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Plant Growth Promoting Traits of Rhizospheric Actinobacteria

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Authors Contribution

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Abstract

Plant growth-promoting rhizomicroflora inhabit the rhizosphere of plants, enhance plant growth with the release of metabolites and also inhibit soil-borne plant pathogens. In the present study, a total of sixty actinobacterial isolates were obtained from soil samples collected from the rhizosphere of cowpea and finger millet crop fields at the University of Agricultural Sciences, Bangalore. All the isolates were screened for their plant growth promoting activities *viz*, ammonia production, indole acetic acid (IAA), gibberellic acid (GA_3) production, HCN production and phosphate solubilization. The results showed that the actinobacterial isolates differed in the levels of plant growth-promoting activities. Screening of the isolates for plant growth promoting traits, 26 isolates produced IAA and GA_3, out of which the most active IAA and GA_3 producers were UASBA46 and UASBA50, which produced 59.26 and 61.73 μgml^{-1} IAA, 24.28 and 25.31 μgml^{-1} GA_3, respectively. UASBA46 (21.48%) and UASBA50 (22.63%) isolates showed the highest phosphate solubilization. Most of the actinobacterial isolates were positive for siderophore and ammonia production. UASBA46 and UASBA50 isolates produced the highest concentration of ACC-deaminase activity of 0.12 and 0.13mmol α-ketobutyrate mg^{-1} h^{-1}, respectively. Further, these actinobacterial isolates were identified as *Streptomyces antibioticus* (UASBA50) and *Streptomyces* sp. (UASBA46) based on 16s rRNA partial genome sequencing.

Keywords : Actinobacteria, Plant growth hormones, IAA, GA_3, ACC deaminase, 16s rRNA

Plants are extensively colonized by a range of beneficial microorganisms and acquire a variety of plant-microbe interactions. Some of these interactions are beneficial, whereas some are detrimental to the plant. The microorganisms grow on plants as a resource of nutrients or habitat niche. In one such symbiotic interaction, the roots of many plants are infected by specific fungi (mycorrhizal association), rhizobia and actinobacteria (particularly streptomycetes) that help the plant to acquire nutrients from the soil.

Plant growth promoting rhizobacteria (PGPR) is a group of naturally occurring, free-living rhizosphere colonizing bacteria that improve plant growth, increase yield, enhance soil fertility and reduce pathogens as well as biotic or abiotic stresses (Vessey, 2003 and Kumar *et al*., 2014). PGPR helps the plants by producing plant growth phytohormones such as indole acetic acid (IAA), cytokinins and gibberellins (Marques *et al*., 2010), solubilization of inorganic phosphate (Jeon *et al*., 2003), asymbiotic nitrogen fixation (Khan, 2005), antagonistic effect against phytopathogenic micro organisms by producing siderophore, antibiotics and fungicidal compounds (Lucy *et al*., 2004; Barriuso *et al*., 2008 and Majeed *et al*., 2015).

Actinobacteria have been and remain the most fruitful source of microorganisms for all types of bioactive metabolites, including agroactive types. Over one thousand secondary metabolites from actinobacteria were discovered during 1988-1992. Most of these compounds are produced by various species of the

genus *Streptomyces*. About 60 per cent of the new insecticides and herbicides reported in the past 5 years originate from Streptomyces. It is also estimated that as many as three-quarters of all streptomycete species are capable of antibiotic production. Actinobacteria produce a variety of antibiotics with diverse chemical structures such as polyketides, b-lactams and peptides in addition to a variety of other secondary metabolites that have antifungal, anti-tumor and immunosuppressive activities.

Actinobacteria are present extensively in the plant rhizosphere and produce various agroactive compounds. In the last few years, this group of bacteria, due to its strong antimicrobial potential and soil-dominant saprophytic nature, gained much attention as plant growth promoters (PGP; Franco-Correa *et al*., 2010). Actinobacteria can actively colonize plant root systems, can degrade a wide range of biopolymers by secreting several hydrolytic enzymes and tolerate hostile conditions by forming spores (Alexander, 1977). Actinobacteria, especially *Streptomyces*, also exhibit immense biocontrol action against a range of phytopathogens (Wang *et al*., 2013). Actinobacteria can produce phytohormones (IAA) and siderophore as well as solubilize phosphate and promote plant growth (Jeon *et al*., 2003).

