Agriculturally Important Microbial Germplasm Database

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ICRISAT Science with a human face

International Crops Research Institute for the Semi-Arid Tropics

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Preface

With a projected increase in world population to 10 billion over the next four decades, an immediate priority for agriculture is to achieve maximum production of food and other products in an environmentally sustainable and cost-effective manner. To meet the food demands of growing populations, agricultural practices have to be modified in view of the limited cultivable land on the earth. Use of chemical pesticides to increase the productivity of crops is the current practice in the agricultural systems but their continuous and injudicious use has resulted in several implications such as development of insecticide resistance in key pest species, pesticide residues in food chain, and degradation in the quality of ecosystem and human health. Furthermore, majority of the world's poor live in countries of the semi-arid tropics, own small farms (for example, 75% of Indian farmers own less than 1.4 to 2.4 ha), and cannot afford expensive inputs such as pesticides and fertilizers. Increasing cost and negative effects of pesticides and fertilizers necessitates consideration of biological options of crop protection and production. Various biological options such as entomopathogens, antagonistic microbes and botanicals serve as an alternative to chemical pesticides and fertilizers and hence these options should be exploited.

Biofertilizers/biopesticides are the alternative to chemical fertilizers/ pesticides; these include botanical extracts and microbes (bacteria, actinomycetes, fungi and viruses). Though botanical extracts have illustrious activity in integrated pest management and integrated fertilizer management, they cannot be used widely due to constraints such as scarcity of natural resources; hence microbes are the alternative solution. Biofertilizers/ biopesticides are eco-friendly, have highly targeted modes of action and very less negative impact on the other organisms, allow growers to maintain ecological balance among the organisms in the environment and reduce dependence on conventional chemical fertilizers/pesticides.

Plant growth-promoting (PGP) microbes are soil bacteria that colonize rhizoplane and rhizosphere and enhance plant growth when inoculated artificially onto the soil or seeds. PGP bacteria can directly or indirectly affect plant growth through various mechanisms which include fixation of atmospheric nitrogen, solubilization of minerals, synthesis of various enzymes and phytohormones, and inhibition of phytopathogens. Different functional and taxonomic groups of microbes are reported to have PGP traits which include free-living bacteria such as *Bacillus, Pseudomonas,*

Erwinia, Caulobacter, Serratia, Arthrobacter, Micrococcus, Flavobacterium, Chromobacterium, Agrobacterium, Hyphomycrobium and symbiotic nitrogen-fixing bacteria such as *Rhizobium, Bradyrhizobium, Sinorhizobium, Azorhizobium, Mesorhizobium* and *Allorhizobium*. The use of PGP microbes has increased in many parts of the world due to their significant contribution to growth and yield which has been demonstrated in crops such as tomato, wheat, rice, bean and pea.

The main objective of this bulletin is to provide complete information of the most potential agriculturally important microorganisms demonstrated for their PGP, antagonistic and entomopathogenic activities at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). These PGP microbes are made available for agricultural scientists, particularly those who are working in plant pathology, microbiology, biological control and plant growth promotion, extension workers, biopesticide/biofertilizer industry and students. Further, the appendix section of this bulletin gives study materials for those who require more information on this topic. Hence, this information bulletin will be of value to scientists, students, extension workers, industry and progressive farmers.

Introduction

The main aim of this bulletin is to provide information of agriculturally important microorganisms available at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India for agricultural scientists, particularly those who are working in plant growth promotion, biological control, plant pathology and microbiology, extension workers, biopesticide/biofertilizer industry and students. The agriculturally important microbial germplasm database at ICRISAT currently contains a total of 59 plant growth-promoting (PGP) microbes including 12 bacteria, 46 actinomycetes and 1 fungus. These PGP microbes were isolated from 25 different herbal vermicomposts and rhizosphere soils from different organically cultivated fields of ICRISAT. The PGP microbes reported in this bulletin possess one or more PGP traits such as chitinase, lipase, protease, indoleacetic acid, siderophore, β-1,3-glucanase, cellulase and hydrocyanic acid. They were also able to grow in NaCl concentrations up to 10%, at pH values between 7 and 11, temperatures between 20 and 40°C and were compatible with some fungicides at field application levels.

These fungicides are:

Bavistin:	carbendazim 50%; methyl benzimidazol-2-yl-carbamate
Benlate:	benomyl 50%; methyl [1-[(butylamino)-carbonyl]-1H-benzimidazol-2-yl] carbamate
Captan:	captan 50%; N-trichloromethylthio-4-cyclohexene-1,2-dicarboximide
Ridomil:	N-(2,6-dimethylphenyl)-N-(methoxyacetyl) alanine methyl ester
Thiram:	dimethylcarbamothioylsulfanyl N,N-dimethylcarbamodithioate

The microbes reported in this bulletin were demonstrated for their plant growth promotion in rice (*Oryza sativa*), sorghum (*Sorghum bicolor*), chickpea (*Cicer arietinum*) and pigeonpea (*Cajanus cajan*) under field conditions. Some of these PGP microbes were demonstrated for their antagonistic potential against plant pathogens such as *Fusarium oxysporum* f. sp. *ciceri* (FOC) (causes *Fusarium* wilt in chickpea), *Sclerotium rolfsii* (causes collar rot in chickpea), *Botrytis cinerea* (causes Botrytis gray mold in chickpea) and *Macrophomina phaseolina* (causes charcoal rot in sorghum) and entomopathogenic potential against polyphagous insect pests including *Helicoverpa armigera*, *Spodoptera litura* and *Chilo partellus* under field/greenhouse conditions. Several of these

PGP microbes were also demonstrated (data not shown) for their secondary metabolite production capability and hence may be used for purifying the metabolites responsible for plant growth promotion and antagonistic entomopathogenic activities.

