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Bacterial bio-agents: A potential biological weapons against plant disease management

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Abstract

Ensuring food and nutritional security to ever increasing population of the world is a prime concern, especially when factor productivity is declining, environmental pollution is increasing and natural resources are as always limited. The pathogenic microorganisms affecting plant health are major and chronic threats to sustainable food production and ecosystem stability worldwide. Currently, chemical based pesticides are thought to be an effective and reliable agricultural management measure for controlling the diseases. Chemical pesticides are highly effective and convenient to use but they are a potential threat for the environment and all kinds of life on earth. Further, those chemicals themselves are acting as selective agents, making the pathogens more resistant and help these pathogens to persist as they are slowly becoming resistant to these agents. Thus, there is a necessity to execute new methods which would supplement conventional strategies for plant disease management and are competent to minimize adverse effects of chemical pathocides on human health and the environments. Therefore, the use of biological control agents for the management of plant pathogens is considered as a safer and sustainable strategy for safe and profitable agricultural productivity.

The promising bacterial based pesticides of different strains of *Pseudomonas fluorescens, Pseudomonas putida* and *Bacillus* spp. are available for sustainable agriculture, which has been reported as a growth promoter and as antagonistic to a variety of pathogens in vitro and in greenhouse and field studies. The disease suppression by these bacterial based pesticides is the net result of multiple mechanisms, including plant growth promotion (PGP), antibiosis, competition for space and nutrients, lysis of pathogen and induced resistance i.e., SAR and ISR.

Keywords Bacterial bioagents, Mode of action, Eco-friendly disease suppression

Introduction

Agriculture plays a vital role in a developing country of the world. It is one of the most important sectors for livelihood and nutritional security of the growing population and it also plays a role in improving economy of the country. In India, the green revolution introduced to enhanced agricultural technologies, in particular, the use of chemical pesticides to increase production and productivity of crop. However, over the years, the extensive and continuous use of pesticides and fertilizers has not only posed an imperative risk to human health and ecosystems but has also been calamitous for soil microorganism. Apart from this, production of agricultural crops is continuously getting vulnerable due to attack of pests such as insects, bacteria, fungi, nematodes, virus etc. Plant diseases are among the main constraints affecting the production and productivity of crops both in terms of quality and quantity. Crop losses are creating a major threat to the food production with about 27 to 42% loss in global food production attributed to plant disease caused by plant pathogens which otherwise would have been doubled if no disease management strategies are applied (Singh, 2014, Alizadeh *et al.,* 2020). Different agricultural practices, such as the use of disease resistant varieties, seed treatment, crop rotation, cover crops, good seed bed preparation and weed management practices have been applied to control plant diseases. However, such practices are not always sufficient protection from crop losses. In recent times, diverse approaches are being used to manage and/or mitigate a variety of pathogens for control of plant diseases. The use of microbial pesticides is one of the best strategies available to combat the diseases in an eco-friendly manner. A variety of bacterial and fungal based biopesticides have been identified and developed but require effective adoption and further development of such agents. Moreover, consumers are becoming more and more concerned about pesticide-free safer foods which results in emergence of eco-friendly strategies for plant disease management.

Nowadays, several beneficial bacterial based biopesticides are widely used in agriculture at commercial level. Bacterial bioagents i.e., *Pseudomanas fluorescens*, *Pseudomonas aureofaciens Pseudomonas chlororaphis, Pseudomonas putida, Bacillus subtilis*, *Bacillus cereus*, *B. pasteurii*, *B. pumilus*, *B. mycoides*, *B. sphaericus*, *B. amyloliquefaciens*, *Burkholderia cepacia*, *Streptomyces lydicus, Arthrobacter* sp. and *Agrobacterium radiobacter* suppresses many plant pathogens on diverse hosts (table-1) and commercial bacterial bioagents with manufacturers are also listed in table-2.