Cowpea and finger millet plays a very important role in providing nutritious food. Cowpea kernel contains essential amino acids, with high nutritional value food having minerals and vitamins, which are essential for good health. Their seeds contain carbohydrates (53%), crude protein (24%) and fat (2%). Besides the fruit, leaves, and flowers of cowpea are also consumed. Cowpea is also utilized as forage, hay and silage. Finger millet (*Eleusine coracana* L.) commonly known as 'nutritious millet' is the fourth most important small millet crop grown globally after sorghum, pearl millet and foxtail millet.

The main objectives of the present study are to isolate indigenous actinobacteria from the cowpea and finger millet rhizosphere, characterize these isolates based on morphological and physiological characteristics as well as by 16SrRNA gene sequence analysis, to screen actinobacteria for various plant growth promoting activities (PGPAs), such as IAA production, phosphate solubilization, siderophore production and *in-vitro* 1 - aminocyclopropane - 1 - carboxylate (ACC) deaminase activity.

Material and Methods

In-vitro screening of actinobacteria for their plant growth promoting activities.

Indole Acetic Acid (IAA) Production

The production of indole acetic acid (IAA) by actinobacteria isolates was determined as per the method outlined by Gordon and Weber (1951). Mycelial discs (8 mm) obtained from colonies grown at 28 ± 2 ºC for 5 days on YMEA (Yeast malt extract agar) were inoculated into 5 ml yeast malt extract broth containing 0.2 per cent L tryptophan, having a pH of 7.0 and the inoculated tubes were kept on shaking incubator at 125 rpm for 7 days at 28 ± 2 ºC. The culture tubes were then centrifuged at 11,000 rpm for 15 minutes. One milliliter of the supernatant was mixed with 2 ml of Salkowski reagent (one ml of 0.5 M $FeCl_3$ in 50 ml of 35% $HClO_4$) (Glickmann and Dessaux, 1995). The appearance of pink color indicated the IAA production. Optical density (OD) values were measured at 530 nm using a spectrophotometer. The amount of IAA produced was estimated against a standard curve of IAA and expressed as µg/ml of the culture filtrate.

Gibberellic Acid (GA) Production

Gibberellic acid (GA) production by the cultures was estimated as per the procedure of Paleg (1965). 25 ml of the culture filtrate was taken in a flask to which 2 ml of zinc acetate was added. After two minutes, two ml of potassium ferrocyanide was added and centrifuged at 10,000 rpm for 15 minutes. From this 5 ml of supernatant was taken and to this 5 ml of 30 per cent, HCl was added and incubated at 20 ^{0}C for 75 minutes. The blank sample was treated only with 5 ml of 30 per cent HCl and the absorbance of the sample and the blank was measured at 254 nm in a

The Mysore Journal of Agricultural Sciences

UV-visible spectrophotometer. The amount of GA present in the extract was calculated from the standard curve and expressed as µg/ ml of the medium. The standard curve of GA was prepared by using graded concentrations of GA.

Phosphate Solubilization

Actinobacteria were purified on SCA agar and then cultivated on an NBRIP medium containing tri-calcium phosphate (TCP) as an insoluble P source. The development of a clear zone around the colony on the culture plates was taken as a zone of phosphate solubilization.

Quantitative Estimation of P

The isolates showing a zone of solubilization on Pikovaskaya's agar were further examined for their ability to release Pi from TCP in a broth medium. One ml of three days grown culture of each isolate was inoculated into 50 ml of Pikovskaya's broth. One ml of the culture supernatant was taken in a 50 ml volumetric flask to which 10 ml of chloromolybdic acid was added and mixed thoroughly. The volume was made upto three fourth with distilled water and 0.25 ml chlorostannous acid was added and the volume was made to 50 ml with distilled water and mixed thoroughly. After 15 minutes, the blue colour developed was read in a spectrophotometer at 610 nm. Simultaneously, a standard curve was prepared using various concentrations of standard KH_2PO_4 (two ppm solution). The amount of phosphorous solubilized by the isolates was calculated from the standard curve and expressed as percent Pi released from the culture filtrate.

