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Coinoculation of Azospirillum with PGPR for Plant Growth Promotion

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Abstract: Azospirillum is nitrogen fixing rhizobacteria found with grasses and cereals. It imparts many beneficial effects on crop plant like improved germination, dinitrogen fixation, phytohormone production, induced systemic resistance, etc. its impact can be even pronounced by co-inoculating it with other plant growth promoting rhizobacteria. Coinoculation or consortium is an inoculant formulation having containing two or more beneficial microorganisms that synergistically enhances plant growth. Countless literature in last few decades has been accumulated on coinoculation (consortium) of agriculturally beneficial microorganisms and certainly has benefits over single inoculation. Here we have reviewed some of the prominent benefits of coinoculation with Azospirillum.

Keywords: *Azospirillum,* Coinoculation, PGPR, biofertilizers

I. INTRODUCTION

Microbes are treasure of plant beneficial features and there are wide array of benefits are provided by microorganisms directly or indirectly to the plants (Sahu et al., 2013; Lavanya et al., 2015a, 2015b; Lavanya et al., 2016; Sahu et al., 2016a, 2016b; Renu et al., 2016a, 2016b; Nair et al., 2017; Renu et al., 2017; Meena et al., 2017). All beneficial microorganisms have their own effects on plant growth and there is no single organism which can provide all these benefits together (Brahmaprakash and Sahu, 2012). In the crop production, it is not practically feasible to apply several PGPR in separate application to the crop. As a consequence of this problem, the concept of consortium came so as to derive more benefit from every application, at the same time, coinoculation also gives synergistic effects. Success of inoculation and profit to the farmer are two major benefits which attracts towards consortium. A group of agriculturally beneficial microorganisms containing a potential N_2 fixer (Azospirillum), P- solubilizing bacteria, mycorrhiza, phytohormones producer and/ or a biocontrol agent will give a complete package for success in inoculation. Consortium is an inoculant formulation containing two or more beneficial microorganisms for enhancing plant growth (Ocampo et al. 1975; Brahmaprakash and Sahu, 2012; Sahu and Brahmaprakash, 2016; Sahu et al., 2016a). In consortium, its members may provide nutrients to others, removing inhibitory products by utilizing it, co-metabolism, etc. all these adds to enhanced growth of plant. It is very important to gain farmer's confidence on bioinoculants. In situation where one organism failed to produce its effect, the other one takes over and produce at least some beneficial effects on plant.

A. Benefits of coinoculation to farmers

1) Direct improvement in yield by plant growth promotion
2) Reduction in disease incidence, thus reduce cost of cultivation by cutting down pesticide use
3) Replacement of part of nitrogen and phosphorus fertilizers
4) Sustaining soil health

B. Azospirillum and Rhizobium coinoculation

This is one of the very common consortium of *Azospirillum.* Various green house and field trials have shown that coinoculation of *Azospirillum* and *Rhizobium* to the legumes resulted in increased N2 fixation, number of nodules, nodule function, hormone induced epidermal-cell differentiation in root hairs and increase in yield (Iruthayathas et al. 1983; Sarig et al. 1986; Andreeva et al. 1993). Phytohormones produced by Epidermal-cell differentiation in root hairs increases the number of potential sites for rhizobial infection (Yahalom et al. 1990).

C. Azospirillum and AM fungi coinoculation

Arbuscular mycorrhizal (AM) fungal inoculation has got several benefits for the plant including P-mobilization, biocontrol, alleviation of stress, etc. Coinoculation of AM fungi with *Azospirillum* can enhance nitrogen nutrition to the plants and at the same time it enhances mycorrhizal infection to the plants.

There are various success stories of this consortium (Barea et al. 1983; Pacovsky 1988; Subba Rao et al. 1985). Significant amount of N and P can be replaced for sustained plant growth. Application of *Glomus intraradices* with *Azospirillum* enhanced uptake of N, P, Zn, Cu and Fe apart from increasing mycorrhizal infection (Veeraswamy et al. 1992). Spore germination of *G. fasciculatum* was stimulated by cell free extract of *A. brasilense* and *A. lipoferum* (Tilak and Dwivedi 1990).

D. Azospirillum and cellulolytic bacteria coinoculation

A different synergism observed in Azospirillum inoculation with cellulolytic bacteria where it enhanced straw decomposition. The association of Azospirillum with polysaccharide degraders is helpful for both organisms as it consumes the fermentation products and removes the product inhibition for the polysaccharide degraders. This principle is utilized in augmenting straw decomposition by cellulolytic bacteria in a synergistic way. Apart from increasing N_2 fixation by Azospirillum, this consortium was found more efficient in decomposing straw than cellulose decomposing bacteria alone (Halsall and Gibson 1985, Halsall et al. 1985; Markus and Kramer 1988). It was reported that straw amended soil has given higher yields by Azospirillum (Hegazi 1988). An increase in pectin degradation was reported by Bacillus and N2 fixation by Azospirillum when inoculated together (Khammas and Kaiser 1992). An increase of N_2 fixation by 22 folds was recorded coinoculating with chitinolytic fungi (Halsall 1993).

Some of the organisms enhance nitrogen fixation of Azospirillum by providing more congenial environment for nitrogen fixation. It was reported that mangrove rhizosphere bacterium Staphylococcus sp. increases the N_2-fixation of the Azospirillum. Release of aspartic acid from the Staphylococcus sp. cells into the medium may be a cause for this (Holguin and Bashan 1996).

