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Research Article

Fluorescent pseudomonads, an antidote and drought stress mitigating PGPR from groundnut (*Arachis hypogaea* L.) rhizosphere

B. PRASANNA KUMAR[1*], N. TRIMURTULU[1], A. VIJAYA GOPAL[1], V. PADMA[1] and P. MADHU VANI[2]

[1]*Department of Agricultural Microbiology, APGC, ANGRAU, Lam, Guntur - 522 034, Andhra Pradesh, India*

[2]*Department of Soil Science, Regional Agricultural Research Station, ANGRAU, Lam, Guntur - 522 034, Andhra Pradesh, India*

**Corresponding author E-mail:* badde.prasannakumaragrico@gmail.com

ABSTRACT: Fluorescent pseudomonads drawn broad attention as production of secondary metabolites, phytohormones, siderophores, enzymes, antibiotics, hydrogen cyanide and volatile compounds. The present study was to exhilarate traits of plant growth promotion by fluorescent pseudomonads under drought stress. Fifty one efficient bacterial isolates were taken to evaluate their growth in different concentrations of polyethylene glycol 6000 (PEG) at 0 % (-0.05 MPa), 10 % (-0.65 MPa), 20 % (-1.57 MPa), 30 % (-2.17 MPa) and 40 % (-2.70 MPa). On the basis of growth at higher PEG (40 %) concentration, four efficient bacteria were preferred. Plant growth promoting traits such as IAA, exopolysachharides (EPS) production, ACC deaminase activity, phosphate solubilization and potassium releasing characters were tested for the selected drought tolerant fluorescent pseudomonads. Among four efficient strains, two strains i.e., PCKR-2 showed P-solubilization Index was (3.80 mm), followed by AGVS (4.33 mm), PCKS (4.12 mm) and PVAS (2.28 mm). Data on potassium solubilization activity show that out of two isolates, PCKR-2 showed the highest solubilization zone (3.50 mm), followed by PCKS (3.17 mm), AGVS (2.83 mm) and PVAS (2.50 mm). The findings suggests that the use of fluorescent pseudomonads will aid better plant growth promotion under drought stress.

KEY WORDS: Antibiotics, drought stress, fluorescent pseudomonads, metabolites, polyethylene glycol 6000

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INTRODUCTION

Peanut or groundnut (*Arachis hypogaea* L., Fabaceae), one of the five most important oilseed crops, serves as a good source of protein, calories, vitamins and minerals. It is consumed both as oilseed and livestock fodder, forming an important revenue source for farmers as well as for commercial producers. Peanut is known to be more tolerant to drought stress than most other related plant species. About 60% of the world peanut production comes from the semi-arid tropics such as Africa, Asia, North, and South America. In recent years, various studies have emerged implicating that the root external environment (rhizosphere) also to be involved in a wide range of stress tolerances in plants, including high salinity, drought and pathogen infection, which provides a novel direction in future improvement of stress tolerance of peanut crop via modifying the soil microbial community (Mateus *et al*., 2019). However, studies on the peanut rhizosphere are scarce.

Rhizosphere-associated microbes possess diverse metabolic capabilities and play crucial roles in the rhizosphere ecosystem, including nutrient cycling and organic matter decomposition, which exert positive effects on plants' health and growth. More importantly, the microbial community can also play a crucial role in plant growth and adaptation to various environmental stresses. Over the past decade, various studies have emerged emphasizing the role of the microbial community in enhancing plants stress tolerance by providing a buffer zone for plants against stress, production of various plant growth promoting hormones and enhancement of nutrient availability (Geng *et al*., 2018). The changed microbial community during stress may, at least in part, have implications for plant survival and health. There is a need to identify root-associated microbial communities that thrive under adverse environments and can confer stress tolerance and potentially be advantageous to the host.