Potassium Solubilization

Actinobacteria were purified on starch casein agar and then cultivated on Aleksandrov agar containing potassium source. The development of a clear zone around the colony on the culture plates was taken as a zone of potassium solubilization.

Quantitative Estimation of Potassium Released from Insoluble Potash-Bearing Mineral

The isolates showing K solubilization zone on Aleksandrov's agar were further examined for their ability to release K in the broth. One ml of three days old culture of each isolate was inoculated into 25 ml of Aleksandrov's broth (Hu *et al.,* 2006).

Zinc Solubilization

Zinc solubilization was checked using zinc oxide as an insoluble zinc source. Spot inoculation of the isolates was done in the center of the modified Pikovskaya's agar medium. These plates were then incubated at 37° for 48 to 72 hrs. The development of a clear zone around the colony on the culture plates was taken as a zone of zinc solubilization.

Ammonia Production

Freshly grown actinobacterial cultures will be inoculated into one ml of peptone water and incubated at 28° for 7-12 days with shaking at 120 rpm. After incubation, 0.5ml of Nessler's reagent was added to each culture tube. The development of yellow to brown color indicated a positive result for ammonia production (Cappuccino and Sherman, 2005).

Siderophore Production

Actinobacterial isolates were inoculated to chromeazurol-S medium (CAS) agar plates. Plates were incubated at 28 ± 2 ºC for seven days. The orange halo zone surrounding the colonies indicated a positive for siderophore production.

ACC Deaminase Activity

Actinobacterial isolates were screened for their ability to utilize ACC (aminocyclopropane-1-carboxylic acid) as a sole N source by using MDF (modified nitrogen free-Dworkin and Foster) medium (Jacobson *et al.,* 1994). The actinobacterial isolates were inoculated to MDF agar plates and incubated at 28 ± 2 ºC for seven days. Growth indicated the ability of the isolates to utilize ACC as the sole N source.

Quantitative Estimation of ACC Deaminase Activity

ACC deaminase activity was assayed according to the modified protocol of Honma and Shimomura (1978) and Penrose and Glick (2003) which measures the amount of α-ketobutyrate produced by the

cleavage of ACC in the presence of ACC deaminase. The number of millimoles of α- ketobutyrate produced by this reaction is determined by comparing the absorbance at 540 nm of a sample to a standard curve of α- ketobutyrate ranging between 0.1 and 1.0 mmol.

Genomic DNA Isolation, PCR Amplification and Sequencing of the 16SrRNAGene

Total genomic DNA was isolated according to the alkaline lysis method. Universal Primers 27F52 AGAGTTTGATCMTGGCTCAG3 and 1492R2 TACGGYTACCTTGTTACGACTT32 were used for the PCR amplification of the 16SrRNA gene of the selected strains. Agarose gel electrophoresis (1%) was used for analyzing PCR product and the remaining mixture was purified by using a PCR Purification kit Purified PCR products were sequenced commercially by got sequenced by Chromegene Pvt. Ltd., Bengaluru, Karnataka. The obtained gene sequences were compared with others in the GenBank databases using the NCBI Nucleotide BLAST at http:// blast.ncbi.nlm.nih. gov/Blast.cgi. Sequences were submitted to NCBI Gene Bank database and accession numbers were obtained.

Results and Discussion

IAA Production and Gibberellic acid by Selected Actinobacteria : Qualitative analysis of cultures supernatant of selected actinobacterial isolates revealed the production of variable amounts of IAA. Twenty-five actinobacterial isolates were observed to produce the phytohormone indole-acetic acid ranging from 23.10-61.73 µg ml^{-1}. Maximum IAA production was reported in actinobacterial isolate UASB A50 (61.73 µg ml^{-1}) and UASBA46 (59.26 µg ml^{-1}). Khamna *et al.* (2010) also reported 36 actinobacterial isolates producing IAA, from rhizosphere soils of 14 Thai medicinal plants ranging from 5.5 to 144 µg/ml. Gibberellic acid is a plant growth regulator of economic importance (Gelmi *et al.,* 2002). For instance, maximum gibberellic acid production was observed in UASB A50-25.31 µg ml^{-1}.

