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EFFECT OF PLANT GROWTH-PROMOTING *STREPTOMYCES* SP. ON PLANT GROWTH AND YIELD OF TOMATO AND CHILLI

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ABSTRACT

The family Solanaceae contains many vegetable species having great economic importance in agriculture. Tomato and chilli are the two most important vegetable crops in this family that are rich in essential nutrient and antioxidants . Plant growth-promoting rhizobacteria (PGPR) are widely reported to have beneficial effect on crop plants as they colonize on roots and accelerate plant growth by many ways. Ten strains of *Streptomyces* sp. *viz.* CAI-17, CAI-24, CAI-26, CAI-78, CAI-121,CAI-127, KAI-26, KAI-27, KAI-32 and MMA-32 were reported earlier by ICRISAT microbiologist group, to have plant growth-promoting (PGP) potential in rice, sorghum and chickpea; biocontrol potential against charcoal rot in sorghum and *Fusarium* wilt in chickpea. In the present investigation, the above ten strains were further evaluated for their PGP effect on growth and yield of tomato and chilli under field conditions. All the tested strains significantly enhanced growth parameters including plant height, number of branches and yield over the un-inoculated control. Among the ten strains, CAI-17, CAI-24 and KAI-32 were found to significantly enhance the yield of tomato while CAI-24, CAI-26 and KAI-32 strains significantly enhanced the yield of chilli over the un-inoculated control. Consortia of all ten strains also significantly enhanced the yield of chilli but not tomato. It is concluded that the selected strains of *Streptomyces* can be exploited for the growth promotion of tomato and chilli.

KEYWORDS: Tomato, chilli, actinomycetes, *Streptomyces* spp., plant growth-promotion

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) and chilli (*Capsicum annuum* L.) are the two most important vegetable crops belonging to the family Solanaceae. Tomato is a protective food because its nutrition value, and anti-oxidant properties. Tomato is the third largest grown and consumed vegetable crop in the world after potato and sweat potato. In India, the total area under tomato was 809 (000 ha), production 19697 (000mt) and productivity 24.2 (mt/ha) (Horticultural statistics at a Glance, 2017). Chilli is an important commercial vegetable crop as well as spices throughout the world. The crop is a rich sources of Vitamin A, B, C and K (Simonne *et al*., 1997) and it has seven times more vitamin C then orange (Shreya *et al*., 2014). The area and production of chilli in India was 287 (000 ha) and 3406 (000mt) (Horticultural Statistics at a Glance, 2017). Both crops are severally damaged by many insect pests, fungal and bacterial pathogens leading to huge economic losses to the farmers. The biotic stresses are normally managed by the usage of insect pest and disease resistant varieties (Witek *et al*., 2016), crop rotation and application of chemical pesticides (Srivastava and Sharma, 2014). However, these options are expensive and also many a times not successful. Further, the excessive use of chemical pesticides have serious environmental and health concerns and have detrimental impact on terrestrial and aquatic ecosystems. In order to overcome these potential problems, the usages of plant growth-promoting rhizobacteria (PGPR) are widely used as these are inexpensive and equally effective (Zaidi *et al*., 2015).

PGPR are known to colonize the rhizosphere and rhizoplane of the host plants and enhance the plant growth by direct (by production of growth hormones such as indole acetic acid [IAA], fixation of nitrogen and uptake of nutrients) and/or indirect (by systemic resistance and production of siderophore, hydrocyanic acid, lytic enzymes, antibiotics and lipopeptides) mechanisms. PGPR such as *Rhizobium, Pseudomonas, Bacillus* and *Streptomyces* were reported widely to help the plants not only by mobilizing the nutrients but also by controlling plant pathogens and insect pests (Gopalakrishnan *et al*., 2011a, b; Hariprasad, 2016).

Streptomyces are Gram-positive bacteria belonging to the order Actinomycetales and family Streptomycetaceae (Kämpfer, 2007). These are aerobic, filamentous and

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spore-forming bacteria. *Streptomyces* are mostly saprophytes and colonize on the rhizosphere and rhizoplane of the plant roots (Vurukonda *et al*., 2018). *Streptomyces* represent an excellent alternative for improving nutrient availability to crop plants and promoting innovation and sustainability in agricultural systems. These attributes may be due to features such as quorum sensing, controlled gene expression, multiplication rate, antibiotics, siderophore, cellulase, phytohormones, amino acid synthesis, chitinase, lipase, â-1, 3-glucanase and ACC-deaminase production. *Streptomyces*–plant interactions can be divided into bio-fertilization, bio-stimulation, and bio-protection (Hamdali *et al*., 2008; Sadeghi *et al*., 2012; Jog *et al*., 2014). *Streptomyces* are widely reported as biocontrol agent against phytopathogens and insect pest (Hariprasad, 2016) and for instance, management of *Fusarium* wilt in chickpea (Gopalakrishnan *et al*., 2011b, Anusha *et al*., 2019); *Botrytis* graymold (BGM) disease in chickpea (Vijayabharathi *et al*., 2018a, b) and dry root rot of chickpea (Gindi *et al*., 2018). *Streptomyces* have also been reported as plant growth promoter in various crops and increase the yield in rice, sorghum and chickpea (Gopalakrishnan *et al*., 2012, 2013a, b; 2015a, b, c), beans (Nassar *et al*., 2003), peas (Tokala *et al*., 2002) and vegetables such as tomato (El-Tarabily, 2008). In the present investigation, a total of ten *Streptomyces* strains (CAI-17, CAI-24, CAI-26, CAI-78, CAI-121, CAI-127, KAI-26, KAI-27, KAI-32 and MMA-32; previously reported as PGPR in rice, chickpea and sorghum) and their consortia were further evaluated for their PGP activity in tomato and chilli under field conditions.