Database

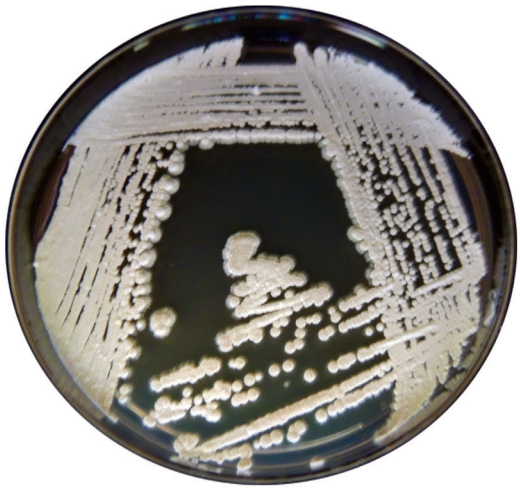
The database consists of 59 agriculturally important microorganisms with PGP potential. This database covers, (i) Accession numbers for cultures deposited and nucleotide sequences submitted in NBAIM and GenBank respectively; (ii) Physiological and PGP properties and image of colony growth on agar based mediums. Brief description of biochemical assay used for evaluating PGP traits are also given in appendix.

Abbreviations used in the database

BCA:	Biocontrol Actinomycete
CAI:	Compost Actinomycete Isolate
KAI:	Karnataka Actinomycete Isolate
MMA:	Masala Mitti Actinomycete
NBAIM:	National Bureau of Agriculturally Important Microorganisms
SAI:	Soil Actinomycete Isolate
SBI:	Soil Bacterial Isolate
SRI:	System of Rice Intensification
VAI:	Vermicompost Actinomycete Isolate
VBI:	Vermicompost Bacterial Isolate
VFI:	Vermicompost Fungal Isolate

The authors sincerely hope that the information provided in this bulletin will be useful for all the stakeholders mentioned earlier. For more information please contact S Gopalakrishnan, (email: s.gopalakrishnan@cgiar.org).

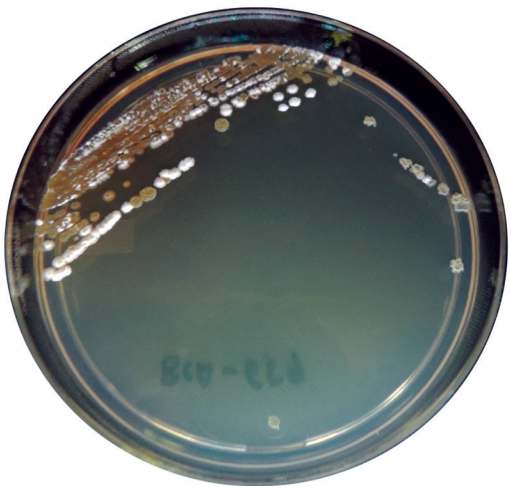
Isolate BCA-508	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770887
Isolated from	Rice rhizosphere soil
Physiological traits Temperature	 20–40°C
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, protease+, indole-3-acetic acid+ and hydrocyanic acid+
Entomopathogenic potential on	*H. armigera, S. litura* and *C. partellus*



Isolate BCA-546	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770898
Isolated from	Rice rhizosphere soil
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 8% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm) and sensitive to Captan (3000 ppm), Thiram (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, protease+, indole-3-acetic acid+, hydrocyanic acid+ and β-1,3-glucanase+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina*, *R. bataticola* (RB-24 and RB-115), *F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)
Entomopathogenic potential on	*H. armigera*, *S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum and chickpea

Isolate BCA-657	
Scientific name	*Streptomyces* sp
GenBank accession number	KM191338
Isolated from	Rice rhizosphere soil
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm) and Thiram (3000 ppm) and sensitive to Captan (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, cellulase+, lipase+, protease+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *M. phaseolina* and *R. bataticola* (RB-6 and RB-115)

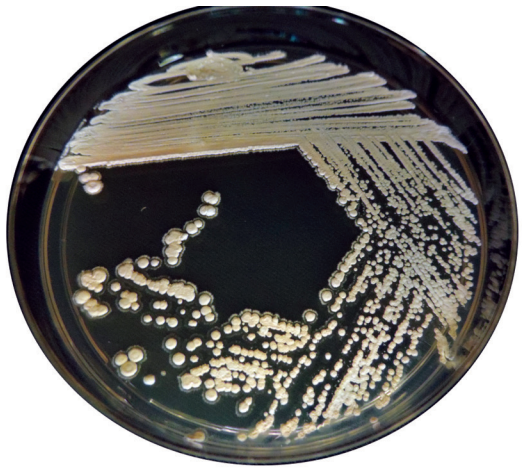
Isolate BCA-659	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770889
Isolated from	Rice rhizosphere soil
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 4% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm), and Captan (3000 ppm) and sensitive to Thiram (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, protease+, indole-3-acetic acid+, hydrocyanic acid+ and β-1,3-glucanase+
Antagonistic potential on	FOC, *B. cinerea*, *M. phaseolina*, *R. bataticola* (RB-6 and RB-24), *F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)
Entomopathogenic potential on	*H. armigera*, *S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum and chickpea



