A Review: Actinobacteria as Microbial Weapons to Protect the Tea Ecosystem

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Abstract
Numerous pathogens and pests seriously diminish or destroy tea. In the end, it has an impact on the quantity and quality of tea produced. The diseases grey blight, brown blight, and blister blight are the most economically significant leaf diseases affecting tea in southern India. The most significant leaf blight disease is blister blight, which is brought on by *Exobasidium vexans*. On an annual crop basis, blister blight losses can reach 43 percent. The tea plant is attacked by a variety of pest species in addition to pathogens. The red spider mite, *Oligonychus coffeae* (Nietner) (Acarina: Tetranychidae), is a significant pest that significantly reduces tea crop yields. Red spider mites cause an annual crop loss of 11 to 16%. Agrochemicals have proven effective in managing these serious tea plant diseases and pests. Today, there are many serious concerns being expressed regarding environmental contamination, huge doses of chemical fertilizer, developmental resistance, and health risks. We must create alternative methods that are eco-friendly. This review article discusses how actinobacteria serve as a superior, ecologically sound substitute to dangerous agrochemicals in the tea ecosystem.
Key words: Biocontrol, tea, actinobacteria, agrochemicals, plant defense

Introduction

Tea is one of the greatest prevalent hot drinks in the world for its owing taste and health benefits. Tea plant is disposed to numerous biotic stresses in nature due to by fungal diseases, insects and weeds. The extreme loss of crop in tea plant is credited to pathogens (16%) followed by insects (8%) and weeds (16%) (Jayanthi et al., 2016). The blister blight disease is the record significant leaf disease. *Exobasidium vexans*, the causative agent of blister blight disease, is an obligate fungus that completes its whole life cycle in tea. The disease mostly targets young, succulent, and fragile harvestable leaf and stalk, wreaking havoc on the quantity and quality of tea for human consumption. The red spider mite (RSM) is a serious pest of tea (*Camellia sinensis*) in the majority of tea-producing nations. Adults and nymphs of the red spider mite (RSM) lacerate cells, leaving reddish brown spots on the top surface of mature leaves, which become red in severe infestations, resulting in crop loss (Roy et al., 2014)

In order to maintain the superior level of agricultural goods and lower output losses, agrochemicals are frequently used to manage or prevent diseases, pests, and weeds. To cultivate tea without pesticide residues is currently the main challenge facing tea growers. In the economically industrialised nations, there is an increasing demand for residue-free tea or tea with little to no pesticide residue, and this quality of tea is paying off(Lehmann-Danzinger, 2000). Limiting the use of these dangerous chemicals and switching eco-friendly alternatives is crucial for maintaining sustainable agriculture.

According to Bhattacharyya (2012), soil is a diverse natural environment whose health is significantly impacted by a number of variables, including root exudates, microbiological components with complex metabolic activities, and other biotic and abiotic elements. In an agroecosystem, crop health is determined by the diversity and interactions of the soil's microbes. Scientific studies into the immense resource of microbial variety in soil have been prompted by the knowledge that microorganisms are essential to the ecosystem because of their crucial role in accelerating processes like management of biogeochemical cycles, degradation of xenobiotic chemicals, organic material degradation, nutrient availability, water absorption, weed control, and disease suppression (serving as biocontrol agents) (Bhattacharyya & Sarmah, 2018).

The ability of Actinobacteria, a group of these bacteria, to produce various bioactive chemicals that are poisonous to phytopathogens but have no deleterious effects on humans or the environment, allows them to suppress the growth of a wide variety of bacterial and fungal phytopathogens (Zucchi TD et al., 2018 and Costa FG et al., 2013). Actinobacteria that promote plant growth are also known as biocontrol agents and biofertilizers. They are an excellent and safer alternative to toxic fertilizer and fungicides. In the context of the tea ecosystem, this review article examines how actinobacteria can serve as a superior and ecologically sound alternative to the use of potentially harmful agrochemicals.

General Characteristics of Actinobacteria

The prokaryotic organisms known as actinobacteria are classified as bacteria but stand out sufficiently to be examined separately. Actinobacteria elongated cells, which divide to form threads or hyphae, give them a fungi-like appearance. Actinobacteria hyphae are considerably smaller than fungal hyphae, which allows them to be distinguished from one another. This category of microbes is notable for its capacity to use a wide range of soil-based substrates, particularly some that are not fully biodegradable, like arthropod and plant polymers like chitin, cellulose, and hemicellulose. Despite being initially identified as soil microbes (Pepper & Gentry, 2015).

One of the most diverse taxonomic groups, Actinobacteria includes several different genera with vastly varying morphologies, physiologies, and metabolic capacities (Barka et al., 2016). These Gram-positive bacteria with high G+C content are widespread in soils, plant tissue, and a variety of unique environments, including hot springs, alkali saline soil, marine sponges, deep-sea sediments, and plants. They are a rich source of secondary metabolites that are bioactive (Qin et al., 2016). There are six classes in the phylum Actinobacteria: *Actinobacteria, Acidimicrobiia, Coriobacteriia, Nitriliruptoria, Rubrobacteria, and Thermoleophilia*. There are also 53 families overall, 43 of which are exclusive to

Actinobacteria (Goodfellow et al., 2012). *Streptomyces* is the actinobacteria genus whose favourable effects on plant health have received the most research (Borah et al., 2022).

Diversity of actinobacteria in tea rhizosphere

The rhizosphere microorganism community is a crucial component of the tea plantation ecosystem. It helps tea plants grow and develop and makes them less likely to get sick or die from other pressures (Bag et al., 2022). A lot of research has been done on how plant rhizosphere microorganisms are put together and what they do.

Beneficial microorganisms are significant subgroups of microbiological communities that promote ecological functions by being essential to plant disease resistance and stress tolerance. The perennial, evergreen, broad-leaved cash crop known as tea (*Camellia sinensis* (L.) O. Ktze.) is grown in hot, humid climates (Wang et al., 2016). The form and function of soil microbes in tea gardens under various environmental conditions such as natural foods compared to conventional management, geographical area, standing age, different N fertilisation, as well as land use transformation from forests to tea gardens and their relationship to the physical and chemical properties of soil have been thoroughly researched. Tea gardens currently struggle with declining soil quality and dangerous illnesses (Zhang et al., 2022).

Actinobacteria are found everywhere in nature, including the interior of plant tissue and saprophytic actinobacteria that live in the soil. They spend most of their lives as dormant spores in the soil, especially in places with few nutrients (Barka et al., 2016). Actinobacteria in plants usually live close to the root system, making the rhizosphere, a special ecological niche, or in a symbiotic relationship with the endophytes, which live in the plant's inner tissue. Actinobacteria make up a significant component of the rhizobia microbial biomass. For the maintenance of microbial diversity, actinobacteria generally have neutral interactions and live with naturally occurring microorganisms (Borah et al., 2022). Continuous tea farming frequently results in changes to the soil's pH, organic matter content, and bacterial populations. After several years of continuous cropping, the relative abundance of helpful plant-bacteria drastically dropped, which had a negative impact on tea cultivation in the continuously cropped system. Actinobacteria were found to be one of the most prevalent phyla in studies on the microbial biodiversity of tea. With an abundance of 43.12%, actinobacteria dominated the bacterial community in the rhizosphere of an ancient wild tea (Zi et al., 2020). Several actinobacteria have been identified using a 16S rRNA gene sequence-based phylogenetic study of actinobacterial species in the root system. Numerous tea cultivars have been used as sources of plant-beneficial actinobacteria, which are found in the genera *Brevibacterium, Brachybacterium, Leucobacter, Kocuria, Micrococcus, Microbacterium, Streptomyces, Mycobacterium, Pseudarthrobacter, Saccharomonospora, Leucobacter, Actinomadura, Leifsonia, Kribbella, Kytococcus, and Micromon* (Borah et al., 2022)

Biocontrol potential of Actinobacteria

Chemical-based management strategies are getting more expensive, and people want to buy agricultural products that don't use chemicals. This means that we need to find alternatives that are good for the environment. Non pathogenic bacteria that are found in nature can be used to treat plant diseases in a way that works and lasts. The effectiveness of

Trichoderma spp. and *Bacillus subtilis* as biocontrol agents has prompted researchers to look for substitutes, and filamentous actinobacteria have recently emerged as a possible option. Actinobacteria rely on nearly identical methods to control plant diseases and encourage plant development, which is comparable to other biological control agents and rhizobacteria that also stimulate plant growth. Competing for niche, space, or a source, lytic enzymes, and the creation of inhibitory compounds that fight plant diseases are some of the generally acknowledged methods of biocontrol. These advantageous microorganisms also help host plants' immunological defenses against a variety of diseases and other abiotic stressors (Sharma & Salwan, 2018). The exact mechanisms of action linked to actinobacteria as biological control agents for the ecological control of plant illnesses are highlighted in this chapter.

The actinobacteria have tight control over major plant pathogens. They stand for the increased microbial bulk in the soil as representative genera. Many studies have demonstrated the astonishing diversity of secondary metabolites that all these prolific actinobacteria are capable of producing, including antibiotics, anticancer agents, insecticides, etc. There have been reports of several actinobacteria cultures that were isolated from South Indian tea-growing regions that were morphologically unique based on spore mass color, aerial structure, substrate mycelium pigmentation, and spore chain morphology (Fig.1) (Jayanthi et al., 2016).

In terms of crop management, biological control is considered to be a substitute to agrochemicals. The competition for nutrients or rhizospheric space, the creation of toxins, and the development of defense response in host plants to various diseases and/or abiotic stresses are some of the mechanisms of biocontrol. Free-living rhizobacterial strains have received a lot of interest from different researchers, particularly *Streptomyces* spp.

Chitinases, glucanases, amylases, cellulases, lipases, and proteolytic enzymes are just a few of the enzymes that actinobacteria are widely known for releasing. *S. cavourensis* SY224, a chitinase and glucanase-producing organism, managed the anthracnose infection in pepper. High-activity antifungal chitinases generated by *S. halstedii* and *S. griseus* are efficient biological pesticides for crops (Ebrahimi-Zarandi et al., 2022). According to Gopalakrishnan et al. (2011), *Streptomyces* strains suppressed Fusarium wilt in chickpea through the cooperative production of a number of metabolites, including the enzymes cellulase and protease as well as hydrogen cyanide. On mango plantations, dieback brought on by the fungus *Lasiodiplodia theobromae* is a significant problem, and *Micromonospora tulbaghiae* antifungal effect against the fungus was linked to both antibiotic and chitinase synthesis (Kamil et al., 2018). For both young and old tea farms, leaf infections are among the many ailments that affect tea plants and can cause significant crop loss. Grey blight (*Pestalotiopsis theae*) and brown blight (*Glomerella cingulata*) are two important leaf diseases that affect tea. *Streptomyces* sp. significantly reduced both pathogens (Fig. 2). (Jayanthi et al., 2016)

Plant defense mechanism of actinobacteria

Microorganisms in the soil are essential to the growth and health of plants. Also, they make a significant contribution to the agricultural output of many crops(C. Bhattacharyya et al., 2020). Plants have evolved a general defense system that can offer sustained defense against a wide range of diseases. Chemical agents or earlier inoculation with a necrotizing infection can cause systemic acquired resistance (SAR).

Two types of induced resistance, known as systemic acquired resistance (SAR) and induced systemic resistance (ISR), occur when a plant's defenses are preconditioned by an earlier infection or treatment, leading to resistance to a pathogen's or parasite's subsequent challenge. Certain kinds of plant growth-promoting rhizobacteria (PGPR) fight off soil-borne pathogens, causing systemic resistance in the plant against both root and foliar pathogens, and suppressing illness (Conn et al., 2008).

Signalling systems such as salicylic acid (SA)-independent jasmonic acid (JA), ethylene (ET)-dependent signalling, and the nuclear pore receptor (NPR) (non-expressor pathogenesis-related genes) In plants inoculated with actinobacteria, 1-dependent signalling may raise the levels of JA-responsive genes and ET-responsive genes, which causes ISR to be activated and the plant to grow (Fig. 3). The JA and ET response in plants with bacteria that help them grow could turn on the npr-1 gene, which makes the NPR-1 protein, and then turn on the defense-related gene (Jain et al., 2014). NPR-1 proteins are called "master regulators" in defense pathways because, when they get a signal, they turn on the affirmation of the PR gene or a defense-related gene. This is how salicylic acid resistance (SAR) and inducible salicylic acid resistance (ISR) are set up (P. Bhattacharyya & Sarmah, 2018).

Most of the microorganisms in the rhizosphere are actinobacteria, which also invade plant tissues and make enzymes and secondary metabolites that kill pests and help plants grow. Although the mechanisms are currently poorly understood, non-pathogenic Actinobacteria can also cause systemic resistance (ISR) to infections. Actinobacterial defense priming has a lot of potential to be an effective technique for contemporary plant protection. The association between biocontrol action and the encouragement of plant growth has two significant ramifications. Second, Actinobacteria can defend host plants in vivo by not only blocking the pathogen but also by inducing plant disease resistance. Firstly, the selection of biological control strains should not be restricted to the outcomes of in vitro bioactivity studies. Conn et al. (2018) discovered ISR caused by Actinobacteria as a response to *Micromonospora* or *Streptomyces* strain inoculations (Ebrahimi-Zarandi et al., 2022). Actinobacterial species interact favourably with plants to promote plant development, acaricidal activity and resistance to disease (Fig. 4).

Eco-friendly tea pest management

Pests damage plants, slow growth, and lower crop yields in every cropping system. Tea ecosystems support insect pests that reduce crop output by 5% to 55%. When tea cultivation began, synthetic pesticides and acaricides have controlled these arthropod pests. However, long-term use of synthetic pesticides can cause insect resistance, disturb the natural predatory complex, leave residue in tea, and harm human health and the environment. These concerns require alternative pest management methods other than chemical pesticides (Barua, 2018). Discovering eco-friendly insecticides and pesticides is growing in popularity. As hazardous pesticides pollute the ecosystem, pest control must change.

Entomopathogens could be used to get rid of pests, protect biodiversity, and replace pesticides with a wide range of effects (Lacey et al., 2001; Roy and Muraleedharan, 2014). Entomopathogens, which include fungi, bacteria, and viruses, are good for IPM programs because they only hurt insects. Microbial pesticides prevent plant pests like plant pathogens and tea pests to improve plant growth. Due to their biopesticide potential in tea plantations, bacterial species such as *Bacillus* spp. and *Pseudomonas* spp., fungal isolates like *Aspergillus, Beauveria bassiana, Gliocladium, Metarhizium anisopliae, Paecilomyces, Penicillium, Trichoderma, and Verticillium lecanii*, actinomycetes like *Streptomyces*, and mycorrhizal fungi have increased agricultural productivity (P. Bhattacharyya & Sarmah, 2018). Actinobacteria generate antibiotics and agro-active chemicals as biopesticides, according to Jayanthi et al., 2016, acaricidal activity of actinomycetes increased red spider mite mortality in tea. (Fig.5)

Conclusion

This review looks at the effects of actinobacteria and shows how its different parts help plants grow, fight diseases, get rid of pests, and make the soil more productive, all of which are important parts of sustainable farming and a great alternative to chemicals that are bad for the environment. Actinobacterial defensive mechanism Priming has a great deal of promise as a successful modern plant protection method. The antibiosis and lytic enzyme production of an actinobacteria biocontrol strain should cooperate optimally with the stimulatory action of that strain or another member of a synthetic community. As another important issue, more research needs to be done on actinobacterial bioinoculant formulation using different additives, carriers, and different ways of inoculation in the field to make effective commercial products. Also, the mechanism of tea plant defense and the role of rhizosphere actinobacteria are still not well understood. In the future, more work should be done to study about actinobacteria in depth. This will help plants to grow and stop tea pathogens, as well as the need to research how they will work at the molecular level.

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Conflicts of interest and financial disclosures:

There are no conflicts of interest to declare.

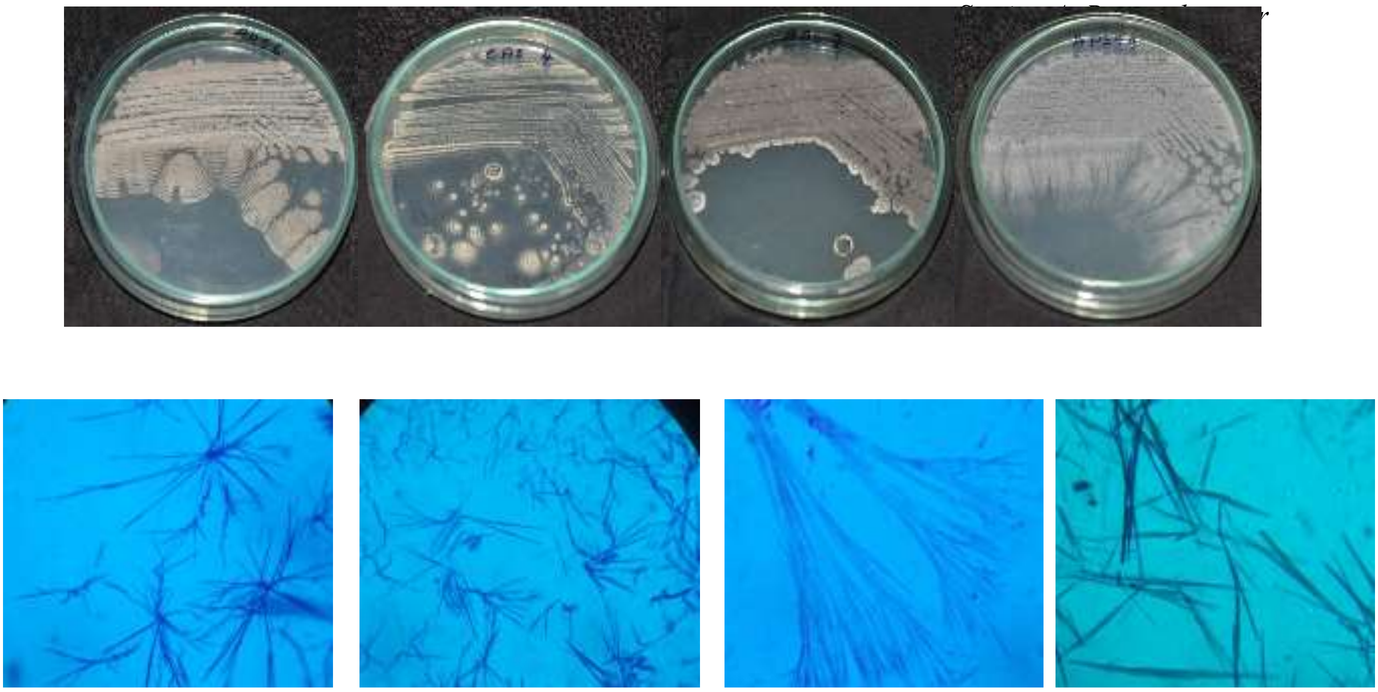

Fig: 1 Plate and spore morphology of actinobacteria isolated from tea soil

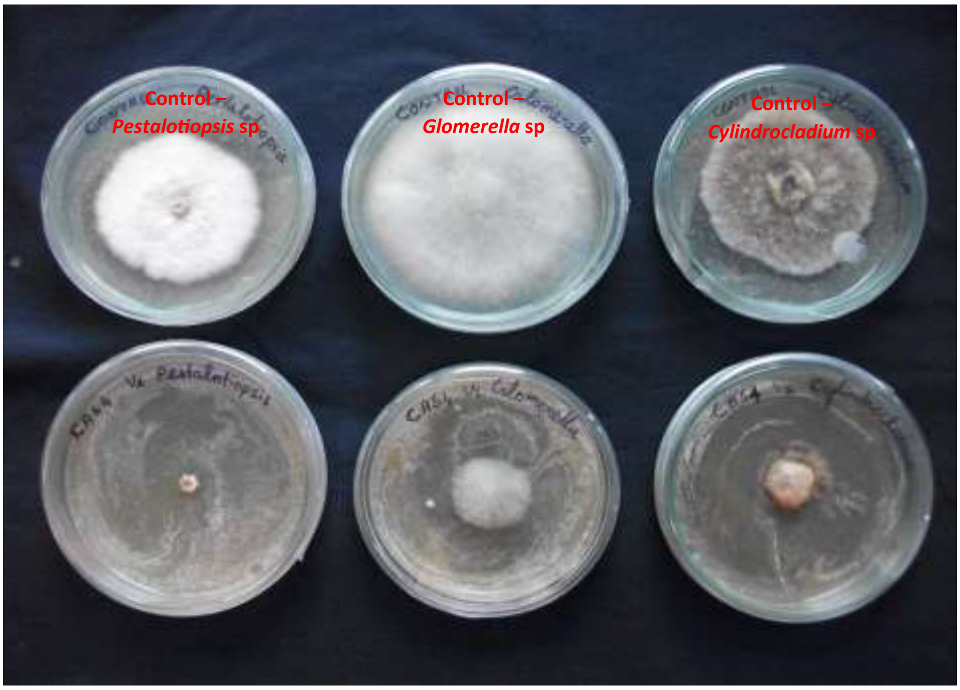

Fig: 2 Actinobacteria effectively inhibiting the tea foliar pathogens

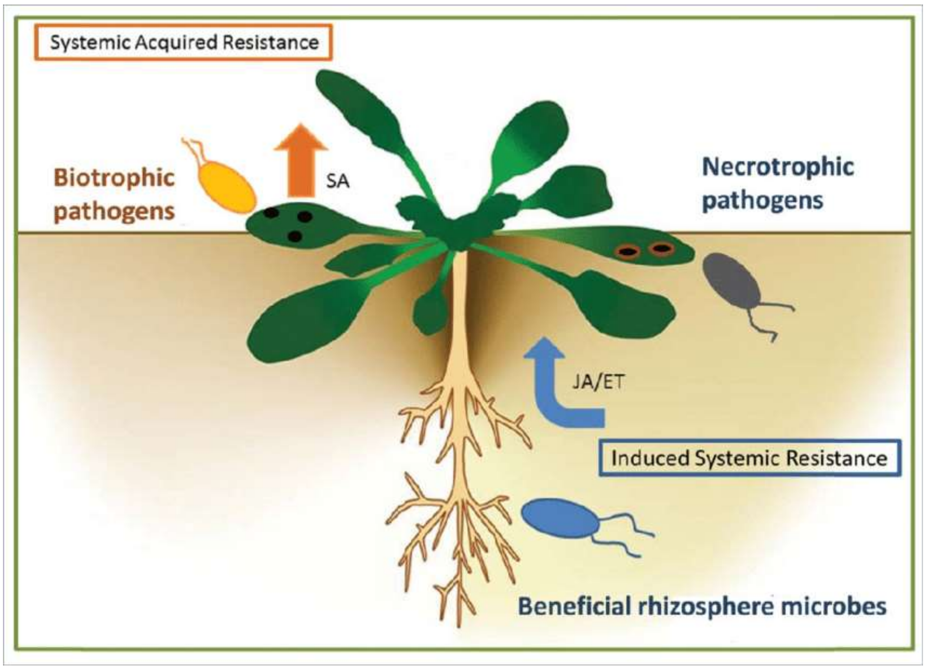

Fig: 3 Plant defense mechanism (Source from (Chen et al., 2014))

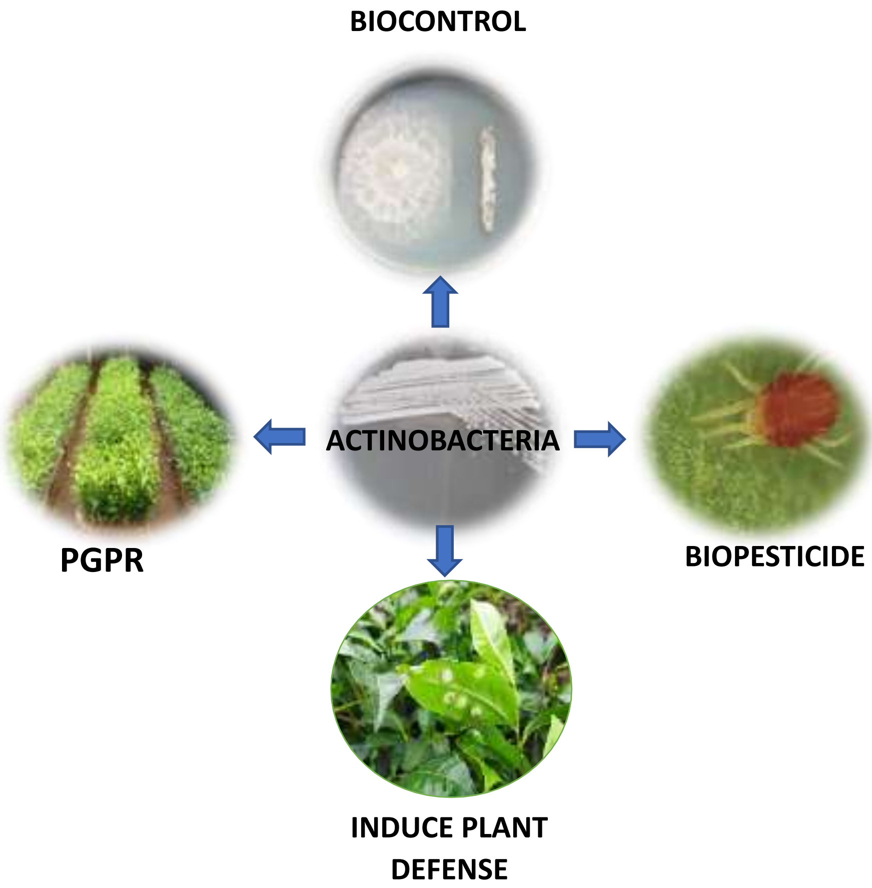

Fig: 4 Role of actinobacteria in tea ecosystem

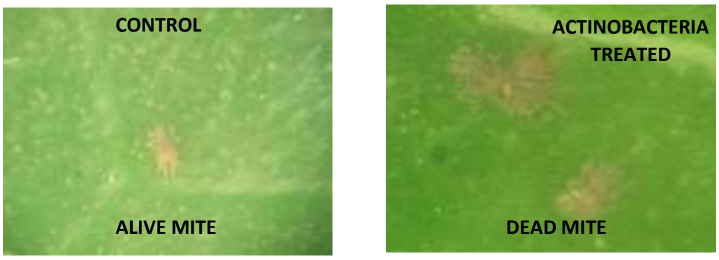

Fig: 5 Acaricidal activity of actinobacteria against red spider mite in tea

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