MATERIAL AND METHODS

Streptomyces strains

Ten strains of *Streptomyces* spp. (CAI-17, CAI-24, CAI-26, CAI-78, CAI-121,CAI-127, KAI-26,KAI-27, KAI-32 and MMA-32) previously reported to have PGP activity in rice and chickpea (Gopalakrishnan *et al*., 2011a; 2011b; 2012; 2013; 2015a; 2015b; 2015c) and biocontrol potential against charcoal rot in sorghum and *Fusarium* wilt in chickpea (Gopalakrishnan *et al*., 2011a; 2011b) were further evaluated for their PGP potential in tomato and chilli.

Evaluation of *Streptomyces* sp. for their PGP potential in tomato and chilli under field conditions

The field evaluation trail was conducted during the post rainy season of 2016-17 at ICRISAT, Patancheru (17°302 N; 78°162 E; altitude 549 m) in peninsular India. Soils at the experiment site are Vertisols containing 52 per cent clay, 21 per cent silt and 26 per cent sand with pH of 7.7-8.5. The soil depth of the field used was 1.2m and this soil retained approximately 200 mm of plant-available water in a 120-cm soil profile. The fields were prepared into broad bed and furrows with beds 1.2 m wide flanked by 0.3-m furrows. Nitrogen (18 kg N ha^{-1}) and phosphorous (20 kg P ha^{-1}) as di-ammonium phosphate (DAP) were incorporated into the soil by surface application. A total of 12 treatments were made consisting of ten *Streptomyces* strains, one consortia (of all the ten strains) and one un-inoculated control. The experiment was laid out in a randomized complete block design (RCBD) with three replicates and individual plot size was 1.5 m × 2 m with a plant to plant and row to row spacing of 30 cm × 60 cm, respectively accommodating 35 plants per plot. In between the plots irrigation and drainage channels were made alternatively.

The ten test strains of *Streptomyces* were inoculated on starch casein broth (SCB) and incubated at rotary shaker for five days. Tomato (cultivar- Rhisika) and chilli (cultivar-HMC150) seeds were sown in small nursery pots and 15 days after sowing (DAS), seedlings were soaked with *Streptomyces* culture (10^8cfu/ml) for 30mins. The seedlings were transplanted at 4-5 cm depth. Booster dose of *Streptomyces* was applied on every 15 days by soil drenching method until the flowering stage. Control plots were maintained without application of *Streptomyces* strains. The plots were irrigated once in 7 to 10 days. The crop was kept weed free by manual weeding. No serious insect pest or phytopathogens attacks were observed during the cropping period. Ten plants of each plot were randomly selected for recording observations in each replication. Once the crop reached the fruiting stage, fruits were plucked once in 7 days. Data recorded include plant height, number of branches, number of fruits and weight of fruits for both tomato and chilli.

Statistical analysis

The field experiment data were subjected to ANOVA (GenStat 10.1 version 2007, Lawes Agricultural Trust, Rothamsted Experimental Station) to evaluate the efficiency of the ten PGP *Streptomyces* strains. Significance of differences between the treatment means were tested at $p = 0.01$ and 0.05.

RESULTS AND DISCUSSION

In tomato, the *Streptomyces* strains enhanced PGP traits including the plant height (up to 18%), shoot weight (up to 41%) and fruit yield (up to 57%), which was attributed by only three strains *viz.,* CAI-17, CAI-24 and KAI-32, that were found to significantly enhance fruit yield over the un-inoculated control. Consortia (of all the ten *Streptomyces* strains) also enhanced tomato plant height, shoot weight and fruit yield over the un-inoculated control but significant result was found in only one PGP trait i.e. plant height (Table 1).

In chilli, the *Streptomyces* strains enhanced PGP traits including plant height (up to 11%), shoot weight (up to 40%) and fruit yield (up to 51%), contributed maily by three strains *viz.,* CAI-24, CAI-26 and KAI-32, thatwere found to significantly enhance fruit yield over the un-inoculated control. Consortia (of all *Streptomyces* strains) also enhanced chilli plant height, shoot weight and fruit yield over un-inoculated control but significant result was found in CAI-24, CAI-26 and KAI-32 strains in two PGP traits such as shoot weight and fruit yield (Table 2).