Table 1

Indole Acetic Acid (IAA) and Gibberellic Acid (GA) production by the actinobacterial isolates

Actinobacterial isolates	IAA production µg ml^{-1})	GA production µg ml^{-1})
UASBA1	34.95 ^{l}	18.28 ^{g}
UASBA3	46.73 ^{f}	13.28^{l}
UASBA5	20.36 ^{r}	11.27 ^{n}
UASBA7	50.79 ^{d}	21.19 ^{d}
UASBA12	48.53 ^{e}	11.49 ^{mn}
UASBA13	37.43 ^{k}	14.29 ^{k}
UASBA18	40.34 ^{i}	14.31 ^{k}
UASBA21	43.80 ^{g}	11.29 ^{n}
UASBA22	51.23 ^{d}	21.57 ^{d}
UASBA24	43.88 ^{g}	14.60 ^{jk}
UASBA26	23.10 ^{op}	13.24 ^{l}
UASBA27	48.49 ^{e}	15.27 ^{i}
UASBA28	32.57 ^{m}	11.24 ^{n}
UASBA30	43.80 ^{g}	15.33 ^{i}
UASBA31	38.78 ^{j}	14.74 ^{j}
UASBA32	52.54 ^{c}	23.32 ^{c}
UASBA34	47.98 ^{e}	16.27 ^{h}
UASBA35	41.99 ^{h}	15.33 ^{i}
UASBA36	46.68 ^{f}	11.73 ^{m}
UASBA39	37.72 ^{k}	11.76 ^{m}
UASBA46	59.26 ^{b}	24.28 ^{b}
UASBA47	21.68 ^{q}	12.96 ^{l}
UASBA50	61.73 ^{a}	25.31 ^{a}
UASB A60	24.35 ^{n}	19.99 ^{e}
UASBA62	22.62 ^{op}	18.96 ^{f}

Note: Mean values followed by the superscript in each column do not differ significantly at Pd"0.05 level by DMRT

Phosphate, Potassium and Zinc Solubilization : Screening of actinobacterial isolates for P-solubilization potential revealed that 25 actinobacterial isolates solubilized tricalcium phosphate in the medium. P-solubilization index ranged from 0.20-1.50 cm, highest P solubilization recorded with isolate UASBA50 - 1.50 cm followed by UASBA46 - 1.30 cm. The isolates which were able to solubilize phosphate on Pikovskayas's medium were further evaluated for the amount of phosphate solubilized. The amount of phosphate solubilized by

