Chapter 11
Bioactive Potential of Actinomycetes in Agriculture Sector

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Abstract Agriculture sector has been under tremendous pressure for merely producing enough food products to fulfil the considerable demand of progressively expanding population in this planet. Although chemical inputs in productive agriculture are imperative for proper plant growth and good yield, negative impacts of such compounds have undoubtedly increased the apparent importance of environmentally friendly pesticides and fertilizers of plants or microbial origin. Microorganisms efficiently perform a significant role in improving plant health, increasing plant yield, effective promotion of plant growth under stressful and adverse conditions, mitigating plant diseases and inducing plant defences. Impressive array of specific functionalities from the beneficial microorganism could significantly increase the necessary sustenance of plants under hostile and adverse conditions as well as increase crop yields with least adverse effect to human health and the environment. Extensive exploration of beneficial microorganisms from poorly explored habitats is still in its nascent stage, and the active search for better microbial isolates from exotic habitats with prospective source of bioproducts could divulge some novel and promising isolates with unique functionalities suitable for use in sustainable agriculture practices.

Keywords Agriculturally important microorganisms · Biofertilizers · Actinomycetes · Endophytes

11.1 Introduction

Ever-growing population across the globe has resulted in increase in considerable demand for food which has led to severe depletion of nutrition in the soil thereby limiting the factors for decreasing agricultural produce. As per published reports, around 70% of the abundant produce from the productive agriculture could be

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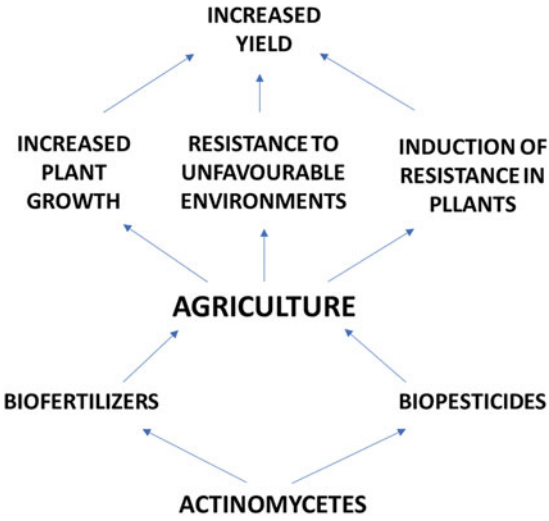

Fig. 11.1 Fundamental aspects of actinomycetes suitable for the possible enhancement of agriculture produce

progressively lost to pests without the extensive use of pesticides [1]. Pesticides are known to protect agricultural plants from phytopathogens such as bacteria, fungi, mites and insects [2]. This in turn results in the extensive use of considerable amount of fertilizers and pesticides which has been known to be harmful towards humans as well as the local environment. Biofertilizers and biopesticides derived from beneficial microorganisms have been thoughtfully considered as a viable alternative to naturally replenish the depleted soil fertility. Among beneficial microorganisms, actinomycetes have been known to secrete impressive array of bioactive metabolites with plant growth promoting functionalities (Fig. 11.1). Actinomycetes are gram-positive bacteria bearing similarities with mycelium of fungi [3]. These groups of specific microorganisms naturally possess plethora of desired functionalities such as secretion of beneficial enzymes, viz., proteases, chitinase and cellulase; potential bio-metabolites; decomposition of complex polysaccharides such as lignin, pectin, cellulose, etc.; and antimicrobial metabolites with antagonistic properties against suitable phytopathogens for sustainable agriculture practices [4]. Some of the actinomycetes belonging to the genus *Streptomyces*, *Actinoplanes* and *Micromonospora* have been known to considerably increase yield in agriculture sector [5, 6].

11.2 Plant Growth Promotion

Actinomycetes, especially *Streptomyces* spp., are able to colonize the rhizosphere as well as rhizoplane region of the plants efficiently. Distinct strains belonging to this recognized genus are equally able to colonize internal tissues of the plants therefore establishing an endophytic relationship with the host plant [7]. As per Olanrewaju and Babalola [8], beneficial properties of actinomycetes could possibly be due to

following attributes, viz., gene expression controlled through the complex mechanism of quorum sensing, production of plant hormones, chitinases, lipases, synthesis of amino acids, secretion of antimicrobial compounds, etc. Actinomycetes obtained from the rhizosphere of the olive tree demonstrated plant growth-promoting traits such as the production of indole acetic acid, ammonia, solubilization of inorganic phosphates and siderophores [9].