Streptomyces sp. are widely reported to play an important role in growth promotion of many agriculturally important crops including cereals (such as rice, sorghum and wheat), pulses (such as chickpea, pigeonpea and green gram) and vegetable crops. *Streptomyces* are also reported to produce secondary metabolites of commercial interest. PGP *Streptomyces* are reported to produce 60per cent biologically active compounds in agriculture such as antifungal, antibacterial and PGP substances (Suzuki *et al*., 2000; Ilic *et al*., 2007; Khamna *et al*., 2009). Therefore, in the present study, we had selected ten strains of *Streptomyces*, previously reported to have PGP traits in rice, chickpea and sorghum, for evaluating their growth promotion traits in tomato and chilli.

In the present investigation, even though all the *Streptomyces* strains were found to enhance the fruit yield of both tomato and chilli, but only three strains namely CAI-17, CAI-24 and KAI-32 were found to significantly enhance tomato yield over un-inoculated control. In chilli also only three strains, namely CAI-24, CAI-26 and KAI-32, were found to significantly enhance fruit yield over un-inoculated control. Of the ten tested *Streptomyces* strains, only two, CAI-24 and KAI-32, were found to significantly enhance fruit yield of both tomato and chilli over un-inoculated control.

The ten *Streptomyces* strains studied in this study were earlier reported to produce Indole acetic acid, siderophore, hydrocyanic acid and â-1, 3-glucanase and lytic enzymes such as chitinase, cellulase, lipase and protease (Gopalakrishnan *et al*., 2011a, 2011b, 2012a, 2012b). Further, all these strains were also reported to enhance PGP traits in rice, chickpea and sorghum under field conditions (Gopalakrishnan *et al*., 2013a & b, 2015) and biocontrol traits against charcoal rot in sorghum and *Fusarium* wilt in chickpea (Gopalakrishnan *et al*., 2011a, 2011b). Hence, it can be concluded that the ten *Streptomyces* strains can be exploited for their PGP potential not only in cereals and legumes but also in vegetable crops such as tomato and chilli.

The ten *Streptomyces* strains used in this study are apparently well adapted not only to the chickpea, rice and sorghum rhizospheres, as reported earlier, but also to the tomato and chilli rhizosphere, as demonstrated in the current investigation. However, there is a need to determine the effectiveness of these strains under multi-location trials to understand the nature of their interaction with other native soil microflora and with other host plants and the environment. Further, the ten *Streptomyces* strains contains a broad range of PGP abilities and demonstrate multiple beneficial actions. Therefore, the selected test strains used in this investigation are potential candidates for the discovery of secondary metabolites of commercial interest and their usefulness in host plant resistance against a range of pathogens and insect pests.

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Table 1. Effect of ten *Streptomyces* strains for their PGP traits on tomato

Strains	At 40 DAS^		At harvest	
	Plant height (cm)	Branches ($plant^{-1}$)	Shoot weight (g $plant^{-1}$)	Yield (t ha^{-1})
CAI-17	59.7**	1.3	1.625	46.4*
CAI-24	57.7**	0.8	1.083	43.7*
CAI-26	57.3**	1.0	1.245	39.6
CAI-78	50.8	0.8	0.789	42.3
CAI-121	55.5	1.0	0.988	37.5
CAI-127	52.3	0.8	1.064	33.6
KAI-26	58.3**	1.3	1.378	36.8
KAI-27	55.7	0.7	1.273	37.4
KAI-32	61.3**	1.5	1.273	65.4*
MMA-32	59.8**	1.8	1.330	39.1
Consortia	58.5**	0.8	0.998	33.0
Control	51.2	1.2	0.960	28.3
Mean	56.4	1.1	1.167	40.3
LSD (5%)	6.15	1.33	0.581	14.72
CV%	6	72	23	17

Table 2. Effect of ten *Streptomyces* strains for their PGP traits on chilli

Strains	At 40 DAS^		At harvest	
	Plant height (cm)	Branches ($plant^{-1}$)	Shoot weight (g $plant^{-1}$)	Yield (t ha^{-1})
CAI-17	41.8	7.3	2.219**	13.09
CAI-24	39.8	7.2	1.639	22.10**
CAI-26	44.3*	8.0	1.697	17.43**
CAI-78	41.5	6.7	1.668	14.70
CAI-121	41.3	7.5	2.146**	11.06
CAI-127	35.3	5.5	2.683**	12.40
KAI-26	39.3	7.5	2.494**	11.34
KAI-27	40.5	8.0	1.537	13.56
KAI-32	43.0	8.3	1.639	21.69**
MMA-32	39.0	6.5	1.639	14.36
Consortia	41.0	7.8	2.291**	17.86**
Control	39.7	7.2	1.610	10.82
Mean	40.6	7.3	1.939	15.03
LSD (5%)	3.99	1.85	0.492	5.51
CV%	6	15	12	17

* : Statistically significant at 0.05, ** : Statistically significant at 0.01
^ : Days after sowing; LSD : Least significant difference; CV : Coefficient of variation

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