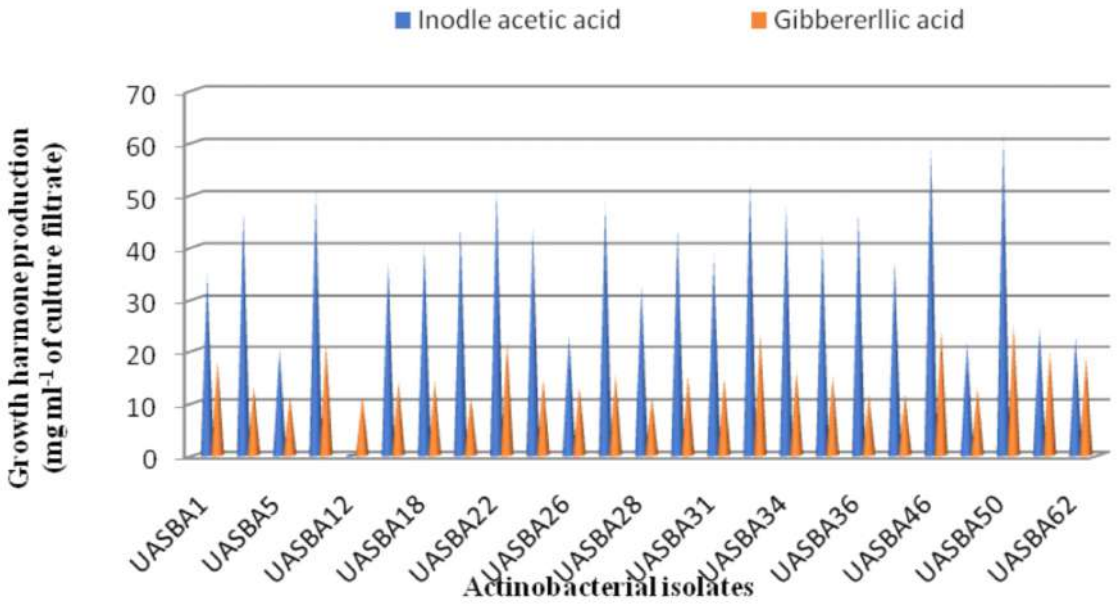

Fig.1: IAA and GA production (µg ml^{-1}) by actinobacterial isolates

actinobacterial isolates remained in the range of 6.66 to 22.63 per cent. The highest percent Pi solubilized was recorded in isolate UASB A50-22.63 per cent followed by UASB A46-21.48 per cent. Anwar *et al.* (2016) screened the phosphate solubilizing ability of actinobacterial isolates, among which six *Streptomyces* were able to solubilize phosphate. *Streptomyces* sp. WA-1 showed the highest phosphate solubilization index. The Highest K solubilization zone was observed in UASB A50 - 1.30 cm and quantitative estimation of potassium revealed actinobacterial isolate UASB A50 (6.30 µg ml^{-1}) which was isolated from cowpea rhizosphere. Archana (2007) isolated 30 K mobilizing bacterial isolates (mica as insoluble K source) from the soils of Belgaum and Dharwad districts of Karnataka and found that K mobilization by the actinobacterial isolates ranged from 2.41 µg/ml to 44.49 µg/ml. The Zn-solubilizing potential varied among these actinobacterial isolates as evidenced by the diameter of the halo or clear zone formed on Luria-Bertani agar plates. Zn-solubilization index ranged from 0.30 - 1.30 cm, maximum being recorded with isolate UASBA50 followed by UASBA46.

Ammonia, Siderophore Production and ACC Deaminase : Among twenty-five actinobacterial isolates screened for ammonia production, twenty-two

TABLE 2
Phosphate potassium and zinc solubilization efficiency of actinobacterial isolates under *in-vitro* condition

Actinobacterial isolates	Zone of solubilization (cm)	P*i* (%)at 10th day	Zone of solubilization K (cm)	Solubilization of K(µg ml^{-1})	Zone of solubilization Zn (cm)
UASBA1	0.80^{f}	14.21^{g}	0.60^{f}	3.60^{e}	-
UASBA3	0.40^{i}	7.53^{k}	0.20^{j}	1.00^{ijk}	-
UASBA5	0.40^{i}	6.66^{l}	0.20^{j}	0.90^{jkl}	-
UASBA7	1.00^{d}	19.48^{d}	0.80^{e}	4.30^{d}	0.60^{e}
UASBA12	0.50^{h}	8.32^{i}	0.30^{i}	1.20^{hi}	0.50^{f}
UASBA13	0.40^{i}	6.50^{l}	0.20^{j}	1.00^{ijk}	-

