International Journal of Agro Nutrifood Practices
Vol-1 Issue-1, March 2021
e-ISSN: 2583-066X

Beneficial Role of Actinomycetes in Soil Fertility and Agriculture

J. Tracy Tina Angelina[1*], Nivedha P[2]

[1] Scientist- Department of Microbiology & Hematology, K.J. Research Foundation, Chennai, India
[2] M.Sc, Applied Microbiology, Domex e-data Pvt. Ltd., Chennai, India
*Corresponding Author Email: tracytina86@gmail.com

Abstract

Actinomycetes are filamentous with Gram-positive bacterial characteristics and have a major contribution to the different sectors of agriculture. Actinomycetes are widely distributed and isolated from soil, ponds, lake sediments, tributaries, creek/tidewaters, and aquatic environments. Actinomycetes experience complex morphologic variation with the development of the substrate mycelia in the preliminary phase life cycle and subsequently of aerial mycelia, which leads to spores resilient to numerous environmental conditions. Both current and new natural bioactive compounds are mainstreamed by microorganisms. Bacteria have been established to be a rich source among the producers of commercially valuable metabolites, with a relatively small community of taxa comprising the preponderance of the compounds that are useful both economically and biotechnologically until now. A broad variety of biological functions such as antimicrobial, disinfectants, anticancer, immunosuppressant, fungicide, herbicidal, antioxidant, and antiviral agent is presented as secondary metabolites produced by different species of Actinomycetes. "Representative genera of Actinomycetes include Streptomyces, Actinomyces, Arthrobacter, Corynebacterium, Frankia, Micrococcus, Micromonospora, and several others".

Index Terms

Actinomycetes, Agriculture, Soil Fertility.

INTRODUCTION

Actinomycetes are filamentous with Gram-positive bacterial characteristics and have a major contribution to the different sectors of agriculture. Actinomycetes are widely distributed and isolated from soil, ponds, lake sediments, tributaries, creek/tidewaters, and aquatic environments. Actinomycetes experience complex morphologic variation with the development of the substrate mycelia in the preliminary phase life cycle and subsequently of aerial mycelia, which leads to spores resilient to numerous environmental conditions. Both current and new natural bioactive compounds are mainstreamed by microorganisms. Bacteria have been established to be a rich source among the producers of commercially valuable metabolites, with a relatively small community of taxa comprising the preponderance of the compounds that are useful both economically and biotechnologically until now. A broad variety of biological functions such as antimicrobial, disinfectants, anticancer, immunosuppressant, fungicide, herbicidal, antioxidant, and antiviral agent is presented as secondary metabolites produced by different species of Actinomycetes. "Representative genera of Actinomycetes include *Streptomyces, Actinomyces, Arthrobacter, Corynebacterium, Frankia, Micrococcus, Micromonospora*, and several others."

THE BENEFICIAL ROLE OF ACTINOMYCETES

Actinomycetes are a consortium of microorganisms that share the characteristics of both bacteria and fungi. Actinomycetes are established to play a beneficial role in agriculture systems and productivity. The main functions of Actinomycetes include the development of a broad range of growth-stimulating compounds and metabolites such as antibiotics, to resist biological and abiotic stress conditions for host plants [1]. Subsequently, these organisms are used as a biocontrol agent and protect the host plants against several dreadful pathogenic organisms. Actinomycetes colonize host plants and provide growth-supporting agents that lead to accelerated plant growth in severe conditions including nutritional insufficiency, scarcity, salinity, and soil pollution because of heavy metal contamination [2]. Actinobacteria are effectively engaged in the mobilization and solubility of water-soluble nutrients such as phosphates and iron. Furthermore, actinobacteria facilitate mycorrhizal symbiosis and the most important biochemical process – nitrogen fixation. Actinomycetes produce a volatile copound (geosmin) that is commonly described as a biological indicator of maintaining soil fertility. In recent times, several research reports indicate that actinomycetes can generate nanoparticles of metal oxide that can be utilized and engaged in biological systems [3].