Mechanism of action of bacterial bio-agents

Plant diseases are the result of interactions among the components of disease triangle i.e., host, pathogen and environment. Biological control agents are the organisms that interact with the components of disease triangle to manage the disease. Various unique and complex mechanisms of action (Junaid *et al.,* 2013) employed by the bacterial biocontrol agents in controlling the plant diseases are described as accordingly:

Antibiosis: Production of low molecular weight compounds or an antibiotic like substances or other chemical metabolites by the microorganism that have a direct effect on the growth of plant pathogen. Bio-agents are known to produce three types of antibiotics viz., nonpolar/volatile, polar/ non-volatile and water soluble. Among all of these the volatile antibiotics are more effective as they can act at the sites away from the site of production (Lo, C. T., 1998, Pal and Gardener, 2006). For example, bacterial bioagents release following antibiotic viz., different strains of *Pseudomanas fluorescens* produces Phenazine-1-Carboxylic Acid (PCA), Pyrrolnitrin, Pyocinine, Pyoluteorin, Oomycin-A, 2,4-Diacetyl-pholoroglucinol (DAPG), Idionine, etc.; different *Bacillus subtilis* strains produces Bacillomycin D, Iturin A, surfactin, fengycin and Mycosubtilin, *Bacillus cereus produce Zwittermycin* A; *Agrobacterium radiobacter* produce Agrocin 84, *B. amyloliquefaciens* produce Bacillomycin, fengycin and *Burkholderia cepacia* produce Pyrrolnitrin, Pseudane antibiotic like substances.

Competition: Both the bio-control agents and the pathogens compete with one another for the nutrients, oxygen, space and other requirements to get established in the environment. This process of competition is considered to be an indirect interaction between the pathogen and the bio-control agent whereby the pathogens are excluded by the depletion of nutrients base and by physical occupation of site. So far, as the competition for nutrients is concerned bio-control agents compete for the rare but essential micronutrients, such as iron and manganese especially in highly oxidized and aerated soils. Iron is required for growth and development of plants and microorganisms. In natural form, iron is present in ferric form, which is insoluble in water and is not utilized by both plants and micro-organisms (Junaid *et al.,* 2013). For example, different strains of *Pseudomanas fluorescens* synthesize siderophore (It is a microbial iron transport agent/act as chelating agents and extra cellular, low molecular weight compounds, it has micronutrients bindable capacity, specially, it binds the iron molecules and make insoluble form to soluble and also facilitate iron uptake to plants and microorganisms (bioagents), during this process, it is less available/unavailable to pathogens and ultimately disease controlled) i.e., Ferribactin, Ferrichrome, Ferroxamine B, Pseudobactin, Pyochelin, Pyoverdine (soluble fluorescent pigment) and *Bacillus subtilis* produce the catecholate siderophores-2 (bacillibactin), 3-dihydroxybenzoate and 2, 3-dihydroxybenzoyl glycine.

Lysis: It is one of the mechanisms used by biocontrol agents to control soil-borne pathogens involve the production of cell wall-degrading enzymes or other metabolites. Numerous microorganisms release lytic enzymes that can hydrolyse a wide variety of polymeric compounds, including chitin, proteins, cellulose, hemicellulose and DNA. Expression and secretion of these enzymes by different microbes can sometimes result in the suppression of plant pathogen activities directly. Besides production of antibiotics and elicitation of systemic resistance in plant against a variety of plant pathogenic diseases, biocontrol strains of plant growth promoting rhizobacteria (PGPR) *viz.*, *Pseudomanas fluorescens* and *Bacillus* spp. are also capable of producing enzymes like chitinase, β-1, 3-glucanase, chitinase, cellulase, and protease having a very strong lytic activity. It exerts a direct inhibitory effect on the hyphal growth of fungal pathogens. Cell wall-degrading enzymes of rhizobacteria affect the structural integrity of the walls of the target pathogen. The other microbial by-products i.e., HCN production by certain *fluorescent pseudomonads* is believed to be involved in the suppression of root pathogens. *P. fluorescens* CHA0 produces antibiotics, siderophores and HCN, but suppression of black rot of tobacco caused by *Thielaviopsis basicola* appeared primarily to be due to HCN production (Junaid *et al.,* 2013).