Actinobacterial isolates	Zone of solubilization (cm)	P*i* (%)at 10th day	Zone of solubilization K (cm)	Solubilization of K(µg ml^{-1})	Zone of solubilization Zn (cm)
UASBA18	0.20 ^{k}	3.90 ^{q}	0.10 ^{k}	0.80 ^{kl}	-
UASBA21	0.30 ^{j}	5.52 ^{mn}	0.10 ^{k}	0.80 ^{kl}	-
UASBA22	1.00 ^{d}	19.35 ^{d}	0.90 ^{c}	5.90 ^{bc}	0.80 ^{d}
UASBA24	0.30 ^{j}	5.67 ^{m}	0.20 ^{j}	0.80 ^{kl}	-
UASBA26	0.40 ^{i}	7.98 ^{ij}	0.30 ^{i}	1.30 ^{h}	0.40 ^{g}
UASBA27	0.80 ^{f}	14.78 ^{ef}	0.60 ^{f}	3.70 ^{e}	-
UASBA28	0.90 ^{e}	15.19 ^{e}	0.50 ^{g}	3.30 ^{fg}	0.50 ^{f}
UASBA30	0.60 ^{g}	9.62 ^{h}	0.40 ^{h}	3.10 ^{g}	-
UASBA31	0.40 ^{i}	7.69 ^{jk}	0.20 ^{j}	1.10 ^{hij}	-
UASBA32	1.20 ^{c}	21.01 ^{c}	0.90 ^{d}	5.80 ^{c}	0.90 ^{c}
UASBA34	0.30 ^{j}	5.16 ^{nop}	0.20 ^{j}	1.00 ^{ijk}	-
UASBA35	0.30 ^{j}	5.06 ^{op}	0.10 ^{k}	0.70 ^{l}	-
UASBA36	0.40 ^{i}	7.79 ^{jk}	0.30 ^{i}	1.10 ^{hij}	-
UASBA39	0.20 ^{k}	3.29 ^{r}	0.20 ^{j}	1.00 ^{ijk}	-
UASBA46	1.30 ^{b}	21.48 ^{b}	1.10 ^{b}	6.10 ^{ab}	1.20 ^{b}
UASBA47	0.20 ^{k}	3.65 ^{qr}	0.20 ^{j}	0.90 ^{jkl}	-
UASBA50	1.50 ^{a}	22.63 ^{a}	1.30 ^{a}	6.30 ^{a}	1.30 ^{a}
UASBA60	0.80 ^{f}	14.57 ^{fg}	0.60 ^{f}	3.50 ^{ef}	-
UASBA62	0.50 ^{h}	9.53 ^{h}	0.50 ^{g}	3.20 ^{g}	0.30 ^{h}

Note: Mean values followed by the same superscript in each column do not differ significantly at the Pd”0.05 level by DMRT

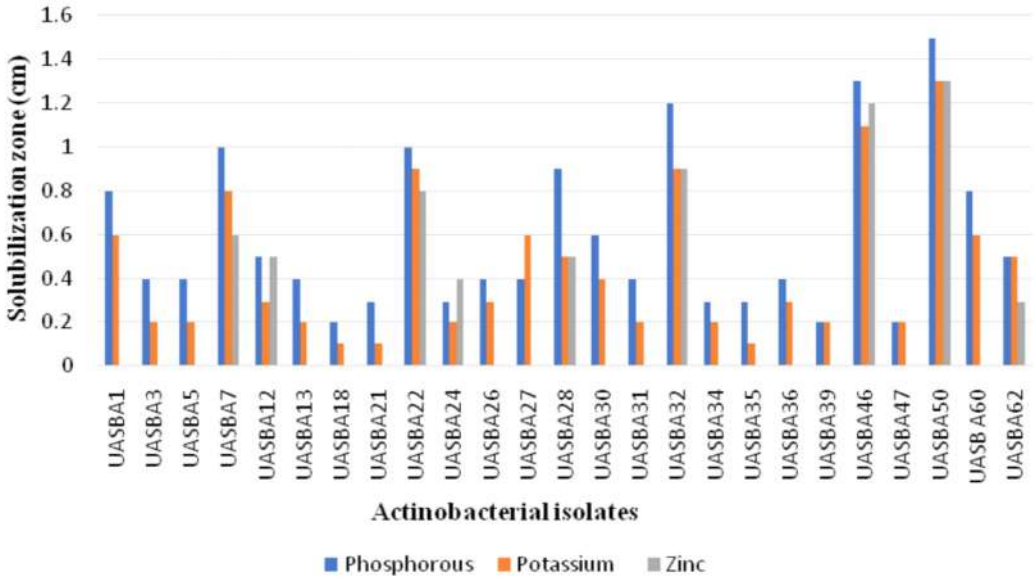

Fig.2: Solubilization of phosphorous, potassium and zinc by actinobacterial isolates (cm)