Isolate BCA-667	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770888
Isolated from	Rice rhizosphere soil
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 8% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm) and sensitive to Captan (3000 ppm), Thiram (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, protease+, indole-3-acetic acid+, hydrocyanic acid+ and β-1,3-glucanase+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina*, *R. bataticola* (RB-6 and RB-24), *F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)
Entomopathogenic potential on	*H. armigera*, *S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum and chickpea

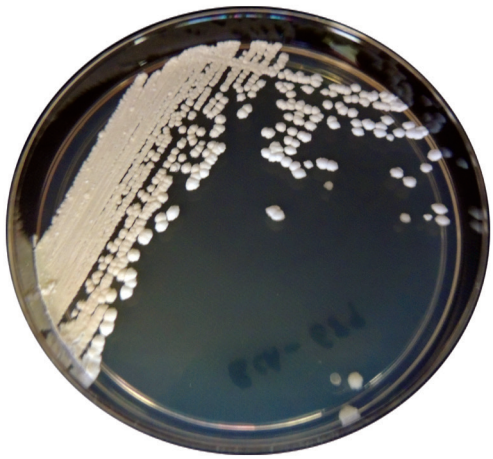
Isolate BCA-671	
Scientific name	*Streptomyces* sp.
GenBank accession number	KM191334
Isolated from	Rice rhizosphere soil
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm) and Thiram (3000 ppm) and sensitive to Captan (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, protease+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina*, *R. bataticola* (RB-6 and RB-24), *F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)

Isolate BCA-679	
Scientific name	*Streptomyces* sp.
GenBank accession number	KM191335
Isolated from	Rice rhizosphere soil
Physiological traits pH Temperature Salinity	 7–11 20–50°C Up to 10% NaCl
Fungicide tolerance and sensitivity (and field application level)	Tolerant to Bavistin (2500 ppm) and sensitive to Thiram (3000 ppm), Captan (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, protease+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina*, *R. bataticola* (RB-24 and RB-115), *F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)



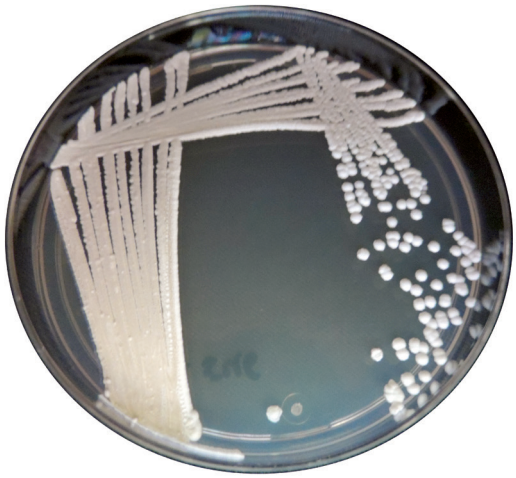
Isolate BCA-687	
Scientific name	*Streptomyces* sp.
GenBank accession number	KM191336
Isolated from	Rice rhizosphere soil
Physiological traits pH Temperature Salinity	 7 20–40°C Up to 6% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm) and sensitive to Thiram (3000 ppm), Captan (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, protease+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *M. phaseolina*, *R. bataticola* (RB-6, RB-24 and RB-115) and *B. cinerea*

Isolate	BCA-689
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770899
Isolated from	Rice rhizosphere soil
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm), and sensitive to Captan (3000 ppm), Thiram (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, indole-3-acetic acid+, hydrocyanic acid+ and β-1,3-glucanase+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina*, *R. bataticola* (RB-24 and RB-115), *F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)
Entomopathogenic potential on	*H. armigera*, *S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum and chickpea

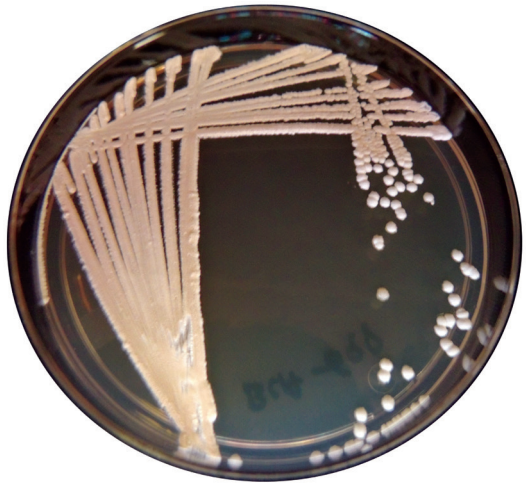


Isolate BCA-690	
Scientific name	*Streptomyces* sp.
GenBank accession number	KM191339
Isolated from	Rice rhizosphere soil
Physiological traits pH Temperature Salinity	 7–11 20–50°C Up to 10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm) and Thiram (3000 ppm) and sensitive to Captan (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, protease+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina*, *R. bataticola* (RB-24 and RB-115), *F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)