Induced Resistance: Plants actively respond to a variety of environmental stimuli, including gravity, light, temperature, physical stress, water and nutrient availability. Plants also possess arrange of active defence apparatuses that are respond to a variety of chemical stimuli produced by soil and plant associated microbes (PGPR). Such stimuli induce through biochemical changes that enhance resistance against subsequent infection by a variety of pathogens. If defence mechanisms are triggered by a stimulus prior to infection by a plant pathogen, disease can be reduced. Induced resistance is a state of enhanced defensive capacity developed by a plant when appropriately stimulated. Systemic acquired resistance (SAR) and induced systemic resistance (ISR) are two forms of induced resistance wherein plant defences are reconditioned by prior infection or treatment that results in resistance against subsequent challenge by a pathogen or parasite. Systemic acquired resistance (SAR) is a form of induced resistance that is activated throughout a plant after being exposed to elicitors (cell wall component of the pathogen which are capable of inducing phytoalexins synthesis) from virulent, avirulent or non-pathogenic microbes or artificial chemical stimuli such as chitosan or salicylic acid (SA). Induced systemic resistance (ISR) is a resistance mechanism in plants that is activated by infection. Its mode of action does not depend on direct killing or inhibition of the invading pathogen, but rather on increasing physical or chemical barrier of the host plant. Selected strains of plant growth-promoting rhizobacteria (PGPR) suppress diseases by antagonism between the bacteria and soil-borne pathogens as well as by inducing a systemic resistance in plant against both root and foliar pathogens. SAR is triggered by plant pathogens and are mediated by SA-dependent pathway (Singh, 2014) which are activated by certain molecules secreted by microorganism (pathogens) referred as elicitors (cell wall polysaccharides, salicylic acid, cyclic lipopeptides, siderophores, antibiotics and the signal molecule N-acyl homoserine lactones reported by Perez-Montano *et al.* 2014) that leads to expression of defence responses (its functions as signal that spread "news" of the infection to nearby cells and also stimulate the cross-linking of molecules in the cell wall and the deposition of lignin, responses that set up a local barricade that slows the spread of the pathogen to other parts of the plant) like physical thickening of cell walls by lignification, deposition of callose, accumulation of phytoalexins (antimicrobial low-molecular-weight compounds formed by the plants in response to infection) and synthesis of various proteins (e.g., chitinases, glucanases, peroxidases and other pathogenesis related (PR) proteins (i.e., PR-1, PR-2) produced in plant in the event of a pathogen attack. Infections activate genes that produce PR- proteins. These PR proteins are antimicrobial and cause lysis of invading cells, reinforcement of cell membranes to resist infections or induce localized cell death. ISR is triggered by beneficial microbes living in the rhizosphere which is generally mediated by salicylic acid (SA) independent pathway where jasmonic acid (JA) and ethylene (ET) are the central players (induced by non-pathogenic bacteria) and typically functions without PR protein activation. Combination of ISR and SAR can increase protection against pathogens that are resisted through both pathways besides extended protection to a broader spectrum of pathogens than ISR/SAR alone. Some strains of *Pseudomanas fluorescens, Pseudomanas putida* and several specific strains of species *Bacillus amyloliquifaciens*, *B. subtilis, B. pasteurii, B. cereus, B. pumilus, B. mycoides,* and *B. sphaericus* are produce significant reduction through induce resistance in the incidence or severity of various diseases on a diversity of hosts (Chaudhary *et al.,* 2007).

Method of application of Bacterial bioagents:

Seed treatment: Seed treatment is a process like vaccination applied in animal as well as human. In broad terms, it provides protection to seeds and plants and improve the establishment of healthy crops. Use for bigger seeds treatment @ 8-10gram bacterial formulation per kg seed while small seeds @ 6-8gram per kg seed before sowing. Mix the required quantity of seeds with bacterial formulation and ensure uniform coating. Shade dries the seeds for 20-30 minutes before sowing is essential. Seed treatment is highly effective against seed and soil borne diseases.

Seed bio-priming: It is a process of biological seed treatment. In this process, involves slurry treatment of seeds with bioagent in the presence of gum arabica, jaggery/or FYM powder. Dissolve 100gram jaggery in one litre of water and prepare solution thereafter add bacterial formulations @ 10 gram/kg seed in this solution and properly mix it. Next day required quantity of seeds are mix properly with culture medium. Use polythene bags for filling treated seed, heaped, covered with moist sack of jute and incubate at approximately 25-32 °C for 48 hours to maintain high humidity. Bioagent adhering to surface of seed grows and form a protective covering on seed coat during this period. This technique has potential advantages over simple coating of seeds as it results in rapid and uniform seedling emergence. Seed biopriming is beneficial for tomato, brinjal, chickpea, soybean etc crops.

Seed material treatment: Apply @ 10gram or 10ml bacterial formulation with one litre of water for the treatment of seed material like sugarcane setts, banana suckers, turmeric, ginger rhizomes and potato tubers before sowing for about 30 minutes. Shade dries the seeds for 20-30 minutes before sowing is essential.

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Soil application: 2-2.5 kg bacterial formulation (powder formulation) or 500-1000 ml (liquid formulation) is added in 25-50 kg farm yard manure (FYM). Mixed thoroughly, cover with jute bag/sugarcane leaves/paddy straw and kept for 2-3 week in shade for proper multiplication. Maintain moisture and mix the mixture in every 3-4 days intervals before broadcasting in the field. Maintain optimum moisture for better multiplication of bioagents. Apply well decomposed bacterial based FYM to the field before 15 days of sowing. This mixture can be applied in furrow/pit/pot and at the time of transplanting/sowing. This mixture is sufficient for one acre of land.

