Plant growth-promotion traits of *Streptomyces* sp. in pigeonpea

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Abstract: The aim of this study was to evaluate three strains of *Streptomyces* (CAI-21, CAI-26 and MMA-32), demonstrated previously to have potential for control of charcoal rot disease in sorghum and plant growth-promotion (PGP) in rice and chickpea, for their PGP traits in pigeonpea under field conditions in 2014 rainy-season. The *Streptomyces* enhanced the nodule number, nodule weight, root weight and shoot weight at 30 days after sowing (DAS) and branches, leaf area, stem weight and root weight at 60 DAS over the un-inoculated control. At crop maturity, the *Streptomyces* enhanced stover and grain yields over the un-inoculated control. The three *Streptomyces* were demonstrated for PGP activity in pigeonpea as well.

Key words: pigeonpea, plant growth promotion, *Streptomyces* sp., yield enhancement

Introduction

Pigeonpea (*Cajanus cajan* [L.] Millsp.) is an important grain legume crop in South Asia and East and Southern Africa. It is a rain-fed rainy season crop frequently subjected to both abiotic, such as drought and water logging, and biotic stresses, such as pod borer (*Helicoverpa armigera* Hübner), wilt (*Fusarium udum* Butler) and sterility mosaic diseases,resulting in severe yield losses. Global yields of pigeonpea have been relatively stagnant (762 kg ha^{-1}) (2) for the last five decades in spite of using various conventional and molecular breeding approaches.

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Hence, in the present study, it was proposed to use the strains of the PGP genus *Streptomyces* Waksman & Henrici as a tool to enhance the plant growth and yield of pigeonpea. *Streptomyces* is a Gram positive bacterium found abundantly in rhizosphere of agriculturally important crops.PGP potential of *Streptomyces* was reported on wheat (*Triticum* aestivum L.; 8), rice (*Oryza sativa* L.; 5), bean (*Phaseolus* spp.; 7), pea (*Pisum sativum* L.; 9), chickpea (*Cicer arietinum* L.; 6) and tomato (*Solanum lycopersicum* L.; 1). Previously, we demonstrated a set of three *Streptomyces* strains (CAI-21, CAI-26 and MMA-32) isolated from herbal vermi-compost, with the potential for bio-control of charcoal-rot disease, caused by *Macrophomina phaseolina* (Tassi) Goid., in sorghum (*Sorghum bicolour* (L.) Moench; 3) and for PGP in rice (4).

The objective of the present investigation was to further ascertain the efficacy of the three *Streptomyces* strains for their PGP traits in pigeonpea under field conditions.

Materials and methods

The experiment was done in 2014 rainy season at ICRISAT, Patancheru in India on vertisols. The experiment was laid out with three replicates and subplot sizes of 4 m × 2 ridges (1.2 m) in a randomized complete block design (RCBD). Seeds of pigeonpea (variety ICPL 88039; short duration [120 days] which yields about 1.6 t ha-^{1}) were treated individually with a *Streptomyces* strain (either CAI-21 or CAI-26 or MMA-32; 10^8 CFU ml^{-1}) for 45 min and sown by hand planting on 30 June 2014 (in rows 60 cm apart and 10 cm between plants) at a depth of 5 cm. Control plots contained no *Streptomyces*.

All the agronomic practices were done as and when required. At 30 days after sowing (DAS), the nodule number (plant^{-1}), nodule weight (mg plant^{-1}), root weight (g plant^{-1}) and shoot weight (g plant^{-1}) and at 60 DAS, number of branches (plant^{-1}), leaf area (cm^{-2} plant^{-1}), leaf weight (g plant^{-1}), stem weight (g plant^{-1}) and root weight (g plant^{-1}) were recorded. The crop was harvested manually on 27 October 2014. At crop maturity, plant height (cm), number of primary branches (plant^{-1}), shoot weight (g plant^{-1}), pod weight (g), number of pods (plant^{-1}), 100 seed weight (g), number of seeds (plant^{-1}), stover yield (g plant^{-1} and t ha^{-1}) and grain yield (g plant^{-1} and t ha^{-1}) were recorded.

Data were analysed by analysis of variance (ANOVA) in the software package SAS considering isolates and replication as fixed in RCBD.

Results and discussion

The plots treated with *Streptomyces* strains CAI-21, CAI-26 and MMA-32 showed significantly enhanced agronomic performance of all the traits measured including nodule number (up to 47%), nodule weight (up to 34%), root weight (up to 28%) and shoot weight (up to 11%) at 30 DAS and number of branches (up to 23%), leaf weight (up to 13%), leaf area (up to 26%), stem weight (up to 22%), and root weight (up to 22%) at 60 DAS over the un-inoculated control plots (Tables 1 and 2).

At crop maturity, the *Streptomyces* strains enhanced the plant height (up to 12%), number of primary branches (up to 14%), shoot weight (up to 22%), pod weight (up to 21%), number of pods (up to 15%), 100 seed weight (up to 28%), seed number (up to 27%), grain yield (up to 36%) and stover yield (up to 25%) over the un-inoculated control plots (Table 3).

Among the three strains of *Streptomyces* studied, CAI-26 enhanced most of the PGP traits and yield parameters. The mechanism by which the three *Streptomyces* strains consistently enhanced agronomical and yield traits on sorghum and rice (from our previous study) and pigeonpea (from this study) could be attributed to their ability to produce indole acetic acid, siderophores and β-1,3-glucanase activities (3, 4).