In one study, it was reported that the actinomycete strains in study were able to produce ammonia and solubilize phosphate as well as effectively colonize the roots of *Solanum lycopersicum* which as observed through scanning electron microscopy thus indicating their potential as prospective biofertilizer [10]. Chloropyrroles, isolated from an actinomycete strain *Catellatospora* sp., and a trehalose, Trehangelin E obtained from the extract of *Polymorphospora* sp., were found to promote elongation of roots in the germinated seeds of lettuce [11, 12].

11.2.1 Plant Growth Promotion Under Salt-Stressed Environment

Growth promotion with the help of actinomycetes in durum wheat plants under salt stress was studied by Djebaili et al. [13, 14]. In the experiment, different strains of actinomycetes were able to solubilize phosphates and produce IAA, hydrocyanic acids and ammonia under different concentration of sodium chloride. The strains were able to produce aminocyclopropane-1carboxylate deaminase activity and alpha-ketobutyric acids. The study inferred that the salt-tolerant actinomycetes could promote healthy plant growth and alleviate the stress of high concentration of salt on wheat plants. In one study, inoculation of seedlings of tomato with a strain of *Streptomyces* sp. resulted in increase in the weight, length of roots, number of roots, enrichment in pathways responsible for the processing of proteins by endoplasmic reticulum and enhancement of biochemical pathways thus indicating the possibility of using the strain as a biofertilizer [15].

11.2.2 Plant Growth Promotion Under Drought

Actinomycete strains have been assessed for their potential as a plant growth promoter under drought condition. Maize plants inoculated with the strains of actinomycetes, i.e. *Arthrobacter arilaitensis* and *Streptomyces pseudovenezuelae*, were able to promote proper growth of the plants as well as demonstrated a significant increase in other growth parameters thus indicating their potential as bioinoculants [16]. In one study, treatment of wheat plants with *Streptomyces pactum* Act 12 enhanced adjustment of osmotic potential and antioxidant capacity with the help of accumulation of abscisic acid and regulation of genes related to

resistance of drought thereby helping in resisting the stress on plants due to drought [17].

11.3 Biocontrol Attributes of Actinomycetes

Actinomycetes are known to secrete an array of hydrolysing enzymes that contribute to biocontrol aspect of the microorganisms. In one study, high levels of glucanases, proteases and chitinases were produced by *Arthrobacter humicola*, and moderate levels of amylases and pectinases were produced by *Streptomyces atratus* [18].

Some of the traits of actinomycete strains responsible for biocontrol of plant pathogens as indicated by Olanrewaju and Babalola [8] are as follows:

(a) Production of volatile organic compounds
(b) Secretion of antimicrobial metabolites
(c) Production of siderophores
(d) Production of growth regulators of plants

Actinomycete strains, viz., *Nocardiopsis aegyptica* and *Streptomyces lycopersicum*, secreted diffusible and volatile compounds with antifungal properties thus highlighting their potential as a biocontrol agent in a consortium [13]. Application of strains of *Streptomyces* spp. was able to control the effects of southern blight as well as root rot disease in *Aconitum carmichaelii* plants. Promotion of plant growth and control of disease was also visible even after stopping of application of the inoculum. Increase in the abundance of beneficial microorganisms in rhizosphere region was also observed [19]. An actinomycete strain *Streptomyces aureoverticillatus* was found to exhibit antibacterial activity against a bacterial phytopathogen *Ralstonia solanacearum* [20]. A strain of actinomycete, *Streptomyces griseorubiginosus*, demonstrated antifungal properties against *Fusarium oxysporum* responsible for causing wilt disease in banana plants. The strain was also able to produce plant growth-promoting properties [21]. A strain of actinomycetes, *Micromonospora* sp., was found to possess nematocidal potential. A compound, benzenepropanoic, extracted from the strain was able to kill 99% of nematode *Meloidogyne incognita* as well as inhibit hatching of the eggs thus establishing as a promising biocontrol agent against the nematode [22]. One of the strains of *Streptomyces antibioticus* was also able to inhibit the hatching of eggs of *M. incognita* as well as increase in the mortality of juvenile nematodes [23]. A pinewood nematode *Bursaphelenchus xylophilus* was inhibited by *Streptomyces* sp. through the production of a nematocidal metabolite teleocidin [23].