Cutting/Seedling's root dip application: Mix 10gram bacterial formulation (powder formulation) or 10 ml (liquid formulation) in one litre of water and dip the cuttings and roots of seedlings for about 30 minutes before transplanting. Root dipping is effective against soil borne diseases.

Nursery bed treatment: 500gram bacterial bioagents (powder formulation) mix in 10-15 kg well decomposed FYM/compost/vermicompost and broadcast in a one-acre area at evening time and at proper moisture conditions.

Soil drenching: One-to-two-kilogram bacterial formulation mix in 200 litres of water and drench the soil in one acre area or 10 gram or 10 ml/litre of water bacterial bioagents is sufficient for soil drenching. Maintain optimum soil moisture while applying.

Horticultural crops: 50-100gram bacterial formulation mix in sufficient quantity of FYM/compost/vermicompost/field soil and apply the mixture per plant in effective root zone of fruit tree. Doses will change in depending upon age of the plant.

Foliar application: 10 gram/litre of water bacterial formulation (powder formulation) or 10 ml/litre of water (liquid formulation) spray uniformly after 35-40 days of transplanting (particularly in cereals, pulses and oilseeds) on diseased plants at cooler hours. 2-3 spray are required depending upon the disease incidence at 10-12 days intervals.

Benefits

1. It is safer both for the environment and the persons who are applying them and avoid environmental pollution (soil, air and water) by leaving no toxic residues.

2. It is comparatively easier to manufacture biocontrol agents, sometimes less expensive than chemical agents.

3. Bio-control agents eliminate the specific pathogens effectively from the site of infection and can be used in combination with biofertilizers.

4. Bio-control agents do not cause any toxicity to the plants; rather these increase crop yields by enhancing the root and plant growth through the encouragement of beneficial microflora in rhizosphere. It also helps in the mobilization of plant nutrients and makes it available to the plant.

5. Bio-control agents avoid problems of resistance and also induce systemic resistance among the crop species that is responsible for protection of invading pathogens.

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Table 1: Various disease controlled by bacterial bio-agents

Crop Name	Disease Name	Target pathogens	Effective Bacterial bioagents
Cereal crops			
Rice	Sheath rot	*Sarocladium oryzae*	*Pseudomanas fluorescens*
	Sheath blight	*Rhizoctonia solani*	*Pseudomanas fluorescens, P. putida*
	Blast	*Magnaporthe grisea*	*Bacillus* sp.
	Bacterial leaf blight	*Xanthomonas oryzae* pv. *oryzae*	*Pseudomanas fluorescens, B. subtilis*
	Leaf and Neck blast	*Pyricularia oryzae*	*Pseudomanas fluorescens*
	Leaf spot	*Helminthosporium oryzae*	*Pseudomanas fluorescens*
Barley	Take-all	*Gaeumanomyces graminis var. tritici*	*Pseudomanas fluorescens*
Wheat	Root rot	*Sclerotium rolfsii, Fusarium oxysporum*	*Pseudomanas fluorescens*
	Loose smut	*Ustilago segatum tritici*	*Pseudomanas fluorescens*
	Take-all	*Gaeumanomyces graminis var. tritici*	*Pseudomanas fluorescens*
	Wilt	*Fusarium graminearum*	*Lysobacter enzymogenes*
Maize	Damping off	*Pyhtium ultimum*	*Pseudomanas fluorescens*
	Wilt	*Fusarium oxysporum*	*B. amyloliquefaciens*
	Maize rot	*Fusarium verticillioides*	*Burkholderia* sp.
Pearl millet	Downy mildew	*Sclerospora graminicola*	*B. subtilis, B. pumilus*
Sorghum	Wilt	*Fusarium oxysporum*	*Paenibacillus sp.*
Pulse crops			
Chickpea	Wilt, seed rot, root rot	*Fusarium oxysporum* f. sp. *ciceris, R. bataticola, Pyhtium sp.*	*Bacillus subtilis*
	Grey mould	*Botrytis cineria*	*Brevibacillus brevis*