During drought stress, phytohormones like abscisic acid, gibberellins, cytokinins, auxins, exopolysaccharides, phosphate solubilization, bacterial biofilm and enzymes like 1-aminocyclopropane 1-carboxylate (ACC) deaminase reduce the level of ethylene in the developing roots and play various roles in plant microbe interactions (Glick, 2012). Bacteria can withstand during stress conditions because of the production of exopolysaccharides, during water stress conditions

(Bashan *et al*. 2004). Field application of microorganisms having drought tolerant ACC deaminase may influence the plant growth (Venkateswarlu *et al*., 2008). Ethylene synthesis by 1-aminocyclopropane-1-carboxylic acid breakdown by ACC-deaminase enzyme which decreases the loss of different stress situations by increasing physiological conditions in the plant roots, at an early stage of stress conditions (Ali *et al*., 2009). Important fluorescent species like *P. aeruginosa*, *P. fluorescens*, *P. putida* (Bhattacharyya and Jha, 2012), which can produce secondary metabolites like volatile compound hydrogen cyanide (HCN), phytohormones and antibiotics (Saber and Ramadan, 2015). Pseudomonads of 16S rRNA group I having the capability to produce soluble yellow-green pigment pyoverdines (PVDs) or pseudobactins (Bultreys and Maraite, 2003) which act as siderophores. Fluorescent pseudomonads are considered as effective biological control agents across soil-borne plant pathogens because of their colonization within the plant roots (Lugtenberg *et al*., 2001). The study was aimed to assess the microbial community associated with the peanut rhizosphere and provide insights into the interaction with respect to the developmental stages of the plant and drought stress tolerance.

MATERIALS AND METHODS

The present experiment was conducted during 2017-18 and carried out at Department of Agricultural Microbiology, Advanced Post Graduate Centre, Acharya N.G. Ranga Agricultural University, Lam, Guntur and Agricultural Research Station, Amaravathi, Guntur district. The overall methodology and materials used in this experiment was explained and discussed under the following headings.

Soil samples collection

Forty-eight soil samples were collected from different villages of four mandals in the Anantapur (Upland) and Prakasam (Coastal) districts for the isolation of drought stress tolerant bacterial strains. The soil samples were mainly collected from groundnut rhizosphere fields along with their GPS Coordinates (Fig. 1). Crop plants were selected randomly in the field and dug out with the intact root system and transferred, carefully into the plastic bags, labeled well and stored at 4°C.

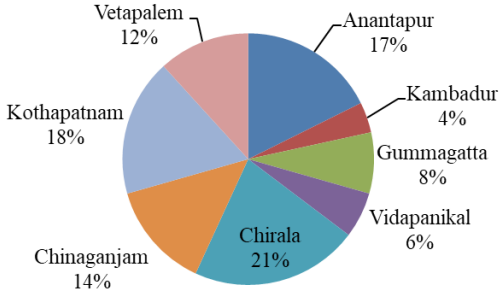

Fig. 1. Percent distribution of efficient bacterial isolates

Isolation of *fluorescent pseudomonad* isolates from different rhizosphere soils

For isolation of rhizobacteria, the method proposed by Vlassak *et al.* (1992) was followed. In this procedure, 10 g of soil from each soil sample was taken in a conical flask of 90 ml saline. The sample was agitated for 15 minutes on a vortex and serial dilutions of soil suspensions were prepared. 0.1 ml of the sample was spread on Nutrient agar media in the petri plates, which were then incubated at room temperatures (28 °C ± 2 °C) for 24-72 h. Two replicates were maintained for each dilution. The plates were examined daily up to 3 days for bacterial colonies

Cultural characterization

The plates incubated for a day at 30±1 °C were observed for the growth of fluorescent *Pseudomonas* colonies on Nutrient agar media where colonies were further confirmed by using KB plates. The colonies were enumerated manually and recorded. All the bacterial isolates were studied for their colony morphology, cell morphology (Gram reaction), pigmentation, spore production and other characteristics according to the standard methods described in Bergey's Manual of Determinative Bacteriology (Holt *et al*., 1994; Cappucino, 1983).