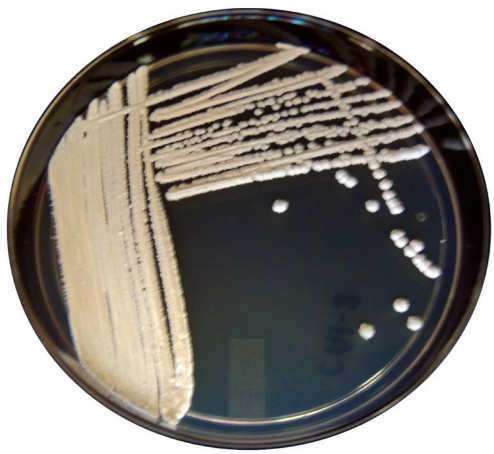
Isolate BCA-696	
Scientific name	*Amycolatopsis* sp.
GenBank accession number	KM191337
Isolated from	Rice rhizosphere soil
Physiological traits	
pH	5–11
Temperature	20–50°C
Salinity	up to 4% NaCl
Fungicide tolerance (at field application level)	Tolerant to Bavistin (2500 ppm), Benlate (4000 ppm), Ridomil (3000 ppm), Captan (3000 ppm) and Thiram (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, protease+, indole-3-acetic acid+, hydrocyanic acid+ and β-1,3-glucanase+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina*, *R. bataticola* (RB-24 and RB-115), *F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)
Entomopathogenic potential on	*H. armigera*, *S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum and chickpea



Isolate BCA-698	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770900
Isolated from	Rice rhizosphere soil
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm), and Captan (3000 ppm) and sensitive to Thiram (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, protease+, indole-3-acetic acid+, hydrocyanic acid+ and β-1,3-glucanase+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina*, *R. bataticola* (RB-24 and RB-115), *F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)
Entomopathogenic potential on	*H. armigera*, *S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum and chickpea



Isolate CAI-8	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770890
Isolated from	Rice straw compost
Physiological traits pH Temperature Salinity	 7–11 20–40°C up to 8% NaCl
Fungicide tolerance and senitivity (at field application level)	Tolerant to Bavistin (2500 ppm) and Captan (3000 ppm) and sensitive to Thiram (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, protease+, indole-3-acetic acid+, hydrocyanic acid+ and β-1,3-glucanase+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina*, *R. bataticola* (RB-24 and RB-115), *Fusarium proliferatum* (FM-242) and *F. andiyazi* (FM-943)
Entomopathogenic potential on	*H. armigera*, *S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum and chickpea



Isolate CAI-13	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770891
Isolated from	Garlic foliage vermicompost
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 8% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
Antibiotic resistance pattern	Tetracycline (25 ppm), chloramphenicol (50 ppm), kanamycin (10 ppm), streptomycin (75 ppm), nalidixic acid (50 ppm) and ampicillin (1100 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina* and *Rhizoctonia bataticola* (RB-6)
Entomopathogenic potential on	*H. armigera, S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice

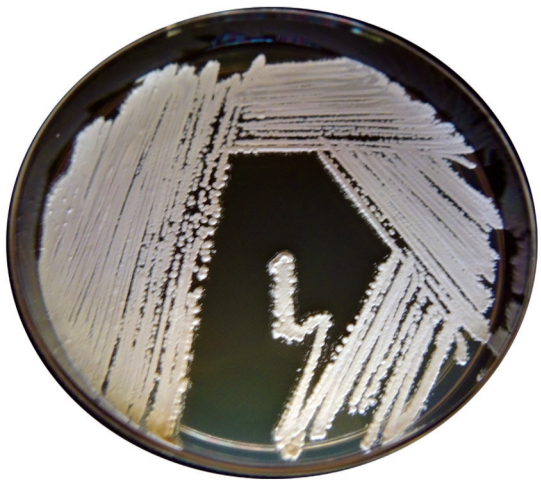
Isolate CAI-17	
Scientific name	*Streptomyces* sp.
GenBank accession number	JQ682619
NBAIM accession number	NAIMCC-B-00592
Isolated from	*Chrysanthemum* foliage compost
Physiological traits pH Temperature Salinity	 7–13 20–40°C Up to 10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
Antibiotic resistance pattern	Tetracycline (2.5 ppm), chloramphenicol (50 ppm), kanamycin (100 ppm), streptomycin (20 ppm), nalidixic acid (100 ppm) and ampicillin (up to 1800 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea*, *M. phaseolina* and *R. bataticola* (RB-6, RB-24 and RB-115)
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice

Isolate CAI-21	
Scientific name	*Streptomyces* sp.
GenBank accession number	JQ682620
NBAIM accession number	NAIMCC-B-01089
Isolated from	*Chrysanthemum* foliage compost
Physiological traits (tolerance) pH Temperature Salinity	 7–11 20–40°C Up to 12% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm), and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase-, cellulase+, lipase-, hydrocyanic acid+, indole-3-acetic acid+
Antagonistic potential on	FOC, *M. phaseolina* and *S. rolfsii*
Field evaluation done for	PGP on sorghum, chickpea, pigeonpea and rice

