

Review Article

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Microbial Inoculants for Sustainable Agriculture

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ABSTRACT

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Expanding utilization of chemical fertilizers in farming make nation self-ward in food production for generation however it deteriorate condition and cause destructive effects on living beings. Overuse of chemical fertilizers in farming is exorbitant and has different adverse effects on soil richness. Further, soil microorganisms assume an essential part in the plant development and improvement by different means viz. nitrogen fixation, phosphate solubilisation, phytohormone generation and so forth. Hence, bio-inoculants for farming purpose i.e. biofertilizers could be a superior other option to chemical fertilizer for agriculture and also for environment sustainability.

Introduction

Soil microorganisms are critical part of sustainable agriculture and soil biodiversity framework. They play a vital part in the plant development and growth. In recent years, it is being seen that over application of synthetic fertilizers and pesticides which fall apart soil fertility as well as make few ecological effects. Beneficial microorganisms offer the possibility to meet our farming needs and in this manner, are better options for maintaining soil health and as an important part of integrated nutrient management for sustainable agricultural practice. When contrasted with the synthetic fertilizers, biofertilizers are more secure with diminished ecological harm, has more focused on movement and compelling in littler amounts.

Moreover, their multiplication can be controlled by the plant and indigenous microorganisms. In addition, microbial inoculants have faster decay systems and are less inclined to incite protection by the pathogens and bugs. Bio-inoculants for agriculture reason are called bio-fertilizers. Very often, microorganisms are not as efficient in natural surroundings as one would expect them to be and therefore, artificially multiplied cultures of efficient selected microorganisms play a vital role in accelerating the microbial processes in soil. Use of biofertilizers in the form of liquid microbial consortia is one of the important components of integrated nutrient management as these are cost effective and renewable source of plant nutrients to supplement the chemical fertilizers for

sustainable agriculture. "Biofertilizers are defined as preparations containing living cells or latent cells of efficient strains of microorganisms that help crop plants in uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil. They accelerate certain microbial processes in the soil which augment the extent of availability of nutrients in a form easily assimilated by plants" Biofertilizers include: nitrogen fixing biofertilizers (*Rhizobium*, *Bradyrhizobium*, *Azospirillum* and *Azotobacter*), phosphate solubilizing biofertilizers (PSB) (*Bacillus*, *Pseudomonas*, *Aspergillus* etc.), phosphate mobilizing biofertilizers (Mycorrhiza), plant growth promoting biofertilizers, potassium solubilizing bacteria, solubilizing bacteria and so on, however some of these genera incorporate endophytic species too. The best-described endophytic microbes incorporate *Azoarcus spp.*, *Gluconacetobacter diazotrophicus* and *Herbaspirillum seropedicae* and so on. The utilization of biofertilizer is well beneath its maximum potential, fundamentally due to non-accessibility of suitable inoculants. In this way, additionally studies on bioinoculants and their exploration will definitely help to comprehend the complexity and dynamism of microbial functioning and their compatibility in soils.

Plant growth promoting rhizobacteria

The rhizosphere, the zone encompassing and influenced by plant roots, is a problem area for a few life forms and a standout amongst the most composite biological communities on Earth (Mendes *et al.*, 2013). The rhizosphere is the natural surroundings for a few microscopic organisms, archaea, parasites, green growth, infections, oomycetes, nematodes, arthropods and protozoa. Mendes *et al.*, (2013) explained the rhizosphere microbiome as far as "the great" (beneficial

microorganisms), "the terrible" (plant pathogens) and "the appalling" (human pathogens). Through different mechanisms plant beneficial microorganisms enhance their growth and development as well as shield them from pathogen. PGPRs can stimulate plant's development either directly or indirectly.

Coordinated mechanisms involve the synthesis of substances like phytohormones, release of nutrients and induction of induced systemic resistance. Several Phosphate (P) solubilizing microbes (PSB) viz. *Xanthomonas sp.*, *Pseudomonas sp.*, *Pseudomonas striata*, *Rhizobium japonicum*, *R. leguminosarum*, *Azotobacter chroococcum*, *Enterobacter aerogens*, *Burkholderia cepacia* and some diazotrops. Different PGPR and their mode of action are listed in table 1. Moreover, indirect mechanisms include induction of symbiotic relationships for root development and biocontrol potential. In many cases various systems are involved to maintain beneficial plant microbial associations (Nihorimbere *et al.*, 2011). Therefore, in present scenario the identification of the mechanisms responsible of plant development and growth is a big challenge.

PGPR under abiotic stress

It has been expected that the rhizosphere microbial groups adds to the capacity of some plant species to get by under outrageous condition (Mendes *et al.*, 2013). For instance, halo-tolerant microorganisms flourish under salt-stress conditions and help in promoting plant growth and development (Jorquera *et al.*, 2012). Upadhyay *et al.*, (2009) demonstrated the capacity of creating indole-3-acidic corrosive, P-solubilization, siderophores generation and N₂ fixation. By 24 halo-tolerant microbes isolated from the rhizosphere of wheat plants developed in a saline zone.

