Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(1): 637-644

Received: 17-11-2018
Accepted: 20-12-2018

**Dr. K Yamunarani**
Assistant Professor, Plant Pathology, Agricultural College and Research Institute Eachangkottai, Tamil Nadu, India

**Dr. A Kalyana Sundaram**
Associate Professor (Ag. Ento.), Agricultural College and Research Institute Eachangkottai, Tamil Nadu, India

**Dr. M Pandiyan**
Dean, Agricultural College and Research Institute Eachangkottai, Tamil Nadu, India

**Correspondence**
**Dr. K Yamunarani**
Assistant Professor, Plant Pathology, Agricultural College and Research Institute Eachangkottai, Tamil Nadu, India

# Streptomycetes as a potential biocontrol agent

**Dr. K Yamunarani, Dr. A Kalyana Sundaram and Dr. M Pandiyan**

**Abstract**
Synthetic fungicides are often able to effectively control plant diseases, but some fungicides result in serious environmental and health problems. Therefore, there is growing interest in discovering and developing new, improved fungicides based on natural products as well as introducing alternative biocontrol agents to manage plant diseases. *Streptomyce*s bacteria appear to be promising biocontrol agents against a wide range of phytopathogenic fungi, which is not surprising given their ability to produce various bioactive compounds. This review provides insight into the biocontrol potential of various S*treptomyces* spp. Studies clearly show that *Streptomyces* spp. have the potential to be used as highly effective biocontrol agents against many fungal and bacterial disease.

**Keywords:** *Streptomyces*, biocontrol agents, biological control

## Introduction

*Streptomyces* is the largest genus of the phylum *Actinobacteria* which consists of a group of Gram-positive, aerobic, non-motile, catalase positive, and non-acid-fast bacteria with a filamentous form that resembles fungi (Flardh and Buttner, 2009; Hasani *et al*., 2014) [14, 38]. Currently, over 700 species of *Streptomyces* have been identified and these bacteria have relatively large genomes of approximately 8–9 Mbp in size with a high GC content of more than 70% (Wu *et al*., 2005; Hasani *et al*., 2014; Ser *et al*., 2015c) [114, 38, 103]. The predominant character of *Streptomyces* morphology is formation of thin strands of mycelium with spiral spore chains. Streptomycetes have a life cycle unique among bacteria. It consists of two phases vegetative and the sporogenous. When these organisms are grown on an adequate solid medium, the spores germinate and grow. Later, the germ tube grows and forms a mat of hyphae firmly attached to the solid surface. This represents the substrate or vegetative mycelium. Subsequently, when the nutritional conditions start to be adverse for the vegetative growth, specialized aerial hyphae arise on the top of the mycelium; this mycelium forms chains of three to many spores called sporophores at maturity. They are formed by formation of cross-walls in the multinucleate aerial filaments followed by separation of individual cells.

When grown in medium, streptomycete colonies form a discrete and lichenoid, leathery or butyrous colonies. Initially, the colonies are relatively smooth surfaced, but later they develop a weft of aerial mycelium that may appear floccose, granular, powdery, or velvety. Streptomycetes produce a wide variety of pigments responsible for the color of the vegetative and aerial mycelia. Colored diffusible pigments may also be formed. The vegetative mycelium is constituted by thin hyphae (0.5-2 µm in diameter) that often lack cross-walls and are extensively branched. Depending on the temperature, the pH and the age of culture the substrate mycelium can show numerous colors and soluble pigments: blue, dark green, red, and violet.

Streptomycetes, which are abundant in soil, are believed to play a major role in composting the organic matter. The members of *Streptomyces* are well-known for their ability to produce a variety of bioactive compounds. *Streptomyces* strains also have important applications in the agricultural field through their biological control potential against phytopathogens, particularly phytopathogenic fungi. The production of most antibiotics is species specific, and these secondary metabolites are important for *Streptomyces* species in order to compete with other microorganisms that come in contact.

## Streptomycetes in soil and their relationship with plant roots

The advantages of *Streptomyces* spp. include their ability to colonize plant root surfaces, survive in various types of soil and also produce spores which allow them to survive longer and in various extreme conditions (Gonzalez-Franco and Robles-Hernandez, 2009; Ningthoujam *et al*., 2009) [29].

Streptomycetes are found to colonize rhizosphere, enter the root tissues and establish endophytic lifestyle with plants (Cao *et al.*, 2004) [118]. Actinomycetes can occur in the plant rhizosphere soil and exercise an antagonistic and competitive effect on the microbial communities. They have the ability to produce active compounds, such as antifungal and antibacterial antibiotics or plant growth regulators (PGRs), that have been developed for agricultural uses (Suzuki *et al*. 2000) [100]. They have also been used as commercially formulated biocontrol agents of plant diseases such as *Streptomyces griseoviridis* cells used to protect crops against infections by *Fusarium* spp. and *Alternaria* spp. Due to production of a wide number of antifungal compounds and chitinase (Mahadevan and Crawford, 1997; Taechowisan *et al*., 2003a) [119, 101], the ability of some streptomycete strains to inhibit plant pathogens and therefore act as promising biological control agents. Some strains were screened and characterized for their activity against soil-borne pathogens. The mode action of Streptomycetes as a potential biocontrol agent is discussed below

**Antibiosis**

Streptomycetes are the largest antibiotics-producing genus in the microbial world. *Streptomyces* species exhibit biocontrol activity that correlates with their production of antibiotics (Rothrock & Gottlieb 1984; Hwang *et al*., 1994; Raatikainen *et al*., 1994) [84, 40, 74]. Streptothricin, actinomycin and streptomycin were the first discovered antibiotics produced by *Streptomyces* spp. (Waksman, 1943; Waksman and Tishler, 1942) [111]. From 1950s to 1970s started the screening of streptomycetes for antibiotics production and a wide number of compounds were found and characterized, example - novobiocin, vancomycin, tetracycline, nystatin (Hopwood, 2007) [39]. They have antibacterial and antifungal activities (Hopwood, 2007) [39]. *Streptomyces violaceusniger* YCED9 was an isolate from a British soil, exhibited biocontrol activity against a variety of plant pathogenic fungi. The strain produces three antifungal antibiotics *viz*., nigericin, geldanamycin and a complex of polyenes that includes guanidylfungin a (Trejo- Estrada *et al*., 1998) [106,]. Anti-Fusarium Activity (AFA) (Trejo-Estrada *et al*., 1998) [106]. Growth and pathogenesis of *R. solani* and *S. homeocarpa* were reduced by the presence of the nigericin produced by YCED9.