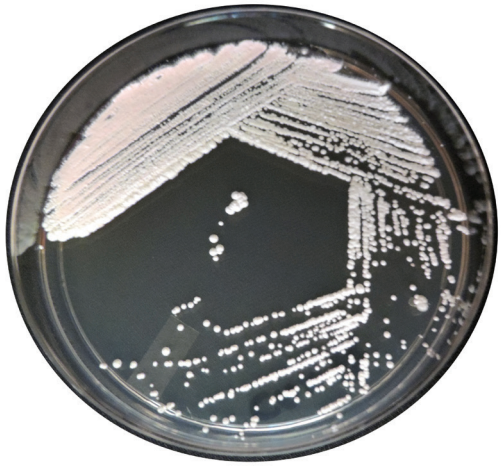
Isolate CAI-24	
Scientific name	*Streptomyces* sp.
GenBank accession number	JN400112
NBAIM accession number	NAIMCC-B-00883
Isolated from	Bitter gourd foliage compost
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 6% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
Antibiotic resistance pattern	Tetracycline (9 ppm), chloramphenicol (10 ppm), kanamycin (10 ppm), streptomycin (10 ppm), nalidixic acid (50 ppm) and ampicillin (700 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea* and *R. bataticola* (RB-6 and RB-24)
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice

Isolate CAI-26	
Scientific name	*Streptomyces* sp.
GenBank accession number	JQ682621
NBAIM accession number	NAIMCC-B-01090
Isolated from	Garlic foliage vermicompost
Physiological traits pH Temperature Salinity	 7–13 20–40°C up to 10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase-, lipase-, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina* and *R. bataticola* (RB-6)
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice

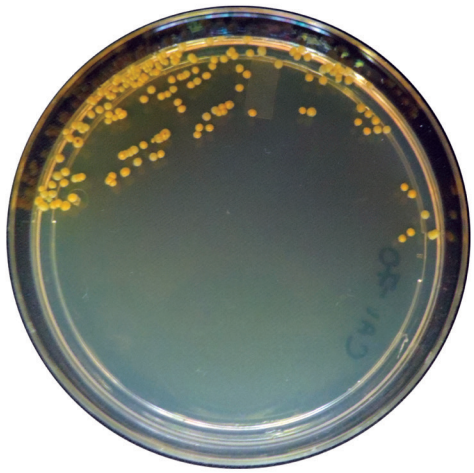
Isolate	CAI-67
Scientific name	*Streptomyces* sp.
GenBank accession number	KM191340
Isolated from	*Nerium* foliage compost
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 8% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm) and Thiram (3000 ppm) and sensitive to Captan (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Cellulase+, lipase+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina, R. bataticola* (RB-24 and RB-115), *F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)



Isolate	CAI-68
Scientific name	*Streptomyces* sp.
GenBank accession number	JQ682622
NBAIM accession number	NAIMCC-B-00884
Isolated from	*Nerium* foliage compost
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 8% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
Antibiotic resistance pattern	Tetracycline (30 ppm), chloramphenicol (50 ppm), kanamycin (10 ppm), streptomycin (200 ppm), nalidixic acid (100 ppm) and ampicillin (100 ppm)
PGP and biocontrol traits	Siderophore+, chitinase-, cellulase+, lipase+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	*B. cinerea*
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice



Isolate CAI-70	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770892
Isolated from	Rice straw compost
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 4% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm) and Thiram (3000 ppm) and sensitive to Captan (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and Bio-control traits	Siderophore+, cellulase+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina*, *R. bataticola* (RB-24 and RB-115)*, F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)
Entomopathogenic potential on	*H. armigera, S. litura* and *C. partellus*



Isolate CAI-78	
Scientific name	*Streptomyces* sp.
GenBank accession number	JQ682623
NBAIM accession number	NAIMCC-B-00593
Isolated from	*Parthenium* foliage compost
Physiological traits (tolerance) pH Temperature Salinity	 7–13 20–40°C Up to 10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
Antibiotic resistance pattern	Tetracycline (2 ppm), chloramphenicol (50 ppm), kanamycin (10 ppm), streptomycin (20 ppm), nalidixic acid (100 ppm) and ampicillin (up to 1800 ppm)
PGP and biocontrol traits	Siderophore-, chitinase-, cellulase+, lipase+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea* and *R. bataticola* (RB-6 and RB-24)
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice

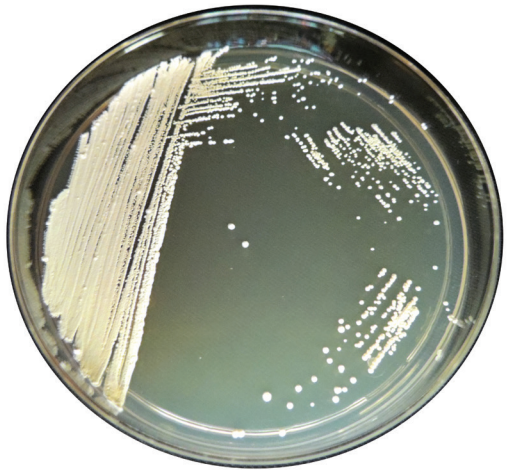
Isolate CAI-84	
Scientific name	*Streptomyces* sp.
Isolated from	*Pongamia* foliage compost
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 6% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), Ridomil (3000 ppm) and Captan (3000 ppm)
Antibiotic resistance pattern	Tetracycline (30 ppm), chloramphenicol (50 ppm), kanamycin (4 ppm), streptomycin (10 ppm), nalidixic acid (50 ppm) and ampicillin (up to 1800 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase-, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC and *B. cinerea*
Field evaluation done on	PGP on sorghum, chickpea and rice