The Mysore Journal of Agricultural Sciences

isolates were found to be ammonia producers and most of the isolates were strong producers as indicated by the intensity of the color developed. Out of 25 isolates, 6 produced distinct orange halo on chrome azurol S (CAS) plates indicating siderophore production. Prasad *et al.* (2014) isolated 116 microorganisms from the rhizospheric soil of rice from nine different locations to understand the diversity of the microorganisms. Among these microorganisms, 110 were bacterial and only 6 were actinomycetes. All 6 actinobacteria showed positive results for the production of siderophore by forming orange-yellow halo zones on the CAS agar media plate. ACC deaminase production potential of actinobacterial isolates, 3 isolates (12%) were positive for ACC deaminase activity as they had a growth on DF-ACC agar plates with ACC as the sole source of nitrogen. The ACC deaminase enzymatic activity ranged from 0.04 mmol $mg^{-1} h^{-1}$ to 0.13mmol $mg^{1} h^{-1}$, indicating wide variations among the isolates. It is evident that among the 3 ACC deaminase positive actinobacterial isolates, two isolates (UASBA46 and UASBA50) recorded significantly higher ACC deaminase activity (0.12 and 0.13 mmol $mg^{-1} h^{-1}$ respectively). Siddikee *et al.* (2010) isolated several halotolerant actinobacterial strains with ACC deaminase activity from the soil of barren fields and the rhizosphere of naturally growing halophytic plants and found that they can increase canola plant growth.

Identification of Selected Actinobacterial Strains by 16srRNA Gene Sequencing : Two promising isolates were selected based on their ability to produce phytohormone IAA, solubilization of inorganic phosphates, ACC deaminase activity, siderophore and ammonia. For selected actinobacteria, single-band PCR products were achieved with universal primers. The sequences of the 16S rRNA gene were analyzed by comparison with sequences in GenBank through Nucleotide BLAST (http://www.ncbi.nlm.nih.gov/BLAST). After comparison, strains UASBA46 showed 96.71% similarity with *Streptomyces* sp. While the strains UASBA50 showed 99 per cent similarity with *Streptomyces antibioticus.* The sequences from strains UASBA46 and UASBA50 have been deposited in the NCBI GenBank and accession numbers were obtained (Table 4). A total of 15 actinobacteria from the East Black Sea Region plateau soil were isolated by using the sucrose gradient method and different growth media. In the light of phylogenetic analysis, it was determined that out of 15 organisms, two belong to *Actinomadura*, three *Kribbella*, three *Nocardia*, six *Micromonospora* and an organism of *Microbacterium*. Elaborate the discussion by adding recent literature.

Microbes and plants are keys to the sustenance of life on the planet earth. They are the drivers of natural processes, like biogeochemical cycles, maintenance of various ecological habitats (supporting specific

TABLE 3

Ammonia, siderophore production and ACC deaminase activity by actinobacterial isolates

Actinobacterial isolates	Ammonia production	Siderophore production	ACC deaminase activity			ACC deaminase activity (mmol α-ketobutyrate $mg^{-1} h^{-1}$)
			+N	-N	+ACC	
UASBA1	-	-	-	-	-	-
UASBA3	+	-	+	-	-	-
UASBA5	+	+	+	-	-	-
UASBA7	+	+	+	-	-	-
UASBA12	+	+	-	-	-	-
UASBA13	-	-	+	-	-	-
UASBA18	+	-	-	-	-	-

Actinobacterial isolates	Ammonia production	Siderophore production	ACC deaminase activity			ACC deaminase activity (mmol α-ketobutyrate $mg^{-1} h^{-1}$)
			+N	-N	+ACC	
UASBA21	-	-	+	-	-	-
UASBA22	-	-	+	-	-	-
UASBA24	+	-	-	-	-	-
UASBA26	+	-	+	-	-	-
UASBA27	+	-	+	-	+	0.04
UASBA28	+	-	-	-	-	-
UASBA30	+	-	+	-	-	-
UASBA31	+	-	+	-	-	-
UASBA32	+	-	+	-	-	-
UASBA34	+	-	+	-	-	-
UASBA35	+	-	-	-	-	-
UASBA36	+	-	-	-	-	-
UASBA39	+	+	+	-	-	-
UASBA46	+	+	+	+	+	0.12
UASBA47	+	-	-	-	-	-
UASBA50	+	+	+	-	+	0.13
UASBA60	-	-	-	-	-	-
UASBA62	+	-	+	-	-	