The antifungal potential of extracellular metabolites from *Streptomyces* against some fungi was previously reported (Rothrock and Gottlieb, 1984; El-Abyad *et al*., 1993; Chamberlain and Crawford, 1999; Joo, 2005; Fguira *et al*., 2005) [84, 19, 26]. It has been reported that *Streptomyces violaceusniger* G10 showed a strong antagonism toward *F. oxysporum* f.sp. *cubense* by producing extracellular antifungal metabolites. Validamycin a (VMA) is an aminoglucoside antibiotic produced by *Streptomyces hygroscopicus* var. *limoneus*. VMA effectively controls rice sheath blight caused by *Rhizoctonia solani* (Wakae and Matsuura, 1975) [110].

The antibiotic Oligomycin A was first isolated from *Streptomyces diastatochromogenes* and was found to be active against several other phytopathogenic fungi in such as *Magnoporthe oryzae*, *Botrytis cinerea*, *Cladosporium cucumerinum*, *Colletotrichum lagenarium*, *Phytophthora capsici*, *Alternaria alternata*, and *Aspergillus niger* (Smith *et al*., 1954; Kim *et al*., 1999; Yang *et al*., 2010) [99, 46, 117]. Oligomycin A's ability to control the development of rice blast was evaluated in the greenhouse and the results showed that rice plants treated with Oligomycin A (50 µg/mL) had reduced lesions. When the concentration of Oligomycin A was increased up to 500 µg/mL, the rice plants did not show any rice blast disease symptoms (Kim *et al*., 1999) [46].

Rapamycin also known as Sirolimus was initially isolated from *Streptomyces hygroscopicus* (Sehgal *et al*., 1975; Sehgal, 1998) [88, 89]. Rapamycin and Pyrroles are potent antifungal agent found to be effective against many fungus and are also commonly found in various *Streptomyces* species (Robertson and Stevens, 2014; Ser *et al*., 2015b, 2016b,c; Tan *et al*., 2015; Awla *et al*., 2016) [77, 90, 91, 4].

An antifungal antibiotic produced by *Streptomyces koyangensis* inhibited the growth of *Pyricularia oryzae* and *Rhizoctonia solani*. Under greenhouse conditions, the antibiotic suppressed blast disease in rice plants (Lee *et al*., 2005) [56]. VOCs produced by *Streptomyces philanthi* inhibited mycelial growth of rice pathogenic fungi such as *Rhizoctonia solani*, *Pyricularia grisea*, *Bipolaris oryzae* and *Fusarium fujikuroi* (Boukaew *et al*., 2014) [6]. Culture filtrates of UCR3-16 showed significant inhibition against the fungal pathogens. The antifungal compounds present in the culture filtrates must be heat labile as antagonistic activity was lost when filtrates were sterilized. Prapagdee *et al*. (2008) [72]

**Cell wall-hydrolysing enzymes**

It has been reported that antifungal mechanism of *Streptomyces* has been attributed to the action of hydrolytic enzymes such as chitinase, β-1, 3-glucanase, chitosanase, and protease (De Boer *et al*., 1998; Wang *et al*., 1999; Wang *et al*., 2002; Chang *et al*., 2007) [17, 112, 113]. *Streptomyces violaceusniger* YCED9 produced the extracellular fungal cell wall-hydrolysing enzymes chitinase and β-1,3-glucanase (Trejo- Estrada *et al*., 1998) [106]. The antagonistic activity of *Streptomyces* to fungal pathogens was usually related to the production of antifungal compounds (Trejo-Estrada *et al*., 1998; Ouhdouch *et al*., 2001; Fguira *et al*., 2005; Taechowisan *et al*., 2005) [106, 26] and extracellular hydrolytic enzymes (Valois, 1996; Trejo-Estrada *et al*., 1998, Mahadevan and Crawford,1999; Mukherjee and Sen 2006) [64]. Chitinase and β -1,3-glucanase are considered to be important hydrolytic enzymes in the lysis of fungal cell walls of *Fusarium oxysporum*, *Sclerotinia minor*, and *Sclerotium rolfsii* (Singh *et al*., 1999; El-Tarabily *et al*.,2000) [98]. The production of chitinase and β-1,3 glucanase enzymes by *Streptomyces* was related to fungal growth inhibition and the biological control of fungal pathogens was possible because of the ability of *Streptomyces* to degrade fungal cell walls (Valois, 1996; Mahadevan and Crawford,1997;El-Tarabily *et al*.,2000; Mukherjee and Sen 2006) [64].

Hyperparasitism may occur due to the release of extracellular lytic enzymes such as chitinases and glucanases from the biocontrol agent (Gonzalez-Franco and Robles-Hernandez, 2009; Palaniyandi *et al*., 2013) [29]. It has also been shown that *Streptomyces* spp. are capable of producing chitinases and glucanases which play important roles in destruction of fungal cell walls (Mahadevan and Crawford, 1997; El-Tarabily *et al*., 2000; Gonzalez-Franco and Robles-Hernandez, 2009) [29].

UCR3-16 produced major fungal cell wall degrading enzymes such as chitinase, and glucanase, lipase and pro-tease.

Chitinase producing *Streptomyces vinaceusdrappus* inhibited mycelial growth of rice fungal pathogens, *Curvularia oryzae*, *Pyricularia oryzae*, *Bipolaris oryzae* and *Fusarium oxysporum* (Ningthoujam *et al*., 2009) [66]. Chitinase and β1,3-glucanase produced by *Streptomyces* sp. 385 lysed cell walls of *Fusarium oxysporum* (Singh *et al*.,1999) [98].

**Plant growth promotion by growth regulators**

Bacteria of the genus *Streptomyces* are common inhabitants of rhizosphere and act as beneficial microorganisms for plant growth and development (Gopalakrishnan *et al.*, 2014; Tokala *et al.*, 2002a) [32, 104]. In addition to their ability to inhibit plant pathogens, some actinomycetes are also known to form close associations with plants, colonize their internal tissues without causing disease symptoms, and promote their growth (Kunoh 2002) [50]. Streptomycetes have been little investigated as Plant Growth Promoting Bacteria (PGPB). Some works were carried during the 1980 to 1990 at the University of Milan and only recently, the interest on streptomycete beneficial effects on plant growth is gaining increased attention; their positive effects on root nodulation in Pea plants were observed (Tokala *et al.*, 2002b) [104], as well as the increase of fresh and dry weight and length of roots and shoots of bean.