Isolate CAI-85	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770897
Isolated from	*Pongamia* foliage compost
Physiological traits pH Temperature Salinity	 5–13 20–40°C Up to 6% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Thiram (3000 ppm), and sensitive to Benomyl (3000 ppm), Bentine (4000 ppm), Ridomil (3000 ppm) and Captan (3000 ppm)
Antibiotic resistance pattern	Tetracycline (50 ppm), chloramphenicol (10 ppm), kanamycin (2 ppm), streptomycin (2.5 ppm), nalidixic acid (100 ppm) and ampicillin (200 ppm)
PGP and biocontrol traits	Siderophore+, chitinase-, cellulase+, lipase-, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina* and *R. bataticola* (RB-24)
Entomopathogenic potential on	*H. armigera*, *S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice

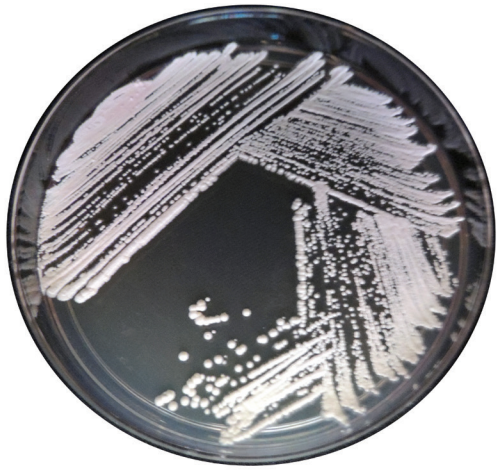
Isolate CAI-87	
Scientific name:	*Streptomyces* sp.
GenBank accession number:	KF770893
Isolated from:	*Pongamia* foliage compost
Physiological traits pH: Temperature: Salinity:	 7–11 20–40°C Up to 6% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), sensitive to Benlate (500 ppm), Ridomil (75 ppm) and Captan (1500 ppm)
Antibiotic resistance pattern:	Tetracycline (7 ppm), Chloramphenicol (25 ppm), Kanamycin (1 ppm), Streptomycin (20 ppm), Nalidixic acid (25 ppm) and resistant to Ampicillin (100 ppm)
PGP and Bio-control traits:	Siderophore+, chitinase+, cellulase+, lipase-, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on:	FOC, *B. cinerea*
Field evaluation done on:	PGP on sorghum, chickpea and rice

Isolate CAI-93	
Scientific name	*Streptomyces fungicidicus*
GenBank accession number	KF742498
Isolated from	Neem foliage compost
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
Antibiotic resistance pattern	Tetracycline (2 ppm), chloramphenicol (50 ppm), kanamycin (3 ppm), streptomycin (25 ppm), nalidixic acid (200 ppm) and ampicillin (up to 1800 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase-, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	*B. cinerea*, *M. phaseolina* and *R. bataticola* (RB-24 and RB 115)
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice

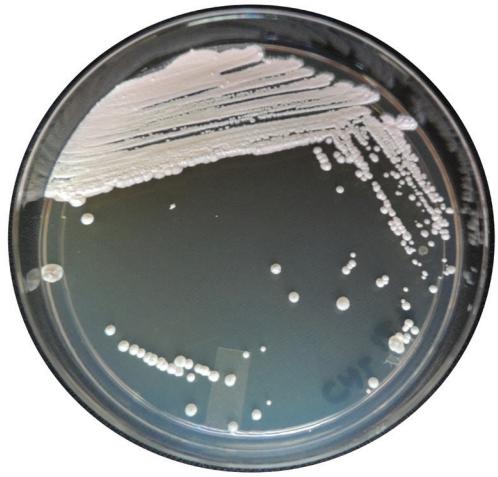
Isolate CAI-97	
Scientific name	*Streptomyces litmocidini*
GenBank accession number	
Isolated from	Rice straw compost
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 6% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), Ridomil (3000 ppm) and Captan (3000 ppm)
Antibiotic resistance pattern	Tetracycline (7 ppm), chloramphenicol (50 ppm), kanamycin (2 ppm), streptomycin (5 ppm), nalidixic acid (200 ppm) and ampicillin (up to 1800 ppm)
PGP and biocontrol traits	Siderophore-, chitinase+, cellulase+, lipase-, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina* and *R. bataticola* (RB-24)
Field evaluation done on	PGP on sorghum, chickpea and rice



