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Actinobacteria for sustainable agriculture

Abstract

Actinobacteria is a phylum and class of Gram-positive bacteria. The phylum Actinobacteria are classified into six classes namely Acidimicrobiia, Actinobacteria, Coriobacteriia, Nitriliruptoria, Rubrobacteria and *Thermoleophilia*. Members of phylum Actinobacteria are ubiquitous in nature. Actinobacteria can be utilized as biofertilizers for sustainable agriculture as they can enhance plant growth and soil health though different plant growth promoting attributes such as solubilization of phosphorus, potassium and zinc, production of Fe-chelating compounds, phytohormones hormones such indole acetic acids, cytokinin, and gibberellins as well as by biological nitrogen fixation. The Actinobacteria also plays an important role in mitigation of different abiotic stress conditions in plants. The members of phylum Actinobacteria such as Actinomyces, Arthrobacter, Bifidobacterium, Cellulomonas, Clavibacter, *Corynebacterium*, Frankia, *Microbacterium*, *Micrococcus*, *Mycobacterium*, Nocardia, *Propionibacterium*, *Pseudonocardia*, *Rhodococcus*, Sanguibacter and Streptomyces exhibited the multifarious plant growth promoting attributes and could be used as biofertilizers for crops growing under natural as well as under the abiotic stress conditions for plant growth and soil health for sustainable agriculture.

Keywords: abiotic stress, actinobacteria, plant growth promotion, soil health, sustainable agriculture

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Introduction

The plant microbiomes (epiphytic, endophytic and rhizospheric) have been isolated and have ability to promote plant growth are referred as plant growth-promoting (PGP) microbes. The plant microbiomes have been sorted out from diverse sources belongs to all three domian archaea, bacteria and fungi. Among three domain systems the members of domain bacteria are well characterized and reported as from diverse abiotic stresses, such as alkaline soil,[1,2] saline soil,[3] acidic soil[1] low temperature[4–11] high temperature,[12–17] and drought.[1] Among all three domain, there are very few report on archaea as plant growth promotion such as halophilic archaea including Natronoarchaeum, Natrinema, Natrialba, Haloterrigena, Halostagnicola, Halolamina, Haloferax, *Halococcus*, Halobacterium and Haloarcula having phosphorus solubilizing attributes under the hypersaline conditions.[3,18]

The microbes associated the plant rhizosphere are termed as rhizospheric microbes and rhizospheric actinobacteria are most dominant in nature. The study of different microbial diversity in form of plant microbiomes it can be concluded the members of phylum actinobacteria has been reported from different genera such as Streptomyces, Sanguibacter, *Rhodococcus*, *Pseudonocardia*, *Propionibacterium*, Nocardia, *Mycobacterium*, *Micrococcus*, *Microbacterium*, Frankia, *Corynebacterium*, Clavibacter, Cellulomonas, Bifidobacterium, Arthrobacter, Actinomyces, and Acidimicrobium.[19] Actinobacteria have been represents a large portion of soil microbiomes in the plant root systems.[20–24] The Actinobacteria has been isolated from diverse sources study e.g. chickpea (*Cicer arietinum*),[25,26] maize (*Zea mays*),[23,27,28] pea (*Pisum sativum*),[24,29,30] rice (*Oryza sativa*),[21,31,32] soybean (Glycine max),[24,33–35] Sugarcane (*Saccharum officinarum*),[36–38] sunflower (*Helianthus annuus*),[22,39,40] and wheat (*Triticum aestivum*).[41–46]

The Gram-positive organisms with a high G+C content belong to phylum Actinobacteria, constitute one of the largest phyla within the domain bacteria and consist of six classes namely, *Thermoleophilia*, Rubrobacteria, Nitriliruptoria, Coriobacteriia, Actinobacteria, and Acidimicrobiia, 3900 distinct species of 391 genera belonging to 67 families of 29 orders.[19] Among 3900 distinct species of actinobacteria, thirty genera namely Streptosporangium, Streptomyces, Saccharothrix, Saccharopolyspora, *Rhodococcus*, *Pseudonocardia*, Nonomuraea, Nocardiopsis, Nocardioides, Nocardia, *Mycobacterium*, Micromonospora, *Microbacterium*, Leucobacter, Kribbella, Kocuria, Kitasatospora, Gordonia, Geodermatophilus, *Corynebacterium*, Cellulomonas, Brevibacterium, Brachybacterium, Bifidobacterium, Arthrobacter, Amycolatopsis, *Agromyces*, Actinoplanes, Actinomyces, and Actinomadura. Among all genera Streptomyces have been most dominant with 961 distinct species followed by *Mycobacterium* (186 species).[19]

Microbes and their applications as bioinoculants have strategies to increase the current crops for sustainable agriculture. Microbes as bioinoculants and biopesticides are an alternative to chemical fertilisers to reduced environmental pollutions. The microbes having the plant growth promoting attributes such as nitrogen fixation and other plant growth promoting attributes such as solubilization of micronutrients phosphorus, potassium and zinc and production of Fe-chelating compounds, phytohormones. The nitrogen fixing actinobacteria such as *Agromyces* sp. ORS 1437,[47] Arthrobacter humicola IARI-IIWP-42,[48] Arthrobactermethylotrophus IARI-HHS1-25,[49] Arthrobacter nicotinovorans IARI-HHS1-1 49, *Corynebacterium* sp. AN1,[50] *Microbacterium*,[51] *Microbacterium* FS-01,[52] and *Pseudonocardia dioxanivorans* CBI190,[53] have been isolated from the rhizosphere of various crops, which contribute fixed nitrogen to the associated plants.

