

## The Rhizosphere Actinobacteria And Biological Control: A Review

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Received 29 June 2020, Accepted 13 September 2020, Published on 8 October 2020

### ABSTRACT

Global crop productivity has been relatively stagnant for the last two decades regardless of the use of various conventional and molecular breeding approaches due to inconsistent climatic changes, incidence of diseases and application of inappropriate dosage of pesticides. The microorganisms in the rhizosphere perform an important role in plant growth-promotion through multiple functions. Amid a variety of microbial communities, actinobacteria play a noteworthy role in soil nutrient cycling as well as in biocontrol. These microbes are described for secreting different extracellular metabolites responsible for inhibition of several phytopathogens, while some of them play a significant role in plant growth regulation. Since last few years, studies on agricultural traits of actinomycetes concerning their use for plant growth promotion and biocontrol activities had opened new opportunities for their applications in sustainable

agriculture and increased crop productivity. Therefore, this manuscript is devoted to the brief review of some of the studies which have a direct or indirect relation with the application of actinobacteria as bio-control agents resulting in improved crop production.

**Keywords:** Actinobacteria, Disease, Phytopathogens, Productivity.

### INTRODUCTION

The crop productivity is severely affected by the attack of various kinds of plant pathogens. A number of diseases caused by numerous plant pathogens result in great loss to the economy of a country. To combat financial losses and to eliminate attack of numerous pathogens, a variety of pesticides are used. These pesticides either kill or suppress the disease causing pathogens and help in increasing food productivity. However, overuse of the pesticides is also associated with a large number of health and environmental issues (Rani et al. 2018a). Consequently, beside inorganic fertilizers, pesticides are 2nd disproportionately utilized chemicals responsible to cause cosmic threats to the ecosystem, especially harmful effects on innate microorganisms, toxicity to plants and doggedness in the soil ecosystem (Bhattacharyya et al. 2017, Rani et al. 2019). Therefore, it is extremely significant to control the exploitation of these agro-chemicals i.e. pesticides, aiming to achieve enhanced efficiency of food production in ecological and economical safer way.

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Since last few years, the use of plant growth-promoting microorganisms has become one of the most attractive options for increasing the sustainability of agricultural practices in India as well as in other countries due to their eco-friendly nature, low production cost and reduced use of non-renewable resources (Gopalakrishnan et al. 2015). Among various plant growth promoting microorganisms, an important class is actinobacteria which includes Gram-positive, filamentous and spore forming microorganisms. These microorganisms have high G+C content, propagate themselves by spores and grow through the soil in the form of hyphae (Vasconcellos et al. 2010).

### Diversity and distribution of actinomycetes in soil

Biodiversity is defined as the assortment of living organisms at species, inter-species and intra-species levels in ecosystem. On reviews of microbial diversity associated with different plants, the diverse group of bacteria, fungi and archaea are found and among bacteria the most dominant phylum is proteobacteria, followed by firmicutes and actinobacteria. The Phylum actinobacteria is majorly divided into six classes, namely Actinobacteria, Acidimicrobiia, Coriobacteriia, Nitrospirae, Rubrobacteriia, and Thermoleophilia, which together contain 29 orders and 67 families and 391 genera with 3900 distinct species (Yadav et al. 2018). Among the six classes of phylum, actinobacteria is the most dominant class (90%). Among the 3900 distinct species of actinobacteria, 30 genera, namely *Actinomyces*, *Actinomadura*, *Actinoplanes*, *Agromyces*, *Amycolatopsis*, *Arthrobacter*, *Bifidobacterium*, *Brachybacterium*, *Brevibacterium*, *Cellulomonas*, *Corynebacterium*, *Geodermatophilus*, *Gordonia*, *Kitasatospora*, *Kocuria*, *Kribbella*, *Leucobacter*, *Microbacterium*, *Micromonospora*, *Mycobacterium*, *Nocardia*, *Nocardioides*, *Nocardiopsis*, *Nonomuraea*, *Pseudonocardia*, *Rhodococcus*, *Saccharopolyspora*, *Saccharothrix*, *Streptomyces* and *Streptosporangium*, have been reported. Among all genera *Streptomyces* is found to be the most dominant (961 distinct species).

