shortfalls and logistics bottlenecks also contributed, though less significantly than the demand-side drivers (FAO, 2022).Moreover, the population of the world is expected to reach more than 9 billion shortly by 2050. There will be a huge challengeahead to feed this growing population, and our prime target would be to produce crops sustainably without hampering the ecosystem (Garten *et al*., 2020; Saha*et al*., 2023).

Ozor and Urama(2013) stated that low fertility soils are one of themajor challenge to food security. Also, soil quality, availability of nutrients, environmental conditions as well as the biological health of the soil are other important criteria for improving crop yield per unit area for achieving the targeted goal of food security (Tilman*et al*., 2011).Fertilizer is defined in many kinds of literature as any material often applied to the soils that provide one or more essential nutrients for plant growth and development (Vanlauwe and Giller, 2006).

In order to address the nutritional requirements of the ever-increasing world population, chemical fertilizers and pesticides are applied on large scale to increase crop production by improving the soil fertility level. However, the injudicious use of agrochemicals has resulted in environmental pollution leading to public health hazards (Kumar *et al*.,2022).According to Farnia and Hasanpoor(2015),the continuous use of chemical fertilizers results in the deterioration of soil quality and gradual loss of soil fertility, which might further lead to the accumulation of heavy metals in plant tissue, affecting the nutritional contents of the yield and edibility. Intensive cropping in agriculture and increase use of chemical fertilizers, which have high nitrogen and phosphorus contents can also leach from agricultural fields into rivers, causing fish mortality, oxygen depletion, an acceleration of aquatic plant growth, and, finally, a decrease in water quality for a sustainable ecosystem (Saha*et. al*., 2023).Since Soil quality, availability of nutrients, environmental conditions as well as the biological health of the soil are all important criteria for improving crop yield per unit area for achieving the targeted goal of food security, Microbiological tools, which include bio-controls and bio-fertilizerscan provide valuable outcomes in both the growth and health of plants (Mahanty*et al*., 2016).

Vessey, 2003 defined Bio-fertilizers as a substance which contains living microorganisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. AbdelAal *et al*., 2023 described bio-fertilizers as living microorganisms that induce plant growth through colonizing the rhizosphere or the internal tissues of the plant when applied to surfaces of plants, soil or seeds. Bio-fertilizers are also capable of phosphate solubilisation, nitrogen fixation, sulphur oxidization, decomposition of organic compounds or plant hormone production. Microbial-based bio-fertilizers are highly beneficial for soil health and sustainable agricultural production. Plant growthpromoting microorganisms (PGPM) are found in microbial-based bio-fertilizers, which are given to seeds or soil to benefit their hosts by reducing phytohormone production, boosting soil nutrient availability, enhancing plant nutrient uptake, and also strengthening their resistance to disease (Saha*et al*., 2023).The use of Bio-fertilizers can perform nutrient cycling and assure optimal development and growth of crops. Bio-fertilizers also have the power to enhance crop productivity through many environmentally friendly mechanisms.

Furthermore, microbial-based bio-fertilizers can increase stress tolerance, prevent the adverse effects of salinity, fix nutrients in the root zone, control the plant pathogen biologically, and enhance the production of foods sustainably and economically (Azmat*et al*., 2020).

According to Daniel *et al*., 2022, Food security is the availability and accessibility of safe and nutritious food that fits the dietary requirements of a healthy and active lifestyle.Food insecurity occurs when people do not have enough access to safe and nutritious food, and thus do not consume enough to live an active and healthy life.Studies have shown that there is a significant amount of pesticide residue present in foodstuffs long after they are harvested for human consumption (Sinha, 2009), hence there is need for bio-fertilizers in ensuring food safety and security.

This Paper explore the application of bio-fertilizer and provide insights about different microorganisms in term of their efficacy for sustainable crop production to obtain food safety and security for future generations.