Pigeon pea	Wilt	*Fusarium udum*	*Bacillus subtilis*
Oilseed crops			
Rye	Vascular wilt	*Fusarium culmorum*	*Pseudomonas fluorescens*
Rapeseed	Stem rot	*Sclerotinia scletiorum*	*Bacillus subtilis* EDR4
Groundnut	Late leaf spot	*Phaeoisariopsis personata*	*Pseudomonas fluorescens*
Castor	Grey rot	*Botrytis cinerea*	*Pseudomonas fluorescens*
Fruit crops			
Apple and Pear	Fire blight	*Erwinia amylovora*	*Bacillus subtilis* QST 713, *Pantoea agglomerans* C9-1, *Pantoea agglomerans* E325
Apple	Root rot	*Fusarium* sp.	*Bacillus subtilis* Y-1
Stone fruit	Crown gall disease	*Agrobacterium tumefaciens*	*Agrobacterium radiobacter* K84
Banana	Bunchy top disease	*Banana bunchy top virus*	*Pseudomonas fluorescens*
	Sigatoka	*Mycosphaerella musicola*	*Bacillus subtilis*
	Wilt	*F. oxysporum f. sp. cubense*	*B. amyloliquefaciens*
Avacado	Root rot	*Dematophora necatrix*	*Pseudomonas fluorescens*
Citrus	Post-harvest decay	*Penicillium* sp.	*Bacillus subtilis* PPCB001
Vegetable crops			
Tomato	Foot and root rot	*Fusarium oxysporum f. sp. radicislycopersici*	*Pseudomonas chlororaphis*
	Mosaic disease	*Cucumber mosaic virus*	*Bacillus pumilus, B. amyloliquefaciens, B. subtilis*
	Tomato mottle disease	*Tomato mottle virus*	*B. amyloliquefaciens, B. subtilis, B. pumilus*
	Foliar diseases	*Corynespora cassiicola*	*B. cereus*
	Wilt	*Fusarium oxysporum*	*Collimonas fungivorans, Pseudomonas fluorescens*

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	Root rot	*Rhizoctonia* spp.	*Pseudomonas fluorescens*
	Bacterial wilt	*Ralstonia solanacearum*	*B. amyloliquefaciens*
Cucumber	Damping off/powdery mildew	*Pythium ultimum/Sphaerotheca fuliginea*	*Pseudomonas fluorescens*
	Damping off	*Rhizoctonia solani*	*Bacillus pumilus*
	Bacterial wilt	*Erwinia tracheiphila*	*Bacillus pumilus*
	Grey mould	*Botrytis cinerea*	*Brevibacillus brevis*
	Root and crown rot	*Pythium aphanidermatum*	*L. enzymogenes*
	Wilt	*Fusarium oxysporum f. sp. cucumerinum*	*Bacillus subtilis*
Potato	Late blight	*Phytophthora infestans*	*Pseudomonas fluorescens*
	Soft rot	*Erwinia amylovora*	*Pseudomonas fluorescens*
	Bacterial wilt	*Ralstonia solanacearum*	*Bacillus cereus, B. subtilis*
Squash	Blight	*Phytophthora capsici*	*Bacillus* sp.
Brinjal	Wilt, damping off	*F. solani, P. aphanidermatum*	*Pseudomonas fluorescens*
Chilli	Damping off	*Pythium aphanidermatum*	*Pseudomonas fluorescens*
Radish	Wilt	*Fusarium* sp.	*Pseudomonas putida*
Pea	Damping off, root rot	*Pythium* sp. and *Aphanomyces* sp.	*Burkholderia cepacia*
	Wilt	*Fusarium oxysporum f. sp. pisi*	*Pseudomonas fluorescens*
Okra	Wilt	*Fusarium oxysporum*	*Pseudomonas fluorescens*
Cauliflower	Damping off	*R. solani, P. aphanidermatum*	*Pseudomonas fluorescens*
Cabbage	Damping off	*R. solani*	*Pseudomonas fluorescens*
Bottle gourd	Collar rot	*Sclerotinia sclerotiorum*	*B. subtilis*
Fenugreek	Root rot	*R. solani*	*Pseudomonas fluorescens*
Bean	Seedling rot	*Pythium sp., S. sclerotiorum, R. solani, B. cineria*	*Pseudomonas fluorescens*
	Root rot	*R. solani*	*Pseudomonas fluorescens*
	Southern blight	*Sclerotium rolfsii*	*Aeromonas caviae*