The main modes of action involved in the PGP activity are the synthesis of the hormone indole-3-acetic acid (IAA) and the improvement of iron and phosphate availability for the plant in the rhizosphere. Here, a collection of 200 endophytic streptomycetes was analyzed for these PGP traits. IAA was produced by almost all isolates, as commonly reported for bacteria, which inhabit the rhizosphere (Patten and Glick, 1996). *Streptomyces* have been reported for the PGP activity. Especially, they are known to synthesize the hormone auxin and improve the availability of iron (Imbert *et al.*, 1995) and phosphate in the rhizosphere (Sousa *et al.*, 2008).

Several studies have reported plant growth promoting activities of endophytic actinomycetes on tomato seedlings (Coa *et al*. 2005; El-Tarabily *et al*. 2008) [14, 23]. The enhancement of plant growth by the strains *Streptomyces* sp. CA-2 and AA-2 could contribute to the protection of the plant against pathogenic fungi as previously reported with other *Streptomyces* spp. by Xiao *et al*. (2002) [115]. The growth promoting effect of the two isolates of actino-mycetes seemed to be correlated with root enhancement and shoot production. In the same cases, where the strains were strictly endo-phytic, such effects were generally attributed to PGRs production (Shi *et al*. 2009). El-Tarabily *et al*. (2008) [31] reported that the involvement of PGRs could not only help the seedlings to grow better but could also help the host to compensate for tissue damage caused by the pathogen agent. Several endophytic bacteria have been reported to produce PGRs *in vitro* and to promote the growth of seedlings (Kuklinsky-Sobral *et al*. 2004; Goudjal *et al*. 2013) [48, 34].

Actinomycetes have been reported to play an important role in the plant rhizosphere by secreting a wide range of antimicrobial products thus preventing growth of common root pathogens. Actinomycetes, especially *Streptomyces*, are prolific producers of secondary metabolites, and are being used as BCAs to control soil-borne and seed borne diseases of plants (Rosales and Mew, 1997) [78]. Antagonistic activity may be due to production of antifungal metabolites volatile compounds (Khamna *et al*., 2010; Boukaew *et al*., 2014) [7, 45] and cell wall degrading enzymes such as chitinase, glucanase. Actinomycetes, especially *Streptomyces* spp. accounting for an abundant percentage of the soil microflora, are particularly effective colonizers of plant root systems and are able to endure unfavourable growth conditions by forming spores (Alexander, 1997) [1]. Despite their preliminary track record as BCAs and plant growth promoting (PGP) activities, *Streptomyces* spp. have been scarcely reported in the literature. Some reports exist for their ability to solubilize phosphate, and production of indole acetic acid (IAA), siderophores, 1-aminocyclopropane-1-carboxylic acid (ACC) deaminase and cell wall degrading enzymes such as chitinase, glucanase and protease (Singh *et al*., 1999; Gopalakrishnan *et al*., 2011; Jog *et al*., 2012; Sadeghi *et al*., 2012; Passari *et al*., 2015; Qin *et al*., 2015) [98, 85, 70].

**Siderophores**

It is well known that microbial siderophores play an important role in plant growth as demonstrated by the effect on root and shoot biomass and length of rice plants, as consequence of the inoculation of a siderophore-producing streptomycete, the growth promoting effect is widely attributed to factors, such as siderophore production and phosphate solubilization (Hamdali *et al*. 2008) [37] and nitrogen fixation (Ribbe *et al*. 1997) [76]. Streptomycetes also showed promising PGP activity because of the frequent production of indole-3-acetic acid (IAA) and siderophores, although they only rarely solubilized phosphate. These traits are very common among the microorganisms that inhabit the rhizosphere and in some works the PGP activity showed *in vitro* was confirmed *in planta*. For instance, rice plants inoculated with siderophore-producing *Streptomyces* sp. enhanced plant growth and significantly increased root and shoot biomass.

**Volatile Substances**

*Streptomyces* are able to produce useful volatile substances with molecular weight of <300 Da, low polarity, and high vapor [Pichersky *et al*., 2006]. Bacterial volatile substances have been successfully recognized by gas chromatography comb with pressure mass spectrometry (GC-MS). More than 120 various substances have been recognized in actinomycetes including Alkanes, Alkenes, Alkens, Alcohols, Ketones, Aldehydes, Acids and Esters. Volatile substances derived from *Streptomyces sp*. and other species of actinomycetes prevent mycelium growth and inhibit spore germination of different fungi (Kai *et al*., 2008, Anitha *et al*., 2010). Cyclohexanol, decanol, 2-ethyl-1-hexanol, nonanol, benzothiazole dimethyl trisulfide are important compounds that inhibit spore germination and mycelium growth of *Sclerotinia sclerotiorum* (Fernandoa *et al*., 2005) [25] Volatile substances of *Streptomyces griseus* reduces spore germination of *Gleosporium aridum* which subsequently lead to faster formation of sclerotinia of *R.solani* and *Sclerotinia cepivorum.* Volatile substances of *Streptomyces platensis* also reduced the growth of *R.solani*, *Sclerotinia sclerotiorum* and *Botrytis cinerea* and reduced the disease level of leaf blight, seedling blight in rice, leaf blight in oilseed rape, and fruit rot in strawberry (McCain., 1966, Wan *et al*., 2008) [62, 37]. In another research, effects of volatile substances of *Streptomyces globisporus* were examined on spore germinating and mycelium growth *Penicillium italicum* and infected fruits. Among 41 volatile substances of this bacterium, Dimethyl disulfide and Dimethyl trisulfide have high inhibiting effects against fungus (Li *et al*., 2010) [117]. Volatile substances of various species of *Streptomyces*, have high potential in biological control.