Phosphorus is an essential element for the establishment and development of plants because it improves the entire root system, consequently improving the shoot. Phosphate solubilization is a common trait among microbes such as archaea, bacteria and fungi. There are many reports on PGP Actinobacteria with phosphate solubilizing attributes and a vast numbers of P-solubilizing microbes have been reported which include members belonging to Streptomyce djakartensis TB-4, Streptomyces sp. WA-1, [54] *Micrococcus* SP N11- 0909,[55] , *Microbacterium* FS-01 52, *Cellulosimicrobium* sp. PB-09,[56] Arthrobacter agilis strain L77,[57] *Micrococcus luteus* IARI-THW-25,[58] Arthrobacter humicola IARI-IIWP-42, *Micrococcus luteus* IARI-IHD-5, *Micrococcus* sp. IARI-IIWP-20 48, Arthrobacter methylotrophus IARI-HHS1-25, Arthrobacter nicotinovorans IARI-

HHS1-1, and Kocuria kristinae IARI-HHS2-64 49. Along with the phosphorus solubilization, potassium solubilization is also help for plant growth promotion and there are many reports on potassium solubilizing Actinobacteria such as *Arthrobacter* sp. 42, Arthrobacter sp. 4, and *Microbacterium* FS-01.[52] The ability to synthesize phytohormones is widely distributed among plant-associated bacteria and indole acetic acids may potentially be used to promote plant growth or suppress weed growth. There are many reports on production of phytohormones by Actinobacteria including *Micrococcus* SP N11-0909 55, Cellulosimicrobium sp. PB-09 56, *Arthrobacter* sp. AS,[18,59] *Micrococcus luteus* IARI-THW-25,[58] *Micrococcus luteus* IARI-IHD-5, *Micrococcus* sp. IARI-IIWP-20, Arthrobacter humicola IARI-IIWP-42, *Kocuria* sp. IARI-IHD-9 48, Arthrobacter methylotrophus IARI-HHS1-25, Arthrobacter nicotinovorans IARI-HHS1-1, Kocuria kristinae IARI-HHS2-64 49, *Micrococcus luteus* IARI-NIAW1-1, Arthrobacter sp. IARI-NIAW1-4, *Micrococcus luteus* IARI-NIAW1-1 60.[60–67]

Iron is an essential nutrient for virtually all organisms and a necessary co-factor for many enzymatic reactions. The Fe-chelating compounds producing microbes shows for both direct and indirect enhancement of plant growth by beneficial Actinobacteria including Streptomyces, *Micrococcus*, *Microbacterium*, Kocuria, *Corynebacterium*, and Arthrobacter.[56–60] There are many insecticidal compounds spinosyns, polynactins, milbemycin, emamectin, avermectin, and abamectin, have been reported to produced by Actinomycetes and applied for the biocontrol of insect. [61–65] Termites are the most problematic pest threatening agriculture and the urban environment. They cause significant losses to annual and perennial crops. They are responsible for the loss of 15–25% of maize yield and about 1478 million Rupees.[66] Most tropical crops are susceptible to termite attack worldwise, which included wheat, tomato, tobacco, tea, sunflower, sugarcane, soybean, rice, potatoes, pigeon pea, pearl millet, mulberry, mango, maize, groundnut, eucalyptus, cowpea, cotton, citrus, chickpea, beans, barley, banana, and almond.[67] The pest management by microbes are effective, eco-friendly, economically viable, and socially acceptable method for sustainable agriculture and environments.[67]

Conclusion

The need of today's world is high output yield and enhanced production of the crop as well as fertility of soil to get in an eco-friendly manner. Actinobacteria should be explored for the use of bio-inoculants for different crops growing under the abiotic stresses such as temperature, pH, drought and salinity. In view of the medical, biotechnological, and ecological importance of the Actinobacteria, an understanding of the evolutionary relationships among members of this large phylum and what unique biochemical or physiological characteristics distinguish species of different classes of Actinobacteria is of great importance and significance. The members of Actinobacteria can be applied for biofortification of minerals for different cereal crops as well as many most dominant Actinobacteria can be used as probiotics as functional foods for human health.

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Conflicts of interest

All authors declare that they have no conflicts of interest to this work.

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