E. Azospirilum and PSB coinoculation

Alagawadi and Gaur (1992) reported that combined inoculation of sorghum in field trial by *Azospirillum brasilense* and the phosphate-solubilizing bacteria (*Pseudomonas striata* or *Bacillus polymyxa*) achieved significantly higher yields and enhanced N and P uptake as compared with single inoculation.

Consortium of *Azospirillum lipoferum* and the phosphate-solubilizing *Agrobacterium radiobacter* in a pot experiments in barley showed a significant increase in grain yield by inoculation with mixtures of either compared with single inoculations. The N_2 fixation and uptake is significantly higher in the plants was significantly higher when *Azospirillum lipoferum* and *Agrobacterium radiobacter* were combined. The higher positive impact of consortial inoculation on plant growth and development was recorded with the short supply of combined nitrogen in soil. Field experiments with three barley cultivars confirmed the assertion that inoculation with these mixed cultures is superior to single culture inoculations (Belimov et al. 1995).

F. Compatibility check before coinoculation

An organism secretes many metabolites in the vicinity which may or may not be beneficial for other organisms. There are few reports of negative effects of coinoculation. In clover, coinoculation of *Rhizobium* with *Azospirillum* prevented nodulation. Colonization of root hairs by *Azospirillum* blocked infection site for *Rhizobium* to develop nodule (Plazinksi and Rolfe 1985*)*. Therefore, compatibility must be studied before constructing the consortium for coinoculation.

II. CONCLUSION

Azospirillum is very prominent bioinoculant for field use. The efficiency of Azospirillum can be even higher if the possibilities of consortial application are harnessed. Much intense improvement is required for preparing improved consortial formulation of Azospirillum with stable performance at field. Many other coinoculation techniques for wider benefit in each crop can also be tried for better results of applied inoculants.

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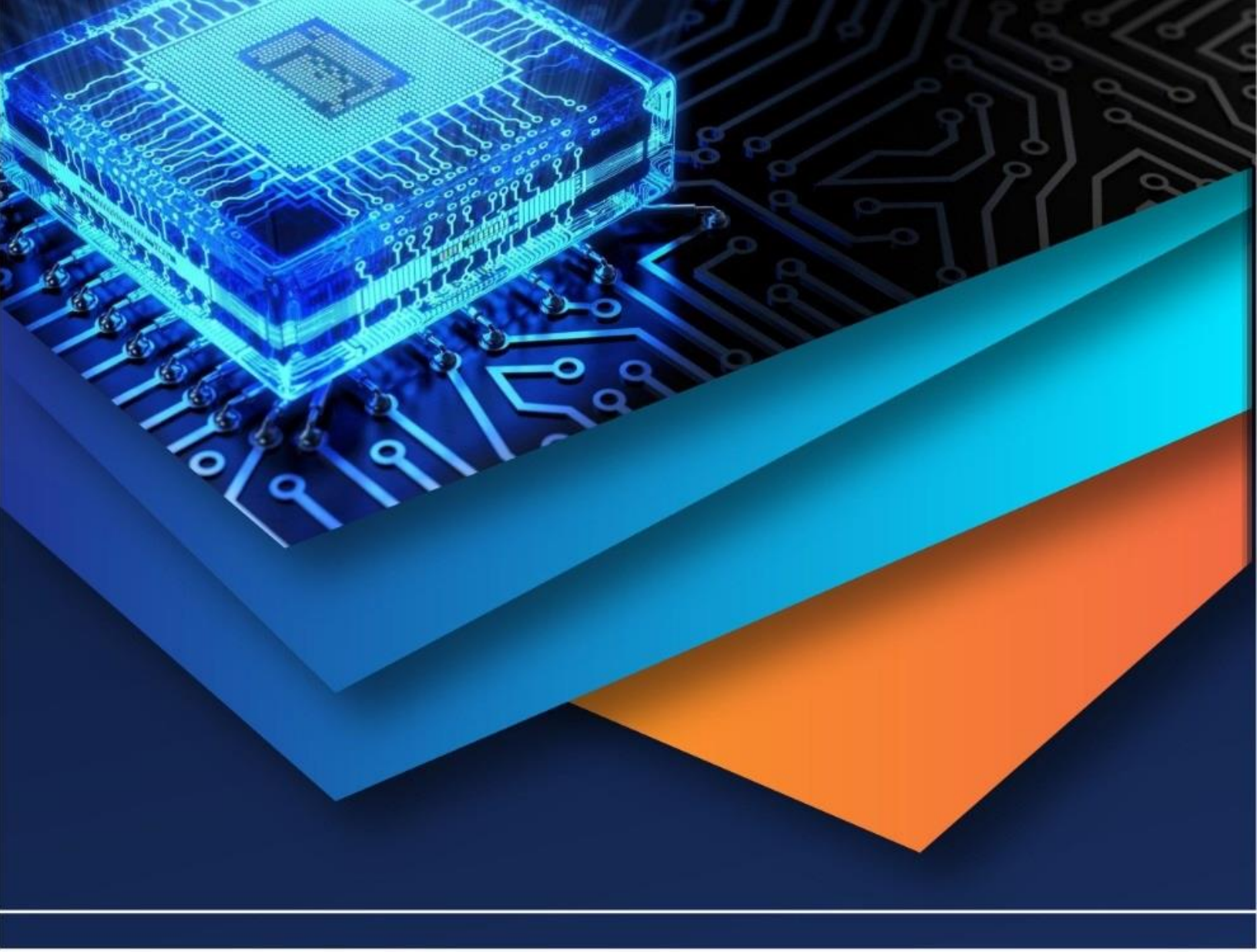

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