In vitro screening of bacterial isolates for plant growth promoting traits

Drought tolerance

Fifty one bacterial isolates were obtained from rhizosphere soils of groundnut crop. All the bacterial cultures were retrieved from glycerol stocks and tested for drought tolerance ability by growing in nutrient broth or tryptic soya broth at different water potential, prepared by the addition of appropriate concentrations of poly ethylene glycol 6000 (PEG) *viz.* 0%, 10%, 20%, 30% and 40% (w/v) (Busse and Bottomley, 1989). 10 ml broth was inoculated with one percent inoculum of 24 h old culture (Sandhya *et al*. 2009). All the forty four firmibacterial cultures were inoculated in each concentration of PEG in triplicates and incubated at 28±2°C for 48 h. Growth was measured in terms of optical density values at 600 nm in spectrophotometer (Shimadzu, Japan) after incubation.

EPS production

Bacterial strains grown on YMG agar medium were inoculated on YMG broth and preincubated at 25 °C for

24 h. 200 µl of culture broth was inoculated into 50 ml of YMG broth and incubated at 25 °C for 5 days at 120 rpm. Elimination of cells was followed by centrifugation (10,000 g for 20 min). The culture broth was mixed with 3 volumes of ethanol and after standing at 4 °C for 24 h (Ashok *et al*., 2011), it was centrifuged (10,000 g, 4°C, 20 min). The weight of the precipitated EPS was measured after drying at 80 °C for 3 days (Ali et al., 2013).

Indole Acetic Acid production

The production of Indole acetic acid was done according to Duby and Maheswari, 2012. LB broth was prepared and 24 hrs old cultures were inoculated into the broth and incubated at 28 °C for 72 h. After the incubation period, the cultures were centrifuged at recommended rpm and time. 2 ml of supernatant was collected into a test tube and two drops of O-phosphoric acid was added. Salkowski reagent was prepared and added into the test tube double the amount of supernatant. To prepare Salkowski reagent 0.4 gms of ferric chloride was added into 5 ml of distilled water and 17.5 ml of perchloric acid was added into 32.5 ml of distilled water and mixed the ratio of 1:150. Incubate the tubes for 30 min in dark. Development of pink color after the respective incubation period indicates the positive test for IAA production.

Screening for 1-Aminocyclopropane-1-carboxylate (ACC) Deaminase Activity

Screening for ACC deaminase activity of drought-tolerant PGPR isolates was done based on their ability to use ACC as a sole nitrogen source. All drought tolerant PGPR isolates were grown in 5 ml of trypticase soya broth (TSB) medium incubated at 28 ^{0}C at120 rpm for 24 hrs. The cells were harvested by centrifugation at 3000 g for 5 minutes and washed twice with sterile 0.1 M Tris-HCl (pH 7.5) and resuspended in 1 ml of 0.1 M Tris-HCl (pH 7.5) and spot inoculated on petri plates containing modified DF (Dworkin and Foster) salts minimal medium 10 ml and distilled water 990 ml, supplemented with 3 mM ACC as sole nitrogen source. Plates containing only DF salts minimal medium without ACC as negative control and with $(NH_4)_2 SO_4$ (0.2 % w/v) as a positive control. The plates were incubated at 28 °C for 72 hrs. Growth of isolates on ACC supplemented plates was compared to negative and positive controls and was selected based on growth by utilizing ACC as a nitrogen source (Honma and Shimomura, 1978).

Phosphate Solubilizing Activity

Phosphate solubilization activity was determined using Pikovskaya's agar medium containing 0.5 % (W/V) $Ca_3(PO_4)_2$ (Pikovskaya, 1948). Pikovskayas agar plates were prepared and sterilized. The inoculums were spot inoculated on the pikovskayas plate. 24 hrs old culture was used for the inoculation. The plates were incubated for 72-96 hrs at room temperature. The clear zone was observed around the spotted area after the incubation period.

Potassium releazing ability

Potassium solubilization determined using Aleksandrov medium containing 0.2% potassium aluminum silicate (Prajapati and Modi, 2012). KMB media was prepared and sterilized. The 24 hrs old culture was spot inoculated on the KMB plates and incubated for 72 hrs at room temperature. Plates were observed for the clear zone around the spotted area after the incubation period (Sugumaran and Janarthanam, 2007).