Bio-fertilizers

Bio-fertilizers are organic substances that contain living microorganisms, such as bacteria, fungi, and algae, which boost soil fertility and improve nutrient availability for plants. These microorganisms establish symbiotic or associative interactions with plants, aiding in nutrient absorption, cycling, and overall plant development. In contrast to conventional chemical fertilizers, bio-fertilizers operate in balance with nature, supporting sustainable farming practices (Tiwari *et al*., 2013).

They enhance soil health, improve soil structure, and help balance soil microbial community. Bio-fertilizers are an eco-friendly alternative to chemical fertilizers, promoting sustainable agricultural practices while reducing environmental pollution and minimizing reliance on synthetic Fertilizers (Daniel *et al*., 2022).

Classification of Bio-fertilizers

According to Stewart and Roberts, 2012, Bio-fertilizers are also known as Microbial inoculants which are organic products that contain specific microorganisms obtained from plant roots and root zones. They have been found to boost plants' growth and yield by 10–40%. Bio-fertilizers are classified into groups based on their functions and mechanisms of action ranging from nitrogen-fixers (N-fixers), potassium solubilizers (K solubilizers), phosphorus solubilizers (P. solubilizer), and plant growth promoting rhizobacteria (PGPR) (Nosheen*et al*., 2021; Daniel *et al*., 2022).

Table 1. Classification of bio-fertilizers and their mechanism of action.

Biofertilizers	Mode of Action	Groups	Examples
Plant growth-promoting	They Produce hormones that encourage root growth, increase nutrient availability,	Plant growth-promoting rhizobacteria	*Agrobacterium*, *Pseudomonas fluorescens*, *Arthrobacter, Erwinia, Bacillus, Rhizobium*, *Enterobacter, Streptomyces*, and *Xanthomonas.*

	and boost crop yields.		
Nitrogen-fixing	They Increase the amount of N2 in the soil by fixing atmospheric nitrogen and making it available to plants.	Free-living, symbiotic, and associative symbiotic.	*Klebsiella, Stigonema, Desulfovibrio, Azotobacter, Anabaena, Clostridium, Rhodospirillum, Rhodopseudomonas Rhizobium,TrichodesmiumAzospirillum* spp., *Herbaspirillum* spp., *Aulosirabejerinkia, Nostoc, Alcaligenes, Enterobacter*and *Acetobacterdiazotrophicus.*
Phosphorus mobilizing	Phosphorus is transferred from the soil to the root cortex. They have wide range of applications	Mycorrhiza	*Arbuscular mycorrhiza*, *Acaulospora* spp., *Scutellospora* spp., *Glomus* spp., *Gigaspora* spp., and *Sclerocystis* spp.
Potassium solubilizing	They Produce organic acids that degrade silicates and aid in the removal of metals to solubilize potassium (silicates) ions and make it available to plants.	Bacteria and Fungi	*Bacillusedaphicus, Arthrobacter* spp., *Bacillus, Mucilaginosus*, and *B. circulanscan. Aspergillus niger*.
Micronutrient	Protons, chelated ligands, acidification, and oxidoreductive systems can all be used to dissolve zinc.	Zinc-solubilizing microbes	*Pseudomonas* spp., *Mycorhiza*, and *Bacillus* spp.
Potassium mobilizing	They transfer in accessible forms of potassium from the soil.	Bacteria and Fungi	*Bacillus* spp. *Aspergillus niger*.
Phosphorus solubilizing	They dissolve phosphate bonds by secreting organic acids which lowers soil pH by converting insoluble forms of Phosphorus in the soil into soluble	Bacteria and Fungi	*Pseudomonas striata, Bacillus circulans, Bacillus subtilis, Peniciliumspp., B. polymyxa, Agrobacterium, Microccocus, Flavobacterium, Aereobacterium. Aspergillus awamori, Penicillum*spp., and *Trichoderma*spp.

forms.

Source: Daniel *et al*., 2022.