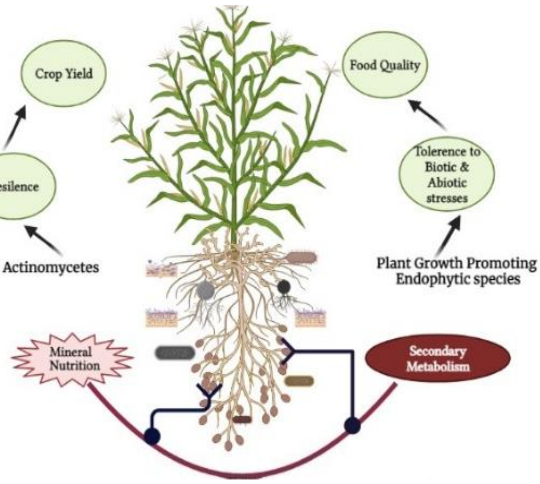
The important issue arises in fast-developing countries, particularly in countries like India, where there is constantly great demand for food grains, whether we are heading for depletion or rising for a viable future. Only through the discovery and use of the most successful and alternative farming techniques, the equilibrium for a more sustainable future will be achieved rather than solely dependent on chemicals. The use of rhizobacteria with numerous plant growth-promoting traits is one of the most powerful tools in organic farming technology. Actinomycetes are a significant group of colonizing organisms in the rhizosphere, which has several growth-enhancing characteristics. Their ability to develop wide-spectrum antibiotics is widely accepted. Actinomycetes have been mainly researched in recent years to support their plant growth and few have been marketed [4].

The demand for food grains in developing countries is being increased by the increasing population and the necessity for trade and economic growth, the requirement for many cash crop products is also being increased. The emergence of many phytopathogens which pose a serious risk to production efficiency and quality of the generated products is another challenge faced by modern agriculture practices. The use of fertilizers and pesticides, chemical agents such as fungicides and insecticides, significantly reduces these obstacles [5].

These chemicals help farmers to harvest advantages whereas, the overuse of chemicals in agriculture is often adverse. The biggest drawback is that chemicals also make the soil sterile and lose the natural biodiversity (fertility and natural composition of soil) and beneficial micro-organisms [6]. The residual potential of these chemical compounds often poses significant risks to human health. There is also an urgent need to lessen these toxic substances and enhance soil fertility, using environment-friendly approaches. It is necessary to reintroduce beneficial bacteria into the soil, to regenerate the soil with its natural fertility. The use of plant growth facilitating rhizobacteria can be beneficial both in terms of its potential role as bio-fertilizers and bio-control agents [7]. Actinomycetes play a significant role in the inhibition of a broad range of plant pathogens by synthesizing several bioactive compounds. The bioactive compounds produced by Actinomycetes are toxic to plant pathogens but do not elicit any harmful effects on human health and the environment. These features make Actinomycetes an enticing chemical substitute [8].

PLANT GROWTH PROMOTION BY ACTINOMYCETES

Streptomyces is the most widely recorded Actinomycete in the soil whereas, *Nocardia*, *Micromonospora*, and *Streptosporangium* are less abundant in soil. Actinomycetes are one of the key root-colonizing species, in particular Streptomyces, that can grow closely with plant roots [9]. Their threaded colonial filament morphology aids them in efficiently colonize the rhizosphere region, and effectively enable host rhizobacteria symbiosis. Actinomycetes can produce several organic compounds and enzymes that support plants after they develop successful colonization. The capability to generate these compounds helps the Actinomycetes to breakdown intricate organic matter into simpler forms that assist the plants to absorb the organic matter easily. They also have several ways of producing compounds such as Indoleacetic acid and siderophores to promote plant growth. Approximately 60% of insecticides and bioactive compounds have been identified from actinomycetes particularly *Streptomyces* sp. in the last five years [10].



Actinomycetes are effective biocontrol agents against several phytopathogens, both fungal and bacterial. *Streptomyces gresioviridis*, the abundant Actinomycete is widely employed as a bio-fungicide [11]. The plant growth promotion of Actinomycetes has been shown by many scientists in different field conditions in plants such as leguminous, tomato, bindweed, quack grass, and rice. Also, they associate synergistically with advantageous arbuscular mycorrhizal vesicular fungi that are vital in the plant consumption of nutrients [12].

Actinomycetes contribute to the cycling of nutrients and the breakdown into simpler forms of complex organic matter. They perform an important role in bio-geo cycles and contribute to the balance in the soil system. They also play a key role in the maintenance of a healthy environment. Actinomycetes produce spores that make them withstand extreme conditions such as drought or salinity [13]. The growth of Actinomycetes will be resumed under a favourable soil environment so that their populations do not decline as other non-spore-producing eubacterial species. Actinomycetes dominate the microbial community and a significant producer of several agriculture essential compounds [14]. Their hideous appearance owns their tendency to thrive in unfavourable conditions. This community has for a long time been studied in different sectors, including agriculture that directly influences humanity. Actinomycetes contribute nearly 61% of the secondary bioactive metabolites, including microbial antibiotics [15]. Several Actinomycete species are known to be powerful and harmless biocontrol agents against a variety of phytopathogens, some of which are commercialized.