In rhizospheric soil, actinobacteria signify a high proportion of the microbial biomass. Their population is found at 106-109 bacteria per gram and they

embody more than 30% of the total population of soil microbiomes. Among different genera of actinobacteria, two genera namely *Streptomyces* and *Nocardia*, have been well represented in rhizospheric soil. It has been reported that *Streptomyces* may represent about 95% of all soil actinobacterial microbiomes (Ventura et al. 2007). The members of actinobacteria play a major role in agricultural soil quality and fertility. Actinobacteria represent a large fraction of microbiomes in the root systems and it is well recognized that they are dominant fraction of the microbial community in soils of wild and agricultural plant species (Ikunaga et al. 2011, Bal et al. 2013, Cavalcaet al. 2013, Li et al. 2014, Ali et al. 2016, Yadav 2017). Together with other phyla, the members of actinobacteria account for a large proportion in the rhizosphere of numerous plants, including wheat (*Triticumaestivum*) (Dubey et al. 2016), rice (*Oryza sativa*) (Balet et al. 2013), maize (*Zea mays*) (Martin-Laurent et al. 2006); sugarcane (*Saccharum officinarum*) (de Oliveira et al. 2011), soybean (*Glycine max*) (Shen et al. 2013), pea (*Pisum-sativum*) (Tariq et al. 2014), sunflower (*Helianthus annuus*) (Ambrosini et al. 2012) and chickpea (*Cicer arietinum*) (Yadav et al. 2010, Khan and Samiran 2012). These microorganisms are responsible for degradation of different complex and recalcitrant organic compounds into simpler ones. Thus, these microorganisms play an important role in nutrient recycling. Also, these bacteria are potent source of secondary metabolites production including growth promoting substances (Hamdali et al. 2008). Therefore, like other plant growth promoting microorganisms, actinomycetes may also promote plant growth by the production of phytohormone-like compounds such as indole acetic acid, solubilizing phosphates, suppressing phytopathogens by competition in the invasion sites, producing siderophores and secreting antibiotic compounds (Hamdali et al. 2008, Damam et al. 2016).

Antagonism is the hostility that results in active resistance, opposition or contentiousness between two microorganisms of different species. Actinobacteria may suppress pathogens by several means directly or indirectly either by exhibiting competition for nutrients or by excreting compounds lethal to pathogens. Several streptomycetes inhabiting rhizosphere play an imperative role in protection of plants from

various plant pathogens, accordingly increasing the plant growth.

### Biocontrol

Biological control is a natural and specific method to control pathogens and improve crop yield by growth-promoting attributes of environmental friendly microorganisms (Negi et al. 2017). Actinomycetes species are the most prolific source for the production of bioactive metabolites including antibacterial, herbicides and fungicides and they are the new natural sources of bioactive compounds (Xing et al. 2013, Aksoy et al. 2016). Among the producers of the commercially important bioactive metabolites, streptomycetes have the ability of producing enormous varieties of secondary metabolites by biological activities (Rashad et al. 2015). Streptomycetes are among the important groups of beneficial antagonists that developed into biofungicides. Therefore, actinomycetes possess several properties which help in plant growth promotion and as biocontrol agent, in combating several plant diseases. They colonize plant root surfaces and exhibit antibiosis against plant root pathogens by synthesis of particular extracellular enzymes, production of siderophore and hydrogen cyanide (Tokala et al. 2002).

### Siderophore production

Iron is a very essential element in all the living organisms as it plays an important role in catalysis of numerous enzymatic reactions where it acts as a co-factor. Earlier, iron was usually present in ferrous form ( $\text{Fe}^{2+}$ ) in soil during oxygen deficient atmosphere which was easily utilized by the microorganisms. However, with the passage of time, as the oxygen deficient atmosphere replaced by oxygen rich environment, iron get oxidized to ferric form ( $\text{Fe}^{3+}$ ) which is not readily utilized by microorganisms. To overcome this challenge, microorganisms evolved to produce small, low molecular weight (300-2000 Daltons), iron chelating molecules i.e. siderophores which form complexes with iron (Wilson et al. 2016). Microbial siderophores are generally classified as hydroxamates, catecholates and carboxylates according