1. Properties of actinomycetes with possible application in sustainable agriculture system

Beneficial actinomycetes have immense potential in the production of biofertilizer and biopesticide formulations (Table 11.1). Their role in promoting

Table 11.1 Different properties of actinomycete species suitable for agricultural application

Sl. No.	Actinomycetes	Properties	Reference
1	*Streptomyces* sp.	Antagonistic effect against *Botrytis cinerea* causing spot disease in faba bean (*Vicia fabae* L.)	El-Shatoury et al. [24]
2	*Streptomyces rochei* ANH	Biosorption of heavy metals, viz., Cr^{6+}, Cd^{2+} and Pb^{2+} from industrial effluents and improve water quality suitable for irrigation	Hamdan et al. [25]
3	*Streptomyces* sp.	A part of consortia to convert waste from husbandry into organic fertilizer	Amrullah et al. [26]
4	*Streptomyces tsukiyonensis*	Antagonistic effect against *Colletotrichum dematium* responsible for causing anthracnose in *Sarcandra glabra*	Song et al. [27]
5	*Streptomyces* sp.	Degradation of lignocellulosic residues by enzymatic hydrolysis during composting	Buzón-Durán et al. [28]
6	*Kribbella speibonae*	Production of siderophores	Acquah et al. [29]
7	*Streptomyces* sp.	Production of exotoxins with insecticidal properties against Diamondback moth, *Plutella xylostella* pest of cabbage and cauliflower	Srujana et al. [30]
8	*Brachybacterium phenoliresistens* and *Microbacterium* sp.	Antifungal properties against *Peronophythora litchi* and *Rhizoctonia solani*	Wu et al. [31]
9	*Streptomyces* spp.	Promotes degradation of lignocellulosic residues during the composting through enzymatic hydrolysis	Buzón-Durán et al. [28]
10	*Streptomyces* sp.	Antifungal action against *Thielaviopsis paradoxa* that causes root rot, fruit rot and bleeding disease of coconuts	M. M. et al. [32]

plant growth, maintaining plant health and secretion of suitable bioactive metabolites with immense potential in agriculture cannot be ruled out [33].

11.4 Future Scopes and Prospects

Biofertilizers have undoubtedly gained considerable attention in the recent years. The untapped microorganisms laden with diverse features have been popularly considered over the chemical fertilizers due to the negative impacts of hazardous chemicals resulting in various health issues and adversely affecting the environment. Biofertilizers are known to assist the active management of critical components of assimilated nutrients for structured farming. Among various strains of microorganisms in this planet, the beneficial roles of actinomycete cannot be overlooked. The

massive population of actinomycetes in diversified soil types and their prominent roles in adequately maintaining fertility of soil and nature are of prime importance in agriculture sector. The proper management of soil ecosystem by the actinomycetes through the diversified attributes such as an ability of plant growth promotion, properly managing the optimal health and vigour of the plants, and secretion of agro-active compounds are significant contributors to agriculture. The remarkable ability of actinomycetes to amply compensate for hazardous and harmful chemical fertilizers and also to boost beneficial effects in plants highlights their prominent role in the vulnerable ecosystem. These actinomycetes are universally recognized to exert substantial beneficial effects in soil and hence provide a substantial way to proportionately increase crop yield in the foreseeable future. Some of the strains of actinomycetes were at par with the chemical fertilizers when evaluated for their plant growth promoting attributes [34].

11.5 Conclusion

Beneficial microorganisms such as bacteria, along with actinomycetes, and fungi have been known to efficiently manage soil-borne phytopathogens. Some of the strains belonging to actinobacteria, viz., *Streptomyces*, *Nocardia*, *Frankia*, *Micromonospora* and *Amycolatopsis*, have been reported to adequately support the plants to absorb required nutrition from the surrounding soil as well as help in the control of pathogens.

The continuous exploration for plant growth promoting characteristics and antimicrobial properties remains a need of the hour to promote sustainable agriculture practices.

Extensive exploration and continuous evaluation of prospective actinomycetes laden with beneficial properties suitable for sustainable agriculture system should be a continuous process to replenish the existing consortia with the more efficient and effective ones.

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