Table.1 Mode of action of PGPR

	ORGANISM	Mode of action	Example	Refernces
Diazotrophs	<i>Rhizobia</i>	Reduce N ₂ to NH ₃ (NITROGEN FIXATION)	<i>Rhizobia, Frankia, Azospirillum Pseudomonas</i>	Kumar <i>et al.</i> , 2014; Suyal <i>et al.</i> , 2014
	<i>Azotobacter</i>	Produced ammonia, vitamins, growth substances, indole acetic acid, gibberellins, cytokinins	<i>Azotobacter chroococcum, A. vinelandii, A. beijerinckii, A. paspali, A. armeniacus, A. nigricans A. salinestri</i>	DeLuca <i>et al.</i> , 1996; Verma <i>et al.</i> , 2001
	<i>Acetobacter</i>	N ₂ fixation, production of plant growth-promoting substances	<i>Acetobacter, Gluconacetobacter, Gluconobacter, Acidomonas</i>	Suyal <i>et al.</i> , 2014
	<i>Pseudomonas</i>	Plant growth promotion activities	<i>P. jessenii P. migulae</i>	Kumar <i>et al.</i> , 2014
Phosphate solubilizing microorganisms	Phosphate solubilizing bacteria (PSB)	Solubilize inorganic phosphates	<i>Pseudomonas, Bacillus, Arthrobacter, Rhodococcus, Serratia, Gordonia, Phyllobacterium</i>	Rani <i>et al.</i> , 2013
Mycorrhiza	Mycorrhiza Arbuscular mycorrhizal fungi (AMF),	Soil exploration and increasing uptake and supply of N, P, K, Zn, Cu, S, Fe, Ca, Mg and Mn to the host roots	<i>Glomeromycota</i>	Mallik, 2000

There is great interest in agriculture and horticulture for bacterial and fungal inoculants that enhance growth of plants under low temperature (Mendes *et al.*, 2013). For example, *Burkholderia phytofirmans* PsJN increased grapevine root growth and physiological activity at 4 °C (Mendes *et al.*,

13). Other abiotic factors that may badly affect plant growth are pH and high concentrations of toxic compounds. Low pH soils or contaminated soils are main challenges in many production systems worldwide. Kawasaki *et al.*, (2012) used a split-root model and a combination of T-

RFLP, DGGE, and 16SrRNA gene pyrosequencing and showed that *Trifolium* and other legumes respond to polycyclic aromatic hydrocarbons contamination in a systemic manner. Similarly, Rani *et al.*, (2013) explored cadmium (Cd) resistant *P. putida* 710A for *Vigna radiata* (L.) Wilczek plant growth promotion and metal sequestering in Cd polluted soils. Also, fungi play an important role in rhizo remediation, for example, inoculation of the endophytic fungus *Lewia sp.* in the rhizosphere of *Festuca arundinacea* (Cruz-Hernandez *et al.*, 2012).

Bioinoculants as biofertilizers

In last few years, *Rhizobia*, constituting about 79 % of the global demand of bio-inoculants, Phosphate-solubilizing bioinoculants comprise 15 %, with other bio-inoculants (Transparency Market Research, 2014; Owen *et al.*, 2014). Due to the wide application of *Azospirillum*, it heads a long list of commercial free living PGPR products that are applied to crops in formulations. Some of the bioinoculants used as both biocontrol agent as well as for enhancing plant growth and development. Furthermore, at commercial level *Bacillus subtilis* is used amongst the most critical types of PGPR utilized under trade names such as Serenade, Kodiak, etc for crops like pea, cotton, beans, vegetables, rice and soybean.

Likely for fruit, nuts, ornamentals and trees PGPR developed by trades names Diegall, Nogall using *Agrobacterium radiobacter* as microbial agent. At long last, *Pseudomonas fluorescens* has likewise been utilized to produce commercial inoculants under the trade names Conquer and Victus and in the form of teeka by CCS HAU, Hisar. Despite their established economic and ecological benefits the utilization of such PGPR as biofertilizer must be deliberately evaluated

due to their importance as opportunistic pathogens (Mendes *et al.*, 2013). These microbial inoculants are available in both form liquid and with solid carriers.

Other than promoting plant growth and development, bioinoculants can mitigate both biotic and abiotic stress on crops, in this way, giving an ecological safe option for sustainable development. However, effective usage of microbial bioinoculants is depends on time span of usability or shelflife, variability in environment, diverse plants species and soil form or health. Besides, the irregularity of bio-inoculant execution and absence of free approval does little to fabricate confidence in their efficacy. In this way, more rudimentary information is required about microbial response, their interaction with both biotic and abiotic factors and for sustainable agriculture maintainable horticulture.

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