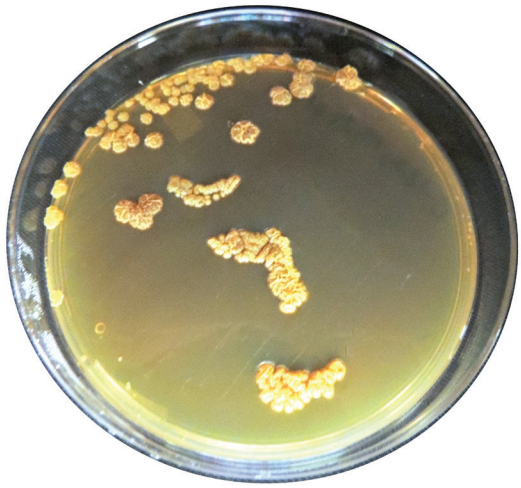
Isolate CAI-121	
Scientific name	*Streptomyces* sp.
GenBank accession number	JN400113
NBAIM accession number	NAIMCC-B-00890
Isolated from	*Chrysanthemum* foliage compost
Physiological traits pH Temperature Salinity	 5–13 20–40°C Up to 8% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
Antibiotic resistance pattern	Tetracycline (30 ppm), chloramphenicol (50 ppm), kanamycin (10 ppm), streptomycin (200 ppm), nalidixic acid (100 ppm) and ampicillin (200 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase-, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC and *B. cinerea*
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice and biocontrol on sorghum



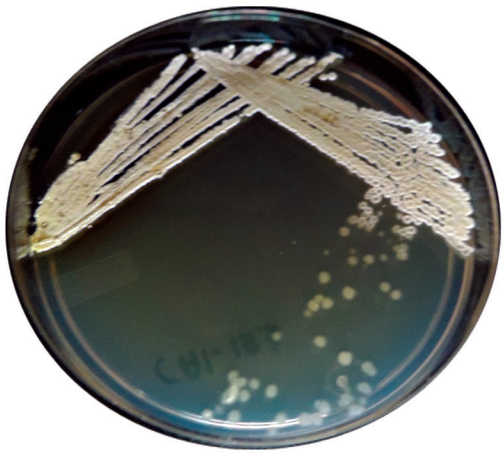
Isolate CAI-127	
Scientific name	*Streptomyces* sp.
GenBank accession number	JN400114
NBAIM accession number	NAIMCC-B-00885
Isolated from	Garlic foliage compost
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 8% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
Antibiotic resistance pattern	Tetracycline (30 ppm), chloramphenicol (50 ppm), kanamycin (10 ppm), streptomycin (200 ppm), nalidixic acid (100 ppm) and ampicillin (400 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC and *B. cinerea*
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice



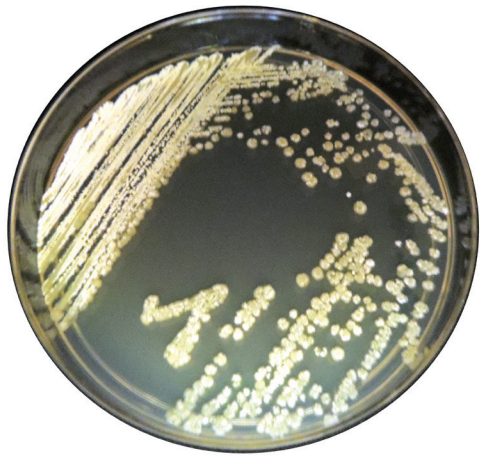
Isolate CAI-132	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770894
Isolated from	*Jatropha* seed compost
Physiological traits	
pH	7–11
Temperature	20–40°C
Salinity	Up to 6% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm) and sensitive to Captan (3000 ppm), Ridomil (3000 ppm), Thiram (3000 ppm), and Benlate (3000 ppm)
Antibiotic resistance pattern	Tetracycline (20 ppm), chloramphenicol (5 ppm), kanamycin (5 ppm), streptomycin (10 ppm), nalidixic acid (100 ppm) and ampicillin (1000 ppm)
PGP and biocontrol traits	Siderophore-, chitinase+, cellulase+, lipase-, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	*M. phaseolina*, FOC and *B. cinerea*
Entomopathogenic potential on	*H. armigera*, *S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum, chickpea and rice



Isolate CAI-133	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770895
Isolated from	*Jatropha* seed compost
Physiological traits pH Temperature Salinity	 7–11 20–50°C Up to 4% NaCl
Fungicide tolerance and sensitivity (at field application level)	Tolerant to Bavistin (2500 ppm) and sensitive to Captan (3000 ppm), Thiram (3000 ppm), Benlate (4000 ppm) and Ridomil (3000 ppm)
PGP and biocontrol traits	Siderophore+, cellulase+, lipase+, β-1,3-glucanase+, indole-3-acetic acid+ and hydrocyanic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina*, *R. bataticola* (RB-24 and RB-115), *F. proliferatum* (FM-242) and *F. andiyazi* (FM-943)
Entomopathogenic potential on	*H. armigera*, *S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum and chickpea



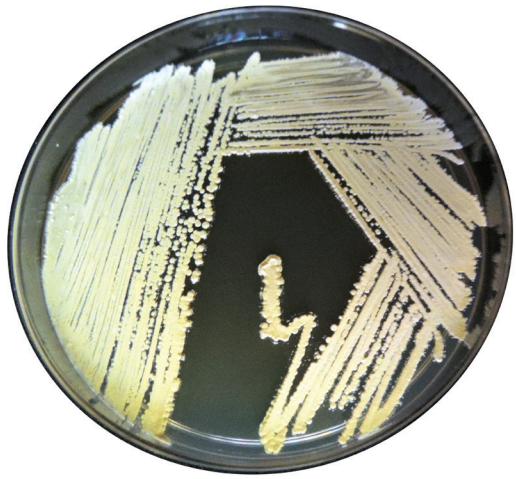
Isolate CAI-134	
Isolated from	*Jatropha* foliage compost
GenBank accession number	
Physiological traits pH Temperature Salinity	 7–13 20–40°C Up to 6% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
Antibiotic resistance pattern	Tetracycline (5 ppm), chloramphenicol (5 ppm), kanamycin (10 ppm), streptomycin (10 ppm), nalidixic acid (100 ppm) and ampicillin (1100 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase-, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC and *B. cinerea*
Field evaluation done on	PGP on sorghum, chickpea and rice