**Streptomyces in biological control**

Biological control is a nonchemical measure that has been reported in several cases to be as effective as chemical control (Dik and Elad, 1999; Elad and Zimand, 1993) [20, 21]. The excessive use of chemical fungicides in agriculture has led to deteriorating human health, environmental pollution and development of pathogen resistance to fungicide. Microbial antagonists are widely used for the biocontrol of fungal plant diseases due to lack of induction of pathogen resistance and reduction of chemical fungicide residues in soil. Mukherjee *et al.,* (1995) has reported *Streptomyces* spp. are well known biocontrol agents that inhibit several plant pathogenic fungi (El-Tarabily *et al*., 2000; Errakhi *et al*., 2007; Joo, 2005; Xiao *et al*., 2002) [115, 24, 43]. The role of actinomycetes in the biocontrol of soil-borne plant pathogens has been demonstrated against various pathogens such as *Fusarium* spp. (Sabaou and Bounaga 1987; Gopalakrishnan *et al*. 2011) [82], *Phytophthora* spp. (Shahidi Bonjar *et al*. 2006) [84], *Pythium* spp.(Hamdali *et al*. 2008) [36], *Rhizoctonia* spp. (Sadeghi *et al*. 2006) [84], and *Verticillium* spp. (Meschke and Schrempf 2010) [63]. The ability of bacteria, especially actinomycetes, to parasitize and degrade the spores of fungal plant pathogen was well established (El-Tarabily *et al*., 1997). Biocontrol of *Phytophthora cinnamomi* and root rot of *Banksia grandis* Willd. was obtained using a cellulase-producing isolate of *Micromonospora carbonacea* (El-Tarabily *et al*., 1996) and control of *Phytophthora fragariae* var. *rubi* causing raspberry root rot was suppressed by the application of actinomycete isolates that were selected for the production of β-1,3, β -1,4 and β -1,6 glucanases (Valois *et al*., 1996).

The genus *Streptomyces* was well known as antifungal biocontrol agents that inhibit several plant pathogenic fungi (El-Tarabily *et al*., 2000; Xiao *et al*., 2002; Joo, 2005; Errakhi *et al*., 2007) [115, 43]. *Streptomyces* was important soil microorganism and well known producers of antibiotics and extracellular enzymes (Crawford *et al*., 1993) [16]. *Streptomyces violaceusniger* SRA14 had a strong antagonistic activity to *Colletotrichum gloeosporioides*. Analysis of the 16S rDNA gene sequences showed that the SRA14 was closely related to *Streptomyces hygroscopicus* (98 per cent similarity). The non-pathogenic strains of *Streptomyces* was applied to control scab of potato (*Solanum tuberosum* L.) caused by *Streptomyces scabies* (Ryan and Kinkel, 1997; Neeno-Eckwall and Schottel, 1999) damping-off of tomato (Sabaratnam and Traquair, 2002) and *Sclerotinia* basal drop.

Mycoparasitism involves the production of extracellular enzymes that hydrolyse the fungal cell walls, whereas antibiosis involves the production of secondary metabolites in the rhizosphere which inhibits the growth and differentiation of fungal pathogens. Members of the genus *Streptomyces* strains YCED9 and WYEC108 were antifungal biocontrol agents (Crawford *et al*., 1993; Crawford 1996) [15, 16]. You *et al*., 1996 have observed increases in streptomycetes population in soil after enrichment with organic matter. This might explain the enhanced antagonism or suppressiveness of soil sometimes seen after organic enrichment (Malajczuk 1983; van Driesche and Bellows 1996). The *Streptomyces* strains have been shown to control *in vivo* lettuce damping off caused by *Pythium ultimum* (Crawford *et al*., 1993) [16], which might be explained by the fact that the lettuce was grown in a rich potting soil. *Streptomyces* were also studied against *Pythium* seed and root rot, *Phytophthora* root rot (Xiao *et al.*, 2002) [115], *Rhizoctonia*; El-Tarabily *et al*., 2000) [21]. Several studies have reported the use of actinomycete strains for biocontrol of *Rhizoctonia solani* damping-off (Coa *et al*.2004; Chung *et al*. 2005; Sadeghi *et al*. 2006; Patil *et al*. 2010) [84]. In addition, commercial products to control crop damping-off, such as Mycostop (*Streptomyces griseovirid* is strain K61) and Actinovate (*Streptomyces lydicus* strain WYEC108), have been registered.

**Conclusion**

This review explores an implementation of antagonistic actinomycetes as plant growth promoters and biocontrol agents in combined way, which make them competitive compared to other commercial biocontrol agents. They are excellent candidates as biocontrol agents for the biological control of devastating plant disease. In order to establish *Streptomyces* as biocontrol agents, more field experiments should be conducted to determine their control efficacy under different environmental conditions. Additionally, more work is needed to optimize isolation, formulation and application methods of *Streptomyces* in order to fully maximize their potential as effective biocontrol agents. As actinomycetes especially *Streptomyces* spp. produce spores that help dissemination and confer resistance to many adverse conditions, they can be promising agents for development as novel biofertil-izers and biocontrol agents.

**References**


1. Alexander M. Introduction to Soil Microbiology, 2nd ed. Malabar, Krieger Publishing 1997.
2. Ariffin H, Abdullah N, Kalsom MSU, Shirai Y, Hassan MA. Production and characterisation of cellulase by Bacillus pumilus EB3. Int. J. Eng. Technol. 2006; 3:47-53.
3. Ara I, Bukhari NA, Aref N, Shinwari MM, Bakir M. Antiviral activities of streptomycetes against tobacco mosaic virus (TMV) in Datura plant: evaluation of different organic compounds in their metabolites. Afr. J. Biotechnol. 2014; 11:2130–2138.
4. Awla HK, Kadir J, Othman R, Rashid TS, Wong M.-Y. Bioactive compounds produced by Streptomyces sp. isolate UPMRS4 and antifungal activity against Pyricularia oryzae. Am. J. Plant Sci. 2016; 7:1077–1085.
5. Bastidas RJ, Shertz CA, Lee SC, Heitman J, Cardenas ME. Rapamycin exerts antifungal activity in vitro and in vivo against Mucor circinelloides via FKBP12-dependent inhibition of Tor. Eukaryot. Cell. 2012; 11:270–281.
6. Boukaew S, Prasertsan P. Suppression of rice sheath blight disease using a heat stable culture filtrate from Streptomyces philanthi RM-1-138. Crop Protection: 2014; 61:1–10.
7. Boukaew S, Plubrukam A, Prasertsan P, Effect of volatile substances fromStreptomyces philanthi RM-1-138 on growth of Rhizoctonia solani on rice leaf. BioControl 2013; 58:471–482.
8. Chamberlain K, DL Crawford. In vitro and vivo antagonism of pathogenic turfgrass fungi by Streptomyces hygroscopicus strains YCED9 and WYE53. J. Ind. Microbiol. Biotechnol. 1999; 23:641–6.
9. Chang WT, YC, Chen, CL Jao. Antifungal activity and enhancement of plant growth by Bacillus cereus grown on shellfish chitin wastes. Bioresour Technol. 2007; 98:1224-30.
10. Chater KF, Biró S, Lee KJ. The complex extracellular