Note: + : Positive, - : Negative

Plate 1: IAA production

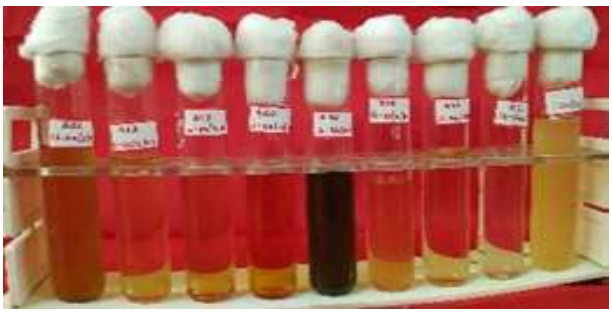

Plate 2: GA solubilization

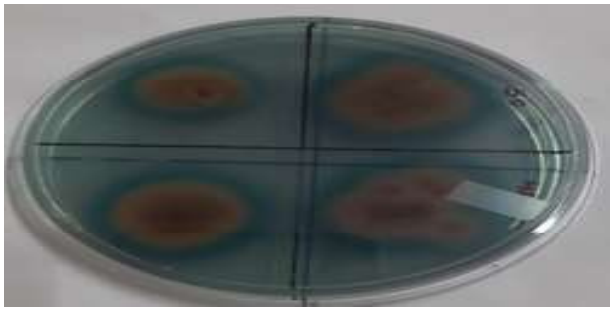

Plate 3: Siderophore production

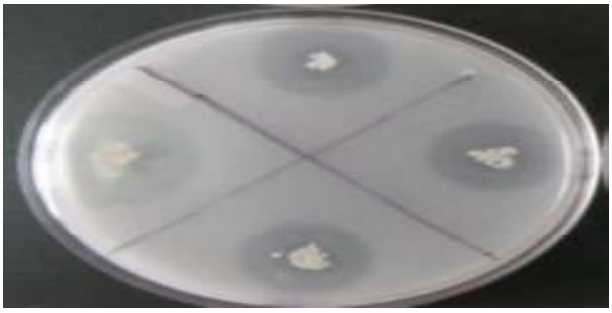

Plate 4: Phosphate solubilization

TABLE 4

Actinobacterial isolates and their nearest match identity by 16S rRNA partial genome sequencing

Actinobacterial isolate	Closest match	NCBI number accession	Percent Identity	Accession
UASB A46	*Streptomyces* sp. strain A2 16s ribosomal RNA gene, partial sequence	MT967491	96.71%	KX641026.1
UASB A50	*Streptomyces antibioticus* strain 66 1 6s ribosomal RNA gene, partial sequence	MT967490	97.63%	MK430540.1

flora and fauna under such special niches), production of oxygen, utilization of carbon dioxide, production of organic compounds used as food, feed and medicine. These naturally thriving and beautifully maintained biosystems have come under serious threat due to deleterious consequences of rampant industrialization and unthoughtful use of a myriad of chemicals for human, animal and agricultural purposes. These problems have drawn the attention of the researchers to find the appropriate remedy. It is during such endeavors that we are learning more about various biotic and abiotic factors, which interact in a very rationale and scientific manner to balance and sustain each other. Actinobacteria and their host plants provide an exciting model to explore and understand their biology and chemistry to develop suitable, non-deleterious applications for human health, agriculture and the environment.

The study revealed that the soil rhizospheric actinobacteria are potential microbial inoculants because of the intense PGP activities such as IAA production, phosphate solubilization, siderophore and HCN production and ACC deaminase production. The strains reported in this study are promising candidates to be developed as commercial biofertilizer formulations and can also be exploited for the production of various agro-active compounds like auxin.

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