Around five hundred *Streptomyces* species make up 70 – 80% of secondary metabolites. A very little contribution was observed by *Saccharopolyspora*, *Amycolatopsis*, *Micromonospora*, and *Actinoplanes* species [16]. The enhanced resistant activity of pathogens to the commonly used formulations is a significant explanation why new antibiotics and secondary metabolites are identified. *Streptomyces*-generated antibiotics can inhibit various microbes in the soil. Features like the development of antibiotics, disease suppression, and their resistance to drought and high temperatures make them desirable bioagents. Actinomycetes are generally utilized as biocontrol agents against a plethora of plant pathogens, such as *Alternaria* sp., *Rhizoctonia* sp., *Verticillium* sp., *Fusarium* sp., and *Macrophomina* sp. [17].

Enzymes and compounds	Actinomycete species
Chitinase	*Streptomyces viridificans, S. coelicolor, S. griseus, S. albovinaceus, S. caviscabies, S. setonii, S. viginiae*
Cellulase	*Thermonospora spp. Actinoplanes philippinensis, A. missouriensis Streptomyces clavuligerus*
Peptidases	*Nocardia spp.*
Proteases	*Nocardia spp.*
Xylanases	*Microbiospora spp.*
Lignases	*Nocardia autotrophica*
Amylases	*Thermomonospora curvata*
Lipases	*Streptomyces spp.*
β-1-3-glucanase	*Streptomyces spp.*
Indole Acetic Acid (IAA)	*S. olivaceoviridis, S. rimosus, S. rochei, S. griseoviridis, S. lydicus, S. viridis, S. coelicolor, S.olivaceus, S.geysiriensis*
Phenazines	*Streptomyces fulvorobeus, S. luridiscabiei, S. fimicarius, S. griseus, S. mediolani, Micromonospora matsumotoense*
Siderophores	*Streptomyces spp.*
Catechol – type Siderophores	*Streptomyces, Actinopolyspora, Nocardia, Saccharopolyspora, Pseudonocardia, Micromonospora*
Novel Anti-Fungal metabolites	*Streptomyces cavurensis., Saccharopolyspora spp., Nocardiopsis spp., Nocardia spp.*
Plant hormone – like compounds	*Streptomyces hygroscopicus*
Nitrogen fixation	*Frankia spp.*
Phosphate Solubilization	*Micromonospora endolithica*

The mechanisms concerning the inhibitory activity of Actinomycetes either individually or synergistically include (i) inhibition of pathogenic organisms by the production of antimicrobial compounds, (ii) siderophore formation and iron competency, (iii) competition for establishing colonization and nutrient acquirement provided by plant seeds and roots, (iv) initiation of plant defence process, (v) deactivation of germination factors of pathogenic species colonized in seed/root exudates, (vi) deprivation of factors contributing pathogenicity such as toxins, parasitism that entail the production of chitinase and β-1, 3 glucanase enzymes and degrades cell wall of infectious agents [18].

Several Actinomycetes such as *Streptomyces*, *Frankia*, *Nocardia* sp., are associated with plant organs, particularly with the roots, symbiotically and asymbiotically [19]. There are several confirmations of actinomycetes engaged in nitrogen fixation. The endophytic Actinomycete namely *Frankia* sp. has been associated with plant roots and fix atmospheric nitrogen for host plants [19]. Thread-like filamentous colonial morphology facilitates Actinomycetes to effectively colonize the rhizosphere. This enables them to create a highly efficient host-rhizobacteria symbiosis. Actinomycetes may produce a variety of organic compounds and enzymes that are advantageous to plants once they have established successful colonization. The actinomycetes' ability to generate these compounds allows them to break down the intricate organic matter present in the soil into simple forms of matter that are easier for plants to absorb. They also have a variety of pathways for producing plant growth-stimulating factors like IAA and siderophores. Actinomycetes, particularly Streptomyces sp., have been responsible for the discovery of approximately 60% of insecticides and bioactive compounds in the last five years [20, 21].

CONCLUSION

Actinomycetes are useful in numerous ways. They take part in several plant-growth-stimulating activities, such as the production of IAA, siderophore, solubilization of phosphate, nitrogen fixation, and the refurbishment of the soil system's ecological balance. Furthermore, there is a lot of evidence that Actinomycetes may be used as biocontrol agents. This bacterial community's distinct characteristics render it an invaluable resource for growing agricultural productivity and performance. Actinomycetes may be used as an alternative to toxic chemicals to promote environmentally sustainable agricultural practices.

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