biology of Streptomyces. FEMS Microbiol Rev. 2010; 34(2):171–98.
11. Chater KF, Genetics of differentiation in Streptomyces. Annu. Rev. Microbiol. 1993; 47:685–713.
12. Chung WC, Huang JW, Huang HC. Formulation of a soil biofungicide for control ofdamping-off of Chinese cabbage (Brassica chinensis) caused by Rhizoctonia solani. Biol Control 2005; 32:287–94.
13. Coa L, Qiu Z, You J, Tan H, Zhou S. Isolation and characterization of end ophyticStreptomyces from surface-sterilized tomato (Lycopersicon esculentum) roots. Lett Appl Microbiol. 2004; 39:425–30.
14. Coa L, Qiu Z, You J, Tan H, Zhou S. Isolation and characterization of end ophyticstreptomycetes antagonistis of Fusarium wilt pathogen from surface-sterilizedbanana roots. FEMS Microbiol Lett. 2005; 247:147–52.
15. Crawford DL. Use of Streptomyces bacteria to control plant pathogens. 1996. US. Patent No. 5527526.
16. Crawford DL, JM Lynch, JM Whipps, MA Ousley. Isolation and characterization of actinomycete antagonists of a fungal root pathogen. Appl Environ Microbiol. 1993; 59:3899-905.
17. De Boer W, PJAK Gunnewiek, P Lafeber, JD Janse, BE Spit, JW Woldendorp. Antifungal properties of chitinolytic dune soil bacteria. Soil Biol Biochem., 1998; 30:193-203.
18. de Lima Procopio RE, Da Silva IR, Martins MK, De Azevedo JL, De Araújo JM. Antibiotics produced by Streptomyces. Braz. J. Infect. Dis. 2012; 16:466–471.
19. El-Abyad MS, MA El-Sayad, AR El-Shanshoury, SM El-Sabbagh. Towards the biological control of fungal and bacterial diseases of tomato using antagonistic Streptomyces spp. Plant Soil. 1993; 149:185-95.
20. Elad Y, G Zimand. Use of Trichoderma harzianum in combination or alteration with fungicides to control cucumber (B. cineria) under commercial green house condition. Phytopathol. 1993; 42:324-332.
21. El-Tarabily K, Soliman M, Nassar A, Al-Hassani H, Sivasithamparam K, Mckenna F, *et al*. Biological control of Sclerotinia minor using a chitinolytic bacterium and actinomycetes. Plant Pathol. 2000; 49:573–583.
22. El-Tarabily KA, Nasser AH, Hardy GE, Sivaithamparam K. Plant growth promotionand biological control of Pythium aphanidermatum, a pathogen of cucumber, byendophytic actinomycetes. J Appl Microbiol 2008; 106: 13–26.
23. El-Tarabily KA, Promotion of tomato (Lycopersicon esculentum Mill.) plantgrowth by rhizosphere competent 1-aminocyclopropane-1-carboxylic aciddeaminase-producing streptomycete actinomycetes. Plant Soil 2008; 30:161–174.
24. Errakhi R, Bouton F, Lebrihi A, Barakate M. Evidence of biological control capaci-ties of Streptomyces spp. against Sclerotium rolfsii responsible for damping-offdisease in sugar beet (Beta vulgaris L.). World J Microbiol Biotechnol. 2007; 23:1503–9.
25. Fernandoa W, Ramarathnama R, Krishnamoorthyb AS, Savchuka SC. Soil Biol Biochem. 2005; 37:955–964.
26. Fguira LF, Fotso S, Ameur-Mehdi RB, Mellouli L, Laatsch H, Res Microbiol. 2005; 156:341-7.
27. Flärdh K, Buttner MJ. Streptomyces morphogenetics: dissecting differentiation in a filamentous bacterium. Nat. Rev. Microbiol. 2009; 7:36–49.
28. Froyd J, Paget C, Guse L, Dreikorn B, Pafford J. Tricyclazole: a new systemic fungicide for control of Pyricularia oryzae on rice. Phytopathology 1976; 6:1135–1139.
29. Gonzalez-Franco C, Robles-Hernandez R. Actinomycetes as biological control agents of phytopathogenic fungi. Tecnociencia Chihuahua. 2009; 3:64–73.
30. Goodfellow M, Simpson KE. Ecology of streptomycetes. Frontiers Appl Microbiol. 1987; 2:97–125.
31. Gopalakrishnan S, Pande S, Sharma M, Humayun P, Keerthi Kiran BK, Sandeep D, *et al*. Evaluation of actinomycete isolates obtained from herbal vermicompost for thebiological control of Fusarium wilt of chickpea. Crop Prot. 2011; 30:1070–8.
32. Gopalakrishnan S, Vadlamudi S, Bandikinda P, Sathya A, Vijayabharathi R, Rupela O, *et al*. Evaluation of Streptomyces strains isolated from herbal vermicompost for their plant growth-promotion traits in rice. Microbiol. Res. 2014; 169:40–48.
33. Gopalakrishnan S, Pande S, Sharma M, Humayun P, Kiran BK, Sandeep D, *et al*. Evaluation of actinomycete isolatesobtained from herbal vermicompost for the biological control of Fusarium wiltof chickpea. Crop Prot. 2011; 30:1070–1078.
34. Goudjal Y, Toumatia O, Sabaou N, Barakate M, Mathieu F, Zitouni A. Endophyticactinomycetes from spontaneous plants of Algerian Sahara: indole-3-acetic acidproduction and tomato plants growth promoting activity. World J Microbiol Biotechnol, 2013.
35. Grissbuhler H, Brenneisen P, Fisher HP. Frontiers in crop production: chemicalresearch objectives. Science 1982; 217:505–10.
36. Hamdali H, Hafidi M, Virolle MJ, Ouhdouch Y. Growth promotion and protectionagainst damping-off of wheat by two rock phosphate solubilizing actinomycetesin a P-deficient soil under greenhouse conditions. Appl Soil Ecol 2008; 40:510–7.
37. Hamdali H, Hafidi M, Virolle MJ, Ouhdouch Y, Growth promotion andprotection against damping-off of wheat by two rock phosphate solubilisingactinomycetes in a P-deficient soil under greenhouse conditions. Appl. Soil Ecol. 2008; 40:510–517.
38. Hasani A, Kariminik A, Issazadeh K. Streptomycetes: characteristics and their antimicrobial activities. Int. J. Adv. Biol. Biomed. Res. 2014; 2:63–75.
39. Hopwood DA: Streptomyces in Nature and Medicine: The Antibiotic Makers. Oxford University Press, New York, NY. 2007.
40. Hwang BK, SJ Ahn, SS Moon. Production, purification and antibiotic activity of the antibiotic nucleoside, tubercidin, produced by Streptomyces violaceusniger. Can. J Bot. 1994; 72:480-485.
41. Jog R, Nareshkumar G, Rajkumar S, Plant growth promoting potential andsoil enzyme production of the most abundant Streptomyces sp. from wheat rhizosphere. J. Appl. Microbiol. 2012; 113:1154–1164.
42. Johnson G, Sangchote S, Cooke A. Control of stem end rot (Dothiorella dominicana) and other postharvest diseases of mangoes (cv. Kensington Pride) during short- and long-term storage. Trop. Agric. 1990; 67:183–187.
43. Joo GJ. Production of an anti-fungal substance for biological control of Phytophthora capsici causing phytophthora blight in red-peppers by Streptomyces halstedii. Biotechnol Lett. 2005; 27:201-5.

