

Green Bioinoculants

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Contributor: R. Z. Sayyed

Biofertilizers are emerging as a suitable alternative to counteract the adverse environmental impacts exerted by synthetic agrochemicals. Biofertilizers facilitate the overall growth and yield of crops in an eco-friendly manner.

Biofertilizer

Bioinoculant

PGPR

1. Introduction

The advent of the Green Revolution in the latter part of the twentieth century triggered a worldwide boom in the agriculture sector. By introducing new high-yielding seed varieties and increasing the use of synthetic fertilizers, pesticides, and other agrochemicals, the Green Revolution contributed significantly to enhanced plant productivity and crop yields [\[1\]](#). The global agricultural landscape has drastically changed since then. Rampant overuse of synthetic agrochemicals for enhancing crop productivity has deteriorated the biological and physicochemical health of the arable soil, leading to a declining trend in agricultural productivity across the globe over the past few decades [\[2\]\[3\]\[4\]](#). In the present scenario, there is a shrinkage of land resources and the depletion of biological wealth. In order to fulfill the escalating demand for sustainable agriculture, the yield and productivity of agricultural crops need to be concurrently increased with the production of agriculture-related commodities. There is no single or straightforward solution to the above-mentioned intricate, ecological, socio-economic, and technical glitches existing in promoting sustainable agriculture [\[1\]](#).

Promoting sustainable agriculture with a gradual decrease in the use of synthetic agrochemicals and more prominent utilization of the bio-waste-derived substances [\[5\]\[6\]](#) as well as the biological and genetic potential of crop plants and microorganisms is an effective strategy to combat the rapid environmental deterioration while ensuring high agricultural productivity and better soil health [\[7\]](#). In addition to the genetic manipulation of the crop physiology and metabolism for yield enhancement, certain members of the soil microbial community, particularly those residing in the plant rhizosphere, might assist plants in preventing or partially overcoming the environmental stresses [\[8\]\[9\]](#). Search for eco-friendly alternatives to mitigate the harmful effects of toxic agrochemicals led to the discovery and subsequent use of biofertilizers and other microbial-based products, including organic extracts and vermicompost teas [\[10\]\[11\]\[12\]](#). These microbial products are non-toxic, environment-friendly, and act as potential tools for plant growth promotion and disease control. Thus, the biological potential and fertility of soil could be increased, whereas the hazardous effects of agrochemicals could be decreased by employing microbial formulations to fertilize agricultural crops [\[13\]\[14\]\[15\]](#). The use of efficient plant growth promoting rhizobacteria (PGPR) as biofertilizers and biological control agents is deliberated as a suitable substitute for minimizing the use of synthetic agrochemicals in crop production [\[16\]\[17\]\[18\]\[19\]](#).

2. Biofertilizers

During the past two decades, the term biofertilizer or bioinoculant has been derived in various ways due to the commendable progress achieved in the studies of the association between microorganisms and plants. A biofertilizer is most commonly defined 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” [16]. Dineshkumar et al. [20] later proposed a modified definition of biofertilizers as “products (carrier or liquid based) containing living or dormant microbes (bacteria, actinomycetes, fungi, algae) alone or in combination, which help in fixing atmospheric nitrogen or solubilizers soil nutrients in addition to the secretion of growth promoting substances for enhancing crop growth and yield”.

The microorganisms present in the biofertilizers employ several mechanisms to provide benefits to the crop plants. They can either be efficient in nitrogen fixation, phosphate solubilization, and plant growth promotion or can possess a combination of all such traits [21][23][22][24]. Biofertilizers can fix atmospheric N₂ through the biological nitrogen fixation (BNF) process, solubilize nutrients required by the plants, such as phosphate, zinc, and potassium, and also secrete plant growth promoting substances, including various hormones [25][26]. Further, when applied as seed or soil inoculants, biofertilizers can multiply, participate in nutrient cycling, and help in crop production for sustainable farming [27][28][29].

The microbial inoculants possess several advantages over their chemical counterparts [30][31][32]. They are eco-friendly, sound sources of renewable nutrients required for maintaining soil health and biology [13][23][29]. Furthermore, they exhibit antagonistic activity against several agricultural pathogens and combat abiotic stresses [8][33][34][35][36]. Various microbial taxa have been commercially used as efficient biofertilizers, based on their ability to obtain nutrients from the soil, fix atmospheric N₂, stimulate the solubilization of nutrients, and act as biocontrol agents [37].

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