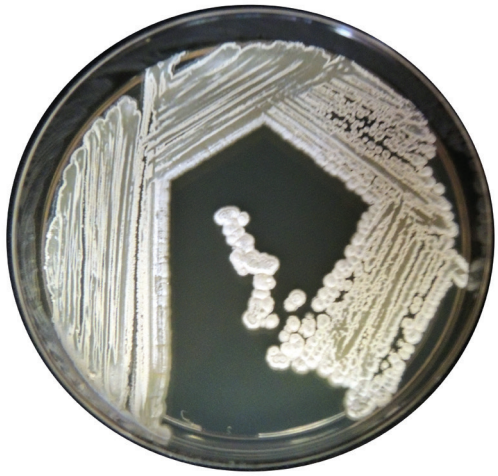
Isolate CAI-140	
Scientific name	*Streptomyces coelicolor*
GenBank accession number	KF742497
Isolated from	*Nerium* foliage compost
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), Ridomil (3000 ppm) and Captan (3000 ppm)
Antibiotic resistance pattern	Tetracycline (10 pm), chloramphenicol (5 ppm), kanamycin (10 ppm), streptomycin (10 ppm), nalidixic acid (100 ppm) and ampicillin (1000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase-, cellulase+, lipase+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina* and *R. bataticola* (RB-24)
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice

Isolate CAI-155	
Scientific name	*Streptomyces* sp.
GenBank accession number	KF770896
Isolated from	*Cascabela thevetia* foliage compost
Physiological traits pH Temperature Salinity	 7–13 20–40°C up to 6% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000 ppm)
Antibiotic resistance pattern	Tetracycline (10 ppm), chloramphenicol (5 ppm), kanamycin (10 ppm), streptomycin (10 ppm), nalidixic acid (100 ppm) and ampicillin (1000 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina* and *R. bataticola* (RB-6 and RB-24)
Entomopathogenic potential on	*H. armigera*, *S. litura* and *C. partellus*
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice

Isolate KAI-26	
Scientific name	*Streptomyces* sp.
GenBank number	JQ682624
Isolated from	Rice straw compost
Physiological traits pH Temperature Salinity	 7–11 20–40^{O}C Up to 10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm) moderately tolerant to Captan (3000 ppm) and Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), and Ridomil (3000ppm)
Antibiotic resistance pattern	Tetracycline (2 ppm), chloramphenicol (50 ppm), kanamycin (5 ppm), streptomycin (15 ppm), nalidixic acid (200 ppm) and ampicillin (up to 1800 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, hydrocyanic acid+ and indole-3 acetic acid+
Antagonistic potential	FOC, *B. cinerea* and *R. bataticola* (RB-6 and RB-24)
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice



Isolate KAI-27	
Scientific name	*Streptomyces* sp.
GenBank accession number	JQ682625
Isolated from	Rice straw compost
Physiological traits pH Temperature Salinity	 7–11 20–40°C Up to 10% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm) and sensitive to Captan (3000 ppm), Ridomil (3000 ppm), Thiram (3000 ppm), Benlate (3000 ppm)
Antibiotic resistance pattern	Tetracycline (11 ppm), chloramphenicol (10 ppm), kanamycin (5 ppm), streptomycin (10 ppm), nalidixic acid (100 ppm) and ampicillin (up to 1800 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase-, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea* and *R. bataticola* (RB-6 and RB-24)
Field evaluation done on	PGP on sorghum, chickpea, pigeonpea and rice



Isolate KAI-32	
Scientific name	*Streptomyces* sp.
GenBank accession number	JN400115
NBAIM accession number	NAIMCC-B-00887
Isolated from	Rice straw compost
Physiological traits pH Temperature Salinity	 5–13 20–40°C up to 8% NaCl
Fungicide tolerance and sensitivity (at field application level)	Complete tolerance to Bavistin (2500 ppm), moderately tolerant to Thiram (3000 ppm), and sensitive to Benlate (3000 ppm), Ridomil (3000ppm) and Captan (3000 ppm)
Antibiotic resistance pattern	Tetracycline (100 ppm), chloramphenicol (50 ppm), kanamycin (2 ppm), streptomycin (10 ppm), nalidixic acid (100 ppm) and ampicillin (up to 1800 ppm)
PGP and biocontrol traits	Siderophore+, chitinase+, cellulase+, lipase+, hydrocyanic acid+ and indole-3-acetic acid+
Antagonistic potential on	FOC, *B. cinerea, M. phaseolina* and *R. bataticola* (RB-6 and RB-115)
Field evaluation done on	PGP on sorghum, chickpea pigeonpea and rice and biocontrol on sorghum