Table 1. Effect of the three *Streptomyces* sp. on agronomic performance of pigeonpea under field conditions at 30 days after sowing

Isolate	Nodule number (plant^{-1})	Nodule weight (mg plant^{-1})	Root weight (g plant^{-1})	Shoot weight (g plant^{-1})
CAI-21	4.6	1.3	254	2.27
CAI-26	5.4	2	214	2.12
MMA-32	7.8	2	203	2.18
Control	4.1	1.3	184	2.02
SE ±	0.25***	0.17*	9.5**	0.04**
LSD (5%)	0.87	0.6	33	0.15
CV%	8	18	8	4

SE = standard error; LSD = least significant differences; CV = coefficients of variation; *statistically significant at 0.05;**statistically significant at 0.01; ***statistically significant at 0.001

Table 2. Effect of the three *Streptomyces* sp. on agronomic performance of pigeonpea under field conditions at 60 days after sowing

Isolate	Number of branches (plant^{-1})	Leaf weight (g plant^{-1})	Leaf area (cm^{-2} plant^{-1})	Stem weight (g plant^{-1})	Root weight (g plant^{-1})	Total shoot weight (g plant^{-1})
CAI-21	10	9.98	2122	11.7	3.82	21.67
CAI-26	11.7	9.75	2031	10.61	3.29	20.37
MMA-32	10	8.76	1973	9.24	3.16	18.01
Control	9	8.73	1576	9.1	2.98	17.83
SE ±	0.17***	0.28*	84.8*	0.29**	0.13*	0.64**
LSD (5%)	0.58	0.96	293.6	0.99	0.46	2.21
CV%	3	5	8	5	7	6

SE = standard error; LSD = least significant differences; CV = coefficients of variation; *statistically significant at 0.05;**statistically significant at 0.01; ***statistically significant at 0.001

It is concluded that the *Streptomyces* strains studied in this investigation were apparently well adapted not only in sorghum and rice rhizosphere but also in the pigeonpea rhizosphere. Hence, these three strains are likely to be potential candidates for the discovery of novel secondary metabolites which may be of importance of various PGP and biocontrol applications. However, there is a need to do additional comprehensive research to exploit the potential of these PGP *Streptomyces* under different field conditions and commercialization.

Table 3. Effect of the three *Streptomyces* sp. on agronomic performance and yield potential of pigeonpea under field conditions at harvest

Isolate	Plant height (cm)	Number of branches (plant^{-1})	Stover weight (g plant^{-1})	Pod weight (g plant^{-1})	Number of pods (plant^{-1})	100-seed weight (g plant^{-1})	Seed number (plant^{-1})	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
CAI-21	150	8.7	22.03	17.03	53	12.33	177	1.73	1.37
CAI-26	161	9.7	28.09	21.4	52	15.93	198	2.25	1.75
MMA-32	148	9	22.17	17.17	45	11.73	160	1.66	1.36
Control	142	8.3	21.91	16.93	45	11.47	144	1.43	1.31
SE ±	1.0***	0.19**	0.77**	0.58**	1.6*	0.64**	3.6***	0.08**	0.07**
LSD (5%)	3.5	0.64	2.65	2	5.5	2.21	12.3	0.28	0.23
CV%	1	4	6	6	6	9	4	8	8

SE = standard error; LSD = least significant differences; CV = coefficients of variation; *statistically significant at 0.05;**statistically significant at 0.01; ***statistically significant at 0.001

References

(1) El-Tarabily KA (2008) Promotion of tomato (*Lycopersicon esculentum* Mill.) plant growth by rhizosphere competent 1-aminocyclopropane-1-carboxylic acid deaminase–producing *Streptomycete* actinomycetes. Plant Soil 308:161-174

(2) FAOSTAT (2013) FAOSTAT, Food and Agriculture Organization of United Nations, Rome, http://faostat3.fao.org

(3) Gopalakrishnan S, Kiran BK, Humayun P, Vidya MS, Deepthi K, Rupela O (2011) Biocontrol of charcoal-rot of sorghum by actinomycetes isolated from herbal vermicompost. Afr J Biotechnol 10:18142-18152

(4) Gopalakrishnan S, Humayun P, Vadlamudi S, Vijayabharathi R, Bhimineni RK, Rupela O (2012) Plant growth-promoting traits of *Streptomyces* with biocontrol potential isolated from herbal vermicompost. Biocontrol Sci Technol 22:1199-1210

(5) Gopalakrishnan S, Vadlamudi S, Bandikinda P, Sathya A, Vijayabharathi R, Rupela O, Kudapa B, Katta K, Varshney RK (2014) Evaluation of *Streptomyces* strains isolated from herbal vermicompost for their plant growth-promotion traits in rice. Microbiol Res 169:40-48

(6) Gopalakrishnan S, Srinivas V, Alekhya G, Prakash B, Kudapa H, Varshney RK (2015) Evaluation of *Streptomyces* sp. obtained from herbal vermicompost for broad spectrum of plant growth-promoting activities in chickpea. Org Agric 5:123-133

(7) Nassar AH, El-Tarabily KA, Sivasithamparam K (2003) Growth promotion of bean (*Phaseolus vulgaris* L.) by a polyamine producing isolate of *Streptomyces griseoluteus*. Plant Growth Reg 40:97-106

(8) Sadeghi A, Karimi E, Dahazi PA, Javid MG, Dalvand Y, Askari H (2012) Plant growth promoting activity of an auxin and siderophore producing isolate of *Streptomyces* under saline soil condition. World J Microbiol Biotechnol 28:1503-1509

(9) Tokala RK, Strap JL, Jung CM, Crawford DL, Salove MH, Deobald LA, Bailey JF, Morra MJ (2002) Novel plant-microbe rhizosphere interaction involving *Streptomyceslydicus* WYEC108 and the pea plant (*Pisum sativum*). Appl Environ Microbiol 68:2161-2171