44. Kashif MD, Kumar V, Kalpana VN, Devi Rajeswari V. Phylogenetic diversity and biological activity of actinomycetes isolated from Gulf of Mannar, Tamil Nadu, India. Pharm. Lett. 2016; 8:16–24.
45. Khamna S, Yokota A, Peberdy JF, Lumyong S, Indole-3-acetic acidproduction by Streptomyces sp: isolated from some Thai medicinal plantrhizosphere soils. Eur Asia J. BioSci. 2010; 4:23–32.
46. Kim BS, Moon SS, Hwang BK. Isolation, identification, and antifungal activity of a macrolide antibiotic, oligomycin A, produced by Streptomyces libani. Can. J Bot. 1999; 77:850–858.
47. Kino T, Hatanaka H, Hashimoto M, Nishiyama M, Goto T, Okuhara M., *et al*. FK-506, a novel immunosuppressant isolated from a Streptomyces. I. fermentation, isolation, and physico-chemical and biological characteristics. J. Antibiot. 1987; 40:1249–1255.
48. Kuklinsky-Sobral J, Araujo WL, Mendes R, Geraldi IO, Pizzirani-Kleiner AA, AzevedoJL. Isolation and characterization of soybean-associated bacteria and their poten-tial for plant growth promotion. Environ Microbiol 2004; 6:1244–51.
49. Kumar PS, Duraipandiyan V, Ignacimuthu S. Isolation, screening and partial purification of antimicrobial antibiotics from soil Streptomyces sp. SCA 7. Kaohsiung J. Med. Sci. 2014; 30:435–446.
50. Kunoh H. Endophytic actinomycetes: attractive biocontrol agents. J Gen Plant Pathol. 2002; 68:249–52.
51. Kwon JH, Kim J, Kim WI. First report of Rhizopus oryzae as a postharvest pathogen of apple in Korea. Mycobiology 2011; 39:140–142.
52. Lahdenpera ML, Simon E, Uoti J. Mycostop – a novel biofungicide based on Strepto-myces bacteria. In: Beemster ABR, Bollen GJ, Gerlagh M, Ruissen MA, SchippersB, Tempel A, editors. Biotic interactions and soil-borne disease. Amsterdam: Elsevier, 1991, 258–63.
53. Lee CH, Kim BJ, Choi GJ, Cho KY, Yang H, Shin C, *et al*. Streptomyces with antifungal activity against rice blast causing fungus, Magnaporthe grisea. J. Microbiol. Biotechnol. 2002; 12:1026–1028.
54. Lee LH, Zainal N, Azman AS, Eng SK, Ab Mutalib NS, Yin WF, *et al*. Streptomyces pluripotens sp. nov., a bacteriocin-producing streptomycete that inhibits meticillin-resistant Staphylococcus aureus. Int. J. Syst. Evol. Microbiol. 2014; 64:3297–3306.
55. Lee LH, Zainal N, Azman AS, Eng SK, Goh BH, Yin WF, *et al*. 2014b). Diversity and antimicrobial activities of actinobacteria isolated from tropical mangrove sediments in Malaysia. Sci. World J. 2014, 1–14.
56. Lee JY, Lee JY, Moon SS, Hwang BK, Isolation and antifungal activity of4-phenyl-3-butenoic acid from Streptomyces koyangensis strain VK-A60. J.Agric. Food Chem. 2005; 53:7696–7700.
57. Li Q, Jiang Y, Ning P, Zheng L, Huang J, Li G. *et al*. Suppression of Magnaporthe oryzae by culture filtrates of Streptomyces globisporus JK-1. Biol. Control. 2011; 58:139–148.
58. Mahadevan B, Crawford DL. Properties of the chitinase of the antifungal biocontrol agent Streptomyces lydicus WYEC108. Enzyme Microb. Technol. 1997; 20:489–493.
59. Mahadevan A. Physiology of host - parasite interaction. Today and Tomorrow Pub., New Delhi. 1999, 167-171.
60. Mahadevan B, DL Crawford. Properties of the chitinase of the antifungal biocontrol agent Streptomyces lydicus WYEC108. Enzyme. Microb. Technol. 1997; 20:489-93.
61. Malajczuk N. Microbial antagonism to Phytophthora. In Phytophthora, Its Biology, Taxonomy, Ecology and Pathology. D.C. Erwin, S. Bartnicki-Garcia and P.H. Tsao, eds. American Phytopathological Society, St. Paul. U.S.A. ISBN 0-890-54050-0.
62. McCain A. Phytopathology. 1983; 56:150-156.
63. Meschke H, Schrempf H. Streptomyces lividans inhibits the proliferation of the fungus Verticillium dahliae on seeds and roots of Arabidopsis thaliana. Microb Biotechnol. 2010; 3:428–43.
64. Mukherjee G, SK Sen. Purification, Characterization, and antifungal activity of chitinase from Streptomyces venezuelae P10. Curr. Microbiol. 2006; 53:265-9.
65. Neeno-Eckwall EC, JL Schottel. Occurrence of antibiotic resistance in the biological control of potato scab disease. Biol. Cont. 1999; 16:199–208.
66. Ningthoujam S, Sanasam S, Tamreihao K, Nimaich S. Antagonistic activities of local actinomycete isolates against rice fungal pathogens. Afr. J. Microbiol. Res. 2009; 3:37–742.
67. Ningthoujam DS, Sanasam S, Tamreihao K, Nimaichand S, Antagonisticactivities of local actinoimycete isolates against rice fungal pathogens. Afr. J.Microbiol. Res. 2009; 3:737–742.
68. Ouhdouch Y, M Barakate, C Finance. Actinomycetes of Moroccan habitats: Isolation and screening for antifungal activities. Eur. J. Soil Biol. 2001; 37:69-74.
69. Palaniyandi SA, Yang SH, Zhang L, Suh JW. Effects of actinobacteria on plant disease suppression and growth promotion. Appl. Microbiol. Biotechnol. 2013; 97:9621–9636.
70. Passari AK, Mishra VK, Gupta VK, Yadav MK, Saikia R, Singh BP. In vitro and in vivo plant growth promoting activities and DNA fingerprintingof antagonistic endophytic actinomycetes associates with medicinal plants. PLoS One. 2015; 10:0139468.
71. Patil HJ, Srivastava AK, Kumar S, Chaudhari BL, Arora DK. Selective isolation, eval-uation and characterization of antagonistic actinomycetes against Rhizoctoniasolani. World J Microbiol Biotechnol. 2010; 26:2163–70.
72. Prapagdee B, Kuekuluong C, Mongkolsuk S, Antifungal potential ofextracellular metabolites produced by Streptomyces hygroscopicus againstphytopathogenic fungi. Int. J. Biol. Sci. 2008; 4:330–337.
73. Qin S, Miao Q, Feng WW, Wang Y, Zhu X, Xing K, Biodiversity andplant growth promoting traits of culturable endophytic actinobacteriaassociated with Jatropha curcas L. growing in Panxi dry-hot valley soil. Appl.Soil Ecol. 2015; 93:47–55.
74. Raatikainen OJ, TH Paivinen, RT Tahvonen. HPLC separation and subsequent detection of aromatic heptaene polyenes in peat after treatment with Streptomyces griseoviridis. Pesticide Science, 1994; 41:149-154.
75. Ramesh S, Mathivanan N. Screening of marine actinomycetes isolated from the Bay of Bengal, India for antimicrobial activity and industrial enzymes. World J. Microbiol. Biotechnol. 2009; 25:2103–2111.
76. Ribbe M, Gadkari D, Meyer O. N2fixation by Streptomyces thermoautotrophicusinvolves a molybdenum-dinitrogenase and a manganese-superoxide