Application of Bio-fertilizer

Microbial bio-fertilizers are mostly heterotrophic, i.e. they depend upon the organic Carbon of soil for their energy requirement and growth. So, they either colonize in rhizosphere zone or live symbiotically within the root of higher plants. Therefore, microbial inoculants must be applied in such a way that the bacteria will be adhered with the root surface and this why they are generally applied to soil, seeds or seedling. In practice, bio-fertilizers can be applied through soil inoculation and seed inoculation (Sujatha et al., 2004).

Soil Inoculation

This is the application of microbes (inoculant) directly to the soil. Inoculants of mixed cultures of beneficial microorganisms have considerable potential for controlling the soil microbiological equilibrium and providing a more favourable environment for plant growth and protection (Ratti*et al*., 2001).

Seed Inoculation

This uses a specific strain of microbe that can grow within the plant roots. Soil conditions have to be favourable for the inoculants to perform well. Selected strains of N-fixing Rhizobium bacteria have proven to be effective as seed inoculants for legumes.Seed treatment can be applied by using two or more bacteria with a synergistic effect. In the case of seed treatment with *Rhizobium*, *Azotobacte*r, *Azospirillum* along with Phosphate-Solubilizing Bacteria (PSB), first the seeds must be coated with *Rhizobium* or *Azotobacter* or *Azospirillum*. When each seed has a layer of the aforementioned bacteria then the PSB inoculants has to be coated on the outer layer of the seeds. This method will provide maximum numbers of population of each bacterium to generate better results (Salihu, 2018).

The role of Bio-fertilizer in Food Production.

Microbial Inoculants also constitute an important component of integrated nutrient management that leads to sustainable agriculture. They can also be used as an economic input to increase food production (Salihu, 2018) since enhancing crop production for the growing people of the world is a significant task in the 21st century. The success of sustainable agricultural principles depends on more than just increasing crop yield, it also depends on maintaining environmental safety and that is why Bio-fertilizer is an alternative to chemical fertilizer as they improve yield by adding nutrients to the soil through the natural processes of nitrogen fixation, solubilizing phosphorus,and stimulating plant growth through the synthesis of growth-promoting substances (Abd El-Lattief, 2016). Their useshave received more attention and demand for bio-fertilizers has unexpectedly increased in China, Canada, Argentina, and in some European countries, as well as in the United States, India, and Africa (Saha*et al*., 2023).

Role of Bio-fertilizers in Addressing Food Security.

Bio-fertilizers offer a sustainable and promising solution to counteract the challenges faced in agriculture, playing a significant role in enhancing food security and improving nutritional outcomes (Pathak and Ram 2013) through the following mode of actions (Tiwari *et al*., 2013):

1. Enhancing nutrient availability for plants by improving the availability of macro and micronutrients for plants.
2. Improving soil health and fertility by stimulating beneficial microbial populations in the soil, to improve fertility and increase organic matter content, enhancing soil moisture retention and nutrient availability.
3. Sustaining an eco-friendly agricultural practices through preserving ecosystem health by Reducing environmental impact caused by synthetic fertilizers.
4. Increasing crop yield and quality by enhancing nitrogen fixation in root nodules, leading to increased nitrogen availability to the crops, promoting better growth and higher yields.
5. Impact on human health and nutrition through improved food quality.

Conclusion

This paper has briefly presented a few examples of bacteria and fungi, which bear a great promise as bio-fertilizers.Bio-fertilizers are the transformative opportunities to simultaneously improve crop production and human nutrition and they do so in an eco-friendly manner. Thus, bio-fertilizer application should be encouraged amongst Farmers, especially in combating food insecurity and soil fertility challenges. The importance of bio-fertilizers has been realized all over the world but research gaps still exist. The field efficiency of bio-fertilizers has to be improved by research and development (Saha*et al*., 2023).The discovery and development of efficient inoculant strains, which can perform under diverse field conditions with various plant species and having a myriad of agronomic benefits is key to the development of novel bio-fertilizers.

Furthermore, bio-fertilizers is a key area for future research. Therefore, bio-fertilizers are one of the key answers, we must take into account if we are to establish a sustainable farming system that will feed the entire world while making a profit and improving both human and environmental well-being.

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