Plantation crops			
Tobacco	Blue mould	*Peronospora tabacina*	*Bacillus pumilus*
	Bacterial wilt	*Ralstonia solanacearum*	*Brevibacillus brevis, Streptomyces rochei*
Arecanut palm	Fruit rot	*Phytophthora* spp.	*Pseudomanas fluorescens*
Cash crops			
Sugarcane	Red rot	*Colletotrichum falcatum*	*Pseudomanas fluorescens* VPT4, ARRIG, and EP1, *Pseudomanas putida* KKM1
Carrot	Root rot	*Athelia rolfsii*	*Pseudomanas fluorescens*
Sugar beet	Damping off	*Pythium ultimum*	*Pseudomanas fluorescens, Enterobacter cloacae, Stenotrophomonas maltophilia*
Cotton	Root rot	*Rhizoctonia solani*	*Bacillus cereus, Enterobacter agglomerans*
	Root rot	*R. solani and F. oxysporum* f. sp. *vasinfectum*	*Aeromonas caviae*
	Root rot	*Macrophomina phaseolina*	*Pseudomanas fluorescens*
	Damping off	*Pyhtium ultimum, Phoma betae*	*Pseudomanas fluorescens*
	Wilt	*Verticillium dehaliae*	*Bacillus subtilis*
Spices crops			
Bell pepper	Blight	*Phytophthora capsici*	*Bacillus* sp.
Pepper	Blight	*Botrytis cinerea*	*B. amyloliquefaciens*

Table 2: Commercial products of Bacterial bioagent in plant disease management.

Trade Name	Bacterial strains/species	Manufacturer

Galtrol	*Agrobacterium radiobacter* strain 84	AgBioChem, Inc., USA
Dygall	*Agrobacterium radiobacter*	Agbioresearch Ltd.
Nagol	*Agrobacterium radiobacter* strain K1026	Bio-care
Nogall	*Agrobacterium radiobacter*	New Bioproducts
GB 34	*Bacillus subtilis* strain GB34	Gustafon, Inc., USA
Kodiac companion	*Bacillus subtilis* strain GB03	Growth products, USA
Frostban	*Pseudomanas fluorescens* strain A 506	Plant health technologies
Bio-jet, Spot less	*Pseudomanas fluorescens* strain TX-1	Eco-Soil Systems Inc.
Ballad Plus	*Bacillus pumilus*	Agraquest Inc.
Serenade	*Bacillus subtilis*	Agraquest Inc.
Rhizo-plus	*Bacillus subtilis* strain FZB 24	FZB Biotechnik, GmbH
Intercept	*Pseudomanas cepacia*	Soil Tech.
Conquer	*Pseudomanas fluorescens*	Mauri Foods
Bio-jet	*Pseudomanas + Azospirillum*	Eco-Soil
Deny	*Burkholderia cepacia*	Stine Microbial Products
Avo Green	*Bacillus subtilis*	Ocean Agriculture, South Africa
Bio-safe	*Basillus subtilis*	Laboratorio de Biocontrole Farroupilha, Brazil
Subtilex/Pro-Mix	*B. subtilis*	Premier Horticulture Inc., Canada
Bioshield	*Pseudomanas fluorescens*	Anu Biotech International Ltd., Faridabad, India
Biotok	*Bacillus subtilis*	Tocklal Experimental Station, Tea Research Associantion, Jorhat, Assam, India
Plant Bio-control Agent-3	*Pseudomanas fluorescens*	Department of Plant Pathology, G.B. Pant Uni. of Agric. And Tech., Pantnagar, Uttarakhand, India

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HiStick N/T, Subtilex	*Bacillus subtilis* strain MB 1600	Becker Underwood, Ames, IA, USA
Bio Yield	*B. subtilis + B. amyloliquefaciens*	Gustafson Inc., Dallas, USA
Ecoshot	*Bacillus subtilis*	Kumiai Chemical Industry, Japan
Mycostop	*Streptomycine griseoviridis*	Kemira Oy, Finland
Actinovate	*Streptomyces lydicus*	Natural Industries, Inc., USA
Biobest	*Bacillus subtilis*	Appliedchem, Thailand
Biosave 10LP, 110	*Pseudomonas syringae*	Village Farms LLC
EcoGuard	*Bacillus licheniformis*	Novozymes, Denmark
Larminar	*B. subtilis*	Appliedchem, Thailand
Rhapsody	*B. subtilis*	AgraQuest, USA
Sonata	*B. pumilus*	AgraQuest, USA
Subtilex	*B. subtilis*	Becker Underwood, USA
Taegro	*B. amyloliquefaciens*	Novozymes, Denmark
YiedShield	*Bacillus pumilus* GB34	Gustafson Inc., USA