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Microbial Inoculants - Alternative Approach for Sustainable Crop Production

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Abstract

Inorganic fertilizers have proved instrumental in improving yield of food grains and pulses, however a complete dependence on these might be environmentally disastrous. Microbial inoculants such as nitrogen fixing bacterium as *Rhizobium* and phosphorus bacterium *viz*., PSB, *Pseudomonas* spp., *Agrobacterium* spp etc. in pulses have been reported for their positive impact on crop growth and productivity. These agents fix atmospheric N and/or improve nutrient availability for plants. The microbial seed leachate production by these agents also act as source of carbon and nitrogen for initial plant growth besides acting as source of phytohormones. Use of inoculants have been reported to stimulate root proliferation, number of nodules and increase both grain and straw yield in various legumes. These microbial inoculants act as partial substitute for inorganic fertilizers in enhancing plant growth and yield across wide variety of crops.

1. Introduction

Use of inorganic fertilizers or agrochemicals in order to boost crop growth and improve the yield of crops is a common practice by almost all farmers. However, the extensive use of agrochemicals for the plant growth promotion causes a negative impact on agro-ecosystem, deteriorates the soil health status and degradation of natural resources. Moreover their conjoint effect will make the production system very fragile and unstable. The spiralling needs of chemical fertilizer have forced the scientists to direct their efforts on finding additional source to satisfy the nutrient hungry soil to enhance crop production. Microbial inoculants are an eco-friendly alternatives used to improve the efficiency of agrochemicals. Apart from fixing atmospheric nitrogen, microbial inoculants have

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different mode of action which promote plant growth and enhance the productivity of crops. Production of microbial seed leachates by the microbial inoculants provide the source of carbon and nitrogen in the initial few days to the crop. Also they produce phytohormones like auxins, cytokinin and gibberellins and organic acid that promote plant growth and improve soil's organic status. The concentration of plant-synthesized auxin determines the effect of auxin produced by microbial inoculants or PGPR. As a result, auxin produced by them will stimulate root development when the concentration of auxin produced by the plant is suboptimal, but will restrict root development when the concentration of auxin produced by the plant is already optimal (Spaepen et al., 2007). Phosphorous present in soil in both organic and inorganic forms, which is sometimes not available to plants. However, several microbial inoculants or phosphate solubilizing bacteria have been reported to mobilize unavailable form of phosphorus to available phosphorus through solubilization and mineralization. Phosphate solubilizing bacteria promote plant growth by producing plant growth hormones and increasing the availability of certain nutrient elements such as iron, zinc and others (Wani et al., 2007). The current review attempts to summarise and assess the prospects of microbial inoculants as an alternative approach to improving crop plant growth and productivity.

2. Impact on Plant Growth and Productivity

Microbial Inoculants have shown tremendous potential for wide array of agricultural crops. Various microbial inoculants have been employed to enhance growth and productivity of crop plants. Several researchers have explained the beneficial impact of microbial inoculants in plant growth. An improvement in yield of different crops has been reported with PSB as an inoculant alone and co-inoculation with other microbes. Sharma et al. (2018) reported that seed biopriming with microbial inoculant (PSB) was found most promising in plant growth promotion, seed yield and its contributing characters in soybean. The application of phosphate solubilizing bacteria in combination with other microbial inoculants was very beneficial for improving plant growth and productivity. Argaw (2012) evaluated the co-inoculation of *Bradyrhizobium japonicum* along with phosphate solubilizing *Pseudomonas spp.* on Soybean (*Glycine max* L. Merril) for various morphological characters and reported that dual inoculation of soybean seeds with *Bradyrhizobium japonicum* and PSB significantly increased rhizospheric bacterial diversity, yield contributing characters and yield response of soybean. Also it was reported by Karmakar et al. (2006) that the dual inoculation of *Rhizobium leguminosarum* with PSB in lentil seeds and soil inoculation methods significantly increased the number and dry weight of nodules as compared to individual inoculation with respective methods. They reported that inoculated seed resulted in higher occupancy of *Rhizobium* in nodules as compared to soil inoculation and they significantly improved the nodulation, grain yield, straw yield, Nitrogen and Phosphorous uptake in lentil. Tagore et al. (2013) found that microbial inoculant *Rhizobium* with PSB was found most effective in terms of nodule number, nodule fresh weight, nodule dry weight, shoot dry weight, and leghemoglobin. The inoculants also showed its positive effect in enhancing all the yield attributing parameters, grain and straw yields.