oxidore-ductase that couple N2reduction to the oxidation of superoxide produced fromO2by a molybdenum-CO dehydrogenase. J Biol Chem. 1997; 272:26627–33.

77. Robertson J, Stevens K, Pyrrolizidine alkaloids. Natural Prod. Rep. 2014; 31:1721–1788.
78. Rosales AM, Mew TW. Suppression of Fusarium moniliforme in rice byrice-associated antagonistic bacteria. Plant Dis. 1997; 81:49–52.
79. Rothrock CS, Gottlieb D. Role of antibiosis in antagonism of Streptomyces hygroscopicus var. geldanus to Rhizoctonia solani in soil. Can. J. Microbiol. 1984; 30:1440–1447.
80. Rothrock CS, D Gottlieb. Role of antibiosis in antagonism of S. hygroscopicus var. geldanus to Rhizoctonia solani in soil. Can. J. Microbiol. 1984; 30:1440-7.
81. Ryan AD, LL Kinkel. Inoculum density and population dynamics of suppressive and pathogenic Streptomyces strains and their relationship to biological control of potato scab. Biological Control, 1997; 10:180–186.
82. Sabaou N, Bounaga N. Actinomycètes parasites de champignons: étude des espèces, spécificité de l'action parasitaire au genre Fusarium et antagonisme dans lesol envers Fusarium oxysporum f. sp. albedinis (Killian et Maire) Gordon. Can J Microbiol. 1987; 33:445–51.
83. Sabaratnam S, Traquair JA, Formulation of a Streptomyces biocontrolagent for the suppression of Rhizoctonia damping-off in tomato transplants. Bio Control. 2002; 23:245–253.
84. Sadeghi A, Hessan AR, Askari H, Aghighi S, Shahidi Bonjar GH. Biological controlpotential of two Streptomyces isolates on Rhizoctonia solani, the causal agent of damping-off of sugar beet. Pak J Biol Sci. 2006; 9:904–10.
85. Sadeghi A, Karimi E, Dahaji PA, Javid MG, Dalvand Y, Askari H. Plantgrowth promoting activity of an auxin and siderophore producing isolate ofStreptomyces under saline soil conditions. World J. Microbiol. Biotechnol. 2012; 28:1503–1509.
86. Schöller CEG, Gürtler H, Pedersen R, Molin S, Wilkins K. Journal of Agricultural and Food Chemistry. 2002; 50:2615-2621.
87. Schumacher RW, Talmage SC, Miller SA, Sarris KE, Davidson BS, Goldberg A. Isolation and structure determination of an antimicrobial ester from a marine sediment-derived bacterium. J. Nat. Prod. 2003; 66:1291–1293.
88. Sehgal SN, Rapamune (RAPA, rapamycin, sirolimus): mechanism of action immunosuppressive effect results from blockade of signal transduction and inhibition of cell cycle progression. Clin. Biochem. 1998; 31:335–340.
89. Sehgal S, Baker H, Vézina C. Rapamycin (AY-22,989), a new antifungal antibiotic. II. Fermentation, isolation and characterization. J. Antibiot. 1975; 28:727–732.
90. Ser HL, Ab Mutalib NS, Yin WF, Chan KG, Goh BH, Lee LH. Evaluation of antioxidative and cytotoxic activities of Streptomyces pluripotens MUSC 137 isolated from mangrove soil in Malaysia. Front. Microbiol. 2015a; 6:1398.
91. Ser HL, Law JWF, Chaiyakunapruk N, Jacob SA, Palanisamy UD, Chan KG, *et al*. Fermentation conditions that affect clavulanic acid production in Streptomyces clavuligerus: a systematic review. Front. Microbiol. 2016a; 7: 522.
92. Ser HL, Palanisamy UD, Yin WF, Chan KG, Goh BH, Lee LH. Streptomyces malaysiense sp. nov.: a novel Malaysian mangrove soil actinobacterium with antioxidative activity and cytotoxic potential against human cancer cell lines. Sci. Rep. 2016b; 6:24247.
93. Ser HL, Palanisamy UD, Yin WF, Malek SNA, Chan KG, Goh BH, *et al*. Presence of antioxidative agent, Pyrrolo [1, 2-a] pyrazine-1, 4-dione, hexahydro-in newly isolated Streptomyces mangrovisoli sp. nov. Front. Microbiol. 2015b; 6:854.
94. Ser HL, Tan LTH, Palanisamy UD, Abd Malek SN, Yin WF, Chan KG, *et al*. Streptomyces antioxidans sp. nov., a novel mangrove soil actinobacterium with antioxidative and neuroprotective potentials. Front. Microbiol. 2016; 7:899.
95. Ser HL, Tan WS, Ab Mutalib NS, Cheng HJ, Yin WF, Chan KG, *et al*. Genome sequence of Streptomyces pluripotens MUSC 135T exhibiting antibacterial and antioxidant activity. Mar. Genomics. 2015; 24:281–283.
96. Shahidi Bonjar GH, Barkhordar B, Pakgohar N, Aghighi S, Biglary S, Rashid Farrokhi P, *et al*. Biological control of Phytophthora drechsleri Tucker, the causal agent of pistachio gummosis, under greenhouse conditions by use of actinomycetes. Plant Pathol J 2006; 5:20–3.
97. Shi Y, Lou K, Li C. Promotion of plant growth by phytohormone-producing endo-phytic microbes of sugar beet. Biol Fertil Soils. 2009;4 5:645–53.
98. Singh PP, Shin YC, Park CS, Chung YR, Biological control of fusarium wilt of cucumber by chitinolytic bacteria. Phytopathology. 1999; 89:92–99.
99. Smith R, Peterson W, Mccoy E. Oligomycin, a new antifungal antibiotic. Antibiot. Chemother. 1954; 4:962–970.
100. Suzuki S, Yamamoto K, Okuda T, Nishio M, Nakanishi N, Komatsubara S. Selectiveisolation and distribution of Actinomadura rugatobispora strains in soil. Actino-mycetologica 2000; 14:27–33.
101. Taechowisan T, CLu Y Shen, S Lumyong. Secondary metabolites from endophytic Streptomyces aureofaciens CMUAc130 and their antifungal activity. Microbiol, 2005; 151:1691–5.
102. Tan LTH, Chan KG, Lee LH, Goh BH. treptomyces bacteria as potential probiotics in aquaculture. Front. Microbiol. 2016; 7:79.
103. Tan LTH, Ser HL, Yin WF, Chan KG, Lee LH, Goh B. H. Investigation of antioxidative and anticancer potentials of Streptomyces sp. MUM256 isolated from Malaysia mangrove soil. Front. Microbiol. 2015; 6:1316.
104. Tokala RK, Strap JL, Jung CM, Crawford DL, Salove MH, Deobald LA, *et al*. Appl. Environ. Microbiol. 2002; 68(5):2161−71.
105. Trejo-Estrada S, Paszczynski A, Crawford D. Antibiotics and enzymes produced by the biocontrol agent Streptomyces violaceusniger YCED-9. J. Ind. Microbiol. Biotechnol. 1998; 21:81–90.
106. Trejo-Estrada SR, Sepulveda IR, Crawford DL. In vitro and in vivo antagonism ofStreptomyces violaceusniger YCED9 against fungal pathogens of turfgrass. World. J Microbiol Biotechnol. 1998; 21:81–90.
107. Trejo-Estrada SR, A Paszczynski, DL Crawford. Antibiotics and enzymes produced by the biocontrol agent Streptomyces violaceusniger YCED9. J Ind Microbiol Biotechnol. 1998; 21:81-90.
108. Valois D, K Fayad, T Barbasubiye, M Garon, C Dery, R