to main chelating groups. The competition for iron acquisition occurs between plants and phytopathogens as siderophore production is one of the features that stimulate plant growth by forming complex with iron form ( $\text{Fe}^{3+}$ ) in the rhizosphere making iron unavailable to the phytopathogens. been implicated for both direct and indirect enhancement of plant growth by beneficial actinobacteria. The direct benefits of bacterial siderophores on the growth of plants have been demonstrated by using radio labeled ferric siderophores as a sole source of iron, showing that plants are able to take up the labeled iron by a large number of plant growth-promoting actinobacteria including *Arthrobacter*, *Corynebacterium*, *Kocuria*, *Microbacterium*, *Micrococcus* and *Streptomyces* (Singh et al. 2014, Verma et al. 2016). *Streptomyces* sp. have been reported to produce siderophores i.e. coelichelin, a peptide siderophores by *Streptomyces coelicolor* (Challis and Ravel 2000), enterobactin by *S. tendae* and *Streptomyces* sp. Tu 6125 (Fiedler et al. 2001). Siderophore producing actinobacteria create iron deficient conditions for phytopathogens by chelating the iron present in the rhizosphere and help to protect plants from disease which leads to the better growth of plants. Khamna et al. (2010) have also revealed that *Streptomyces* CMU-SK126 isolated from Curcuma manggarhizospheric soil exhibited high amounts of siderophore. Lee et al. (2012) reported that actinomycetes are metabolically flexible soil microorganisms capable of producing a range of compounds of interest, including siderophores, which could be applicable for controlling the fungal pathogens for sustainable agriculture and soil health. Further detailed characterization of isolates of interest identified a *Streptomyces* that produced extracellular-enterobactin, the characteristic enterobacteriaceae siderophores and also revealed some of the conditions required for enterobactin production. Another separate *Streptomyces* produced a compound that matched the UV/VIS spectra of heterobactin, a siderophore, which is well known from other actinobacteria such as *Rhodococcus* and *Nocardia*. These compounds have been reported to play a significant role in the physiology of symbiotic bacteria, soil microflora and suppression of diseases by inhibiting phytopathogens. However, the production of siderophores is largely controlled by the presence or absence of iron in the contiguous ecosystem.

### Hydrogen cyanide production

Cyanide is produced as a result of hydrolysis of cyanogenic compounds and is also released as a co-product of ethylene biosynthesis. In plants, most of the cyanide is detoxified primarily by the key enzyme  $\beta$ -cyanoalanine synthase. The remaining HCN at non-toxic concentration may play a role of signaling molecule involved in the control of some metabolic processes in plants. High concentration of HCN is generally toxic to the phytopathogens. So, HCN may play a dual role in plants depending on its concentration. It may be used in defense against herbivores at high toxic concentration and may have a regulatory function at lower concentration (Siegien and Bogatek 2006).

The plant growth promoting rhizobacteria produce several types of compounds with different advantages to the plants. The production of hydrogen cyanide is one of such compounds considered to possess phytoinhibitory and growth suppressing potential. Even though, the production of HCN has been believed as detrimental, it has been recommended that HCN producing microbes present prospective application in controlling weeds, phytopathogens and nematodes. As HCN is recognized as a biocontrol compound based on its ascribed toxicity against plant pathogens, actinobacteria producing HCN can act as potent biocontrol agents. The mechanism of action of HCN is considered to inhibit terminal "cytochrome c oxidase" in the respiratory chain and binds to metalloenzymes which confers it the property of suppressing phytopathogens (Ramette et al. 2003, Olanrewaju et al. 2017, Raniet et al. 2018b). Actinobacteria have been reported to possess the ability to produce hydrogen cyanide by various researchers. For example, different species of *Streptomyces* have been reported to produce HCN conferring important role in disease suppression (Passariet al. 2015, Anwar et al. 2016). Hydrogen cyanide has also been reported to contribute in mineral mobilization and phosphate release which results in indirect increase of nutrient availability to both actinobacteria and their host plants (Rijavec and Lapanje 2016). Based on the ability of HCN to prevent plant pathogen and to enhance nutrient availability, HCN producing actinobacteria can be used as biocontrol as well as plant growth

promoting agents. For example, Gopalakrishnan et al. (2014) characterized six actinomycetes, CAI-13, CAI-85, CAI-93, CAI-140, CAI-155 and KAI-180, isolated from six different herbal vermicomposts for in-vitro plant growth-promoting properties and further evaluated in the field for PGP activity in rice. All the six actinomycete isolates were reported to produce hydrocyanic acid. Phylogenetic analysis of 16S rDNA sequences of the six actinomycetes matched with genus *Streptomyces* but with different species. The isolate CAI-13, CAI85 and CAI-155 had maximum sequence similarity (99%) with *S. caviscabies*, CAI-93 and KAI-180 showed maximum sequence similarity (99%) with *S. globisporus* sub sp. *caucasicus* whereas CAI-140 showed maximum similarity (98%) with *S. griseorubens*.

### CONCLUSION

Actinobacteria are potential producers of different extracellular metabolites that eventually inhibit phytopathogens while some of them play the role of plant growth regulators. Actinobacteria are especially significant soil microflora because they can survive in soils of various types due to their spore forming abilities. They are prolific producers of various bioactive compounds such as antibiotics, siderophores, chitinases and HCN. Actinobacteria thus can be used for the development of novel biocontrol products by using their spores and/or mycelium. In addition, the filamentous nature of the organism and their ability to adhere to solid particles increase their presence in natural biotype and slow down their elimination. These microbes, having the potential to flourish under dry conditions, could be a commendable resource to the poor farmers to augment the supply of nutrients through solubilization or mobilization. Owing to these characteristics, actinobacteria are suggested as potential candidate for microbial inoculants development for sustainable agriculture system.

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