Pseudomonas fluorescens also plays an important role as a potential inoculant for plant growth promotion and productivity. Several studies have explained the beneficial effect of Pseudomonas as a microbial Inoculant in different crops. Sharma et al. (2018) reported that seed bioprimed with microbial inoculant *Pseudomonas fluorescens* (Psf-173) significantly increased field emergence. It was also reported that cold tolerant fluorescent Pseudomonas isolate from Garhwal Himalaya Pf-173 enhanced germination and vigour in pea (Negi et al., 2005). Yadav et al. (2013) concluded in their study that co-inoculated bio-priming with *Trichoderma, Pseudomonas* and *Rhizobium* improves crop growth in *Cicer arietinum* and *Phaseolus vulgaris.* They also reported that among the microbes that were applied alone, the *fluorescent Pseudomonas* was observed as the best among the three microbial strains in promoting seed germination and plant growth in both the crops.

Trichoderma is also actively involved in plant growth promotion. Rojan et al. (2010) studied the mycoparasitic *Trichoderma viride* as a biocontrol agent against *Fusarium oxysporum* f. sp. adzuki and *Pythium arrhenomanes* as a growth promoter of soybean. They reported that *Trichoderma* promoted growth of wheat and soybean under greenhouse conditions. *Trichoderma harzianum* was found to have a positive effect on soybean morphological characteristics, increasing seedling length by 52% and root length by 44%, respectively. Similar enhancement were also noticed on dry matter basis with 55% in case of seedling and 66% for root length respectively. The total chlorophyll content also increased by 206% as compared to un-inoculated (Entesari et al., 2013). Sharma et al. (2018) observed that *Trichoderma harzianum* had a positive effect on plant growth and increased plant height in soybean. They opinioned that rhizobacterial action of microbial inoculant, microbial auxin production and phosphate solubilization would have contributed to better plant growth including plant height.

There are various criteria for measuring the efficacy of bio-fertilizers. These are primarily the count of viable microbial, fungal or algal cells retained in the bio-fertilizers followed by the efficiency of these cells to fix atmospheric nitrogen/ phosphates.

In spite of the numerous technological edges upheld by bio-fertilizers over agro-chemicals in terms of its purity, ease of operations, transport etc., the viability of the microorganisms has been a cause of concern by the stakeholders. The solid based formulations available commercially, have lesser shelf life and inferior performance at field levels. These formulations offer viability up to three months and may not be available during critical crop growth. Further carrier based biofertilizers are temperature sensitive and reported to be unstable in crop plants. On the other hand liquid biofertilizer besides encompassing desirable microorganisms also have special cell structures which encourage the production of dormant spores enabling them to survive longer covering the entire crop cycle. The carrier based biofertilizer derived from various materials such as peat, wood charcoal, lignite etc., are of poor quality with high moisture content and even after bulk sterilization, chances of contamination are fairly high. On the contrary, liquid biofertilizer production adhering to proper hygiene measures and stringent sterilization procedure eliminates chances of contamination. The liquid biofertilizer inhibit a particular microorganism of interest in dormant mode either in form of cyst/ spore for increasing the shelf life. These dormant cells under favorable growth conditions germinate in form of active cells which utilize the carbon source present in the soil media or root primordia. The benefits of liquid biofertilizer vis-a-vis Carrier based biofertilizer galore on account of greater shelf life (1-2 year), fairly high microbial populations, stability under high temperature conditions, zero contamination, ease of identification by fermented smell, ease of application and better remuneration to farmers due to increased crop growth and yield. Moreover ease of protocol measures in production of Liquid biofertilizer has increased the popularity and export possibilities.

Table 1: Microbial inoculants and their positive role in plant growth and productivity

Microbial Inoculant	Dosage	Crop	effect	References
Phosphate Solubilizing Bacteria	8 g kg^{-1} Seed	Soybean	Increased plant growth and yield	Sharma et al. (2018)
Pseudomonas Fluorescence	8 g kg^{-1} seed	Soybean	Increased germination	Sharma et al. (2018)
Rhizobium co-inoculated with PSB	5 g kg^{-1} seed	Chickpea	Increased nodules, yield and its contributing character	Tagore et al. (2013)

3. Future Prospects

The microbial strains have been reported to cause favourable effect on the crop productivity. The research has to be fortified for identification of new strains with similar effect in the scenario of climatic change and plant morphology and reproductive changes. Further policy changes and initiatives with active public-private partnership for awareness of the potentialities of beneficial microbes has to be actively pursued. Strengthening future research on identification of new microbial strains with fixing of other macro and micro nutrients has also to be secured. In view of prominence of organic agriculture wherein bio-fertilizers play an important role, exploring the possibilities of Liquid biofertilizer in securing food supply is the need of the hour.

4. Conclusion

The microbial inoculants have proved to be environmentally safer and as alternative source of nitrogen and phosphorus as compared to inorganic fertilizers and being acceptable to the farmers. Thus, there is an urgent need of integrating these with components of advanced agriculture for securing sustainable food grain and pulses production for the growing population.

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