Brzezinski, *et al*. Glucanolytic actinomycetes antagonistic to Phytophthora fragariae var. rubi, the causal agent of raspberry root rot. Applied and Environmental Microbiology, 1996; 62:1630–1635.
109. Van Driesche RG, TS Bellows. Biological Control. Chapman and Hall. U.S.A. ISBN 1996; 0-412-02861-1.
110. Wakae O, K Matsuura. Characteristic of validamycin as a fungicide for Rhizoctonia disease control. Rev. Plant Prot. Res. 1975; 8:81-92.
111. Waksman SA, Henrici AT. The nomenclature and classification of the actinomycetes. J. Bacteriol. 1943; 46:337–341.
112. Wang SL, TC Yieh, IL Shih. Production of antifungal compounds by Pseudomonas aeruginosa K-187 using shrimp and crab shell powder as a carbon source. Enzyme Microb. Technol., 1999; 25:142–8.
113. Wang SL, WJ Hsiao. WT Chang. Purification and characterization of an antimicrobial chitinase extracellular produced by Monascus purpureus CCRC31499 in a shrimp and crab shell powder medium. J Agr Food Chem., 2002; 50:2249-55.
114. Wu G, Culley DE, Zhang W. Predicted highly expressed genes in the genomes of Streptomyces coelicolor and Streptomyces avermitilis and the implications for their metabolism. Microbiology. 2005; 151:2175–2187.
115. Xiao K, Kinkel LL, Samac DA. Biological control of Phytophthora root rots on alfalfa and soybean with Streptomyces. Biol Control; 2002; 23:285–95.
116. Xiao K, LL Kinkel, DA Samac. Biological control of Phytophthora root rots on alfalfa and soybean with Streptomyces. Biol Control., 2002; 23:285-95.
117. Yang P, Li M, Zhao J, Zhu M, Shang H, Li J, *et al*. Oligomycins A and C, major secondary metabolites isolated from the newly isolated strain Streptomyces diastaticus. Folia Microbiol. 2010; 55:10–16.
118. You JL, Cao LX, Liu GF, Zhou SN, Tan HM, Lin YC, Isolation andcharacterization of actinomycetes antagonistic to pathogenic Vibrio spp. fromnearshore marine sediments. World J. Microbiol. Biotechnol. 2005; 21:679–682.
119. You MP, K Sivasithamparam, DI Kurtboke. Actinomycetes in organic mulch used in avocado plantations and their ability to suppress Phytophthora cinnamomi. Biology Fertility Soils. 1996; 22:237-242.
120. Zhou L, Zhang X, Li C, Christensen MJ, Nan Z. Antifungal activity and phytochemical investigation of the asexual endophyte of Epichloë sp. from Festuca sinensis. Sci. China Life Sci. 2015; 58:821–826.