RESULTS AND DISCUSSION

The bacterial isolates took about 48h to establish their presence on Kings medium B agar. The colony morphology for bacterial isolates are glistening, smooth, small to medium, convex elevation and were tested further by the gram reaction (Shukla *et al*., 2016; Kachhap *et al*., 2015). Among the fifty one drought tolerant bacterial isolates, (Table 1, Fig. 2.) twelve isolates were recorded for the highest optical density at 600 nm, among these, two bacterial isolates were confirmed as fluorescent pseudomonads which are reconfirmed by *gram-negative*, rods as noticed under a microscope (Sharma *et al*., 2014). These two isolates showed yellowish green to light pigmentation, under fluorescent light (Fig. 3). Morpho and cultural characters of the bacterial isolates selected on KB medium was also recorded for pigmentation. Around thirty colonies were selected, purified and were stored in the refrigerator at 4°C. Our results are in agreement with Basha *et al*., (2014) obtained 50 *Pseudomonas fluorescens* and 28 *Rhizobium* isolates from rhizospheric soil and root nodules of redgram, identified and characterized biochemically as *Rhizobium* and *Pseudomonas fluorescens*. Akter *et al.,* (2014) who isolated 325 bacteria has reported 14 of them as fluorescent pseudomonads by morphological and biochemical characterization.

Morphological and cultural characteristics of isolates

Fluorescent pseudomonads took about 48 h to grow on Kings medium B agar plate. Isolates are small size, round margin, white, dull white and smooth colonies. Isolates producing yellowish green to light green pigmentation, glistening, opaque, convex, viscid colonies. In the microscopic studies, these isolates exhibited gram -ve nature with single, isolated, rod-shaped cells with no endospores.

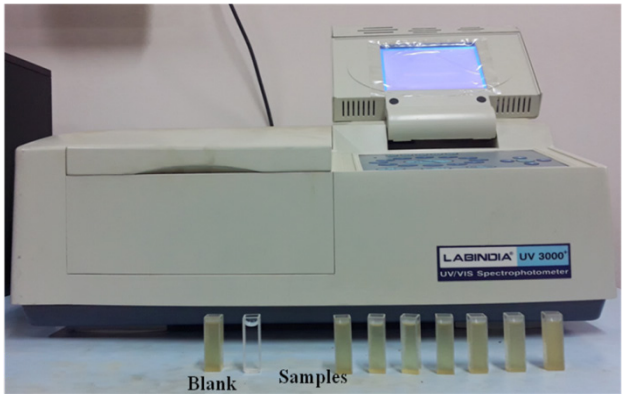

Fig. 2. Optical density (600 nm) of drought tolerant fluorescent pseudomonads

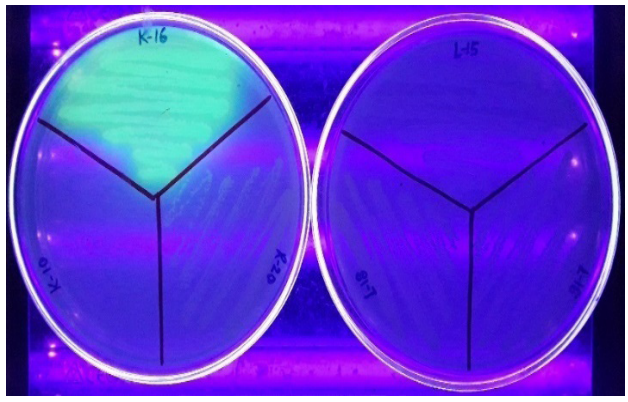

Fig. 3. Kings B Media plate with fluorescent pseudomonads under Ultra-Violet (UV) transilluminator

Table 1. Performance of bacterial isolates against polyethylene glycol 6000 (PEG 6000)

S.No	Name of the isolate	Bacterial growth at various levels of PEG 6000				
		0 % PEG	10 % PEG	20 % PEG	30 % PEG	40 % PEG
		(-0.05 MPa)	(-0.65 MPa)	(-1.57 MPa)	(-2.17 Mpa)	(-2.70 Mpa)
1	**AKPN**	0.475	0.151	0.100	0.055	0.073
2	**PKRN**	0.907	0.117	0.145	0.099	0.087
3	**PVKN-1**	0.597	0.144	0.136	0.090	0.078
4	**PVKN-2**	1.315	0.124	0.134	0.063	0.060
5	**AGPS**	1.111	0.144	0.178	0.082	0.208
6	**AVVS-1**	1.459	0.460	0.261	0.126	0.214
7	**AVVS-2**	1.340	0.591	0.659	0.311	0.228
8	**PCMS-1**	1.004	0.572	0.259	0.121	0.216
9	**PCKS-1**	1.558	0.357	0.143	0.095	0.218
10	**PCKS**	0.284	0.096	0.100	0.094	0.083
11	**PKRS-1**	0.415	0.097	0.087	0.073	0.074
12	**PKRS-2**	0.497	0.096	0.067	0.072	0.078
13	**PVAS-1**	1.205	0.099	0.100	0.096	0.072
14	**PVAS-2**	0.791	0.099	0.097	0.077	0.070
15	**AAAS**	0.151	0.079	0.051	0.000	0.158
16	**AAKS**	0.245	0.124	0.129	0.026	0.179
17	**AGVS**	0.690	1.380	0.170	0.042	0.157
18	**PCKS**	1.171	1.224	0.596	0.015	0.149
19	**PKRS**	1.825	1.632	1.290	0.401	0.182
20	**PVAS**	1.462	1.361	0.882	0.577	0.591
21	**AKPL**	2.037	0.286	0.523	0.782	0.257
22	**PCTL-1**	2.016	1.190	0.984	0.905	0.245
23	**PCTL-2**	2.097	0.664	0.974	0.953	0.199
24	**PCKL-1**	1.918	0.253	0.529	0.233	0.241
25	**PCKL-2**	1.810	0.172	0.767	1.025	0.166

26	**PCKL-3**	2.085	0.209	0.849	0.406	0.225
27	**PCKL-4**	1.927	0.202	1.362	0.762	0.233
28	**PCML**	1.823	0.188	0.815	0.306	0.453
29	**AAAR-1**	1.458	1.550	0.879	0.536	0.297
30	**AAAR-2**	1.124	1.115	0.577	0.316	0.245
31	**AAKR-1**	0.890	0.724	0.538	0.310	0.226
32	**AAKR-2**	1.384	0.901	0.432	0.074	0.088
33	**PCKR-2**	0.570	1.415	0.278	0.213	0.095
34	**PCMR-2**	1.738	1.345	0.876	0.414	0.119
35	**PVAR**	0.150	0.079	0.043	0.103	0.382
36	**PKRS-1**	0.307	0.576	0.414	0.102	0.238
37	**PKRS-2**	1.228	1.244	0.943	0.640	0.407
38	**PKRS-3**	1.423	1.213	0.657	0.522	0.398
39	**AGVS**	0.965	0.896	0.878	0.107	0.245
40	**AGPS**	0.982	1.166	0.830	0.631	0.176
41	**PCTS-1**	1.409	0.713	0.701	0.373	0.148
42	**PCTS-2**	0.673	0.629	0.598	0.360	0.151
43	**PCKS-1**	1.569	1.021	0.672	0.262	0.184
44	**PCMS**	1.048	0.860	0.862	0.382	0.167
45	**PCKS-2**	0.618	0.189	0.208	0.053	0.182
46	**AVVS**	0.426	0.749	1.001	0.504	0.191
47	**PKES-1**	1.307	0.618	0.412	0.475	0.204
48	**PKES-2**	0.837	0.536	0.710	0.478	0.184
49	**PKES-3**	0.970	0.735	0.785	0.530	0.199
50	**PKRS-1**	0.920	0.751	0.528	0.376	0.220
51	**PKRS-2**	1.070	0.786	0.881	0.439	0.249

Performance of fluorescent pseudomonads against plant growth promoting traits

Drought tolerance

All the bacterial isolates were screened for their drought tolerance using nutrient broth including PEG 6000 to induce the osmotic condition. Among which 40% PEG concentration was taken as criteria for selecting efficient isolates as it had the maximum osmotic potential of -2.70 MPa (Nayer and Heidari, 2008) for further experiments. Previously many research studies have been made using PEG 6000 up to 25% (-0.73 MPa) for selecting drought tolerant isolates (Sandhya *et al*. 2009, Sandhya *et al*. 2011) and hence it had been tested up to 40% PEG, in the present study. Among fifty one bacterial isolates tested, supplemented with PEG 6000 at various levels, 12 cultures showed efficient growth up to 40% PEG supplementation (Table 1 and Fig. 4) based on OD at 600 nm. Vardharajula *et al.* (2011) screened *Bacillus* spp. for drought tolerance which could tolerate minimal water potential (-0.73 MPa). Drought stress affected the isolates growth which indicated by increased intracellular free amino acids, proline, total soluble sugars, and exopolysaccharides.

Exopolysaccharide production

The exopolysaccharide production results revealed that all the efficient drought tolerant bacterial isolates are producing exopolysaccharides at various levels among which fluorescent pseudomonads isolates were also able to produce exopolysaccharide production ranging from 3.0 mg/ml to 1.0 mg/ml (Table 2 and Fig. 4). EPS provides a microenvironment that holds water and dries up more slowly than the surrounding environment thus protecting the bacteria and plant roots against desiccation (Hepper, 1975).

The test allows bacteria to survive under moisture stress. All the selected isolates could produce EPS both under stress and unstress conditions. About 50% of cultures produced a higher level of EPS under stress. Minah *et al*. (2015) isolated 74 exopolysaccharide producing bacteria, 15 isolates produced exopolysaccharides with best dry weight (0.10 to 2.24 mg ml-1). Out of 15 isolates of EPS producing bacteria with the dry weight for P3.69 (2.24 mg ml-1) followed by P2.60 (1.96 mg ml-1), P2.37 (1.79 mg ml-1) and P2.57 (1.75 mg ml-1). Vardharajula *et al.* (2011) reported similar results with three *Bacillus* sp. They were studied for the ability to tolerate matric stress and produce EPS under different water potentials. EPS production in all the three *Bacillus* sp. strains increased with increasing water stress. Among the isolates, strain HYD-17 showed the highest production of EPS.

IAA production

Many of the plant growth promoting organisms utilize L-tryptophan which is secreted in root exudates as a precursor for IAA. Therefore, the ability to produce IAA vary with strains or types of microorganisms. IAA production was almost higher in bacteria grown under stress conditions (Khamna *et al*., 2010). In the present study, IAA production results revealed that among the twelve efficient drought tolerant isolates four bacterial isolates were showing positive results for IAA production (Table 2). PGPR isolates were found to produce IAA which is the most physiologically active auxin in plants that influences root and shoot elongation by cell wall extension. Similar results were observed with Saravanan *et al.* (2016) isolated 17 morphologically different bacterial isolates. Among 17 isolates, 5, 9 and 11 showed positive results for IAA production.

ACC deaminase activity

The degradation of 1-aminocyclopropane-1-carboxylic acid (ACC) catalyzed by ACC deaminase, the immediate precursor of the plant hormone ethylene, into α-ketobutyrate and ammonia. All the drought tolerant bacterial isolates were able to produce a significant amount of ACC deaminase activity (Table 2 and Fig. 4). Renuga (2005) recited that plant growth promoting *Pseudomonas putida* can utilize 1-aniinocyclopropanc- l-carboxylase as a sole nitrogen source because it possessed the unusual enzyme ACC deaminase, which hydrolysis ACC to ammonia and a-ketobutyrate. Torbaghan *et al*. (2017) reported the maximum ACC deaminase production (0.4374 mM) among the three groups of isolates, followed by alkalophile isolates (0.241 mM) and halophile (0.0848 mM).

Phosphate solubilization

Among four efficient isolates, the isolates i.e., PCKR-2 showed P-solubilization Index as 3.80 mm, followed by AGVS (4.33 mm), PCKS (4.12 mm) and PVAS (2.28 mm) (Table 2 and Fig. 4). PGP bacteria influences plant growth during abiotic and biotic stresses. Many bacteria are known to solubilize phosphate in the soil, rendering phosphorus availability to plants. Shweta *et al*. (2008) reported a study on fluorescent pseudomonads and its beneficial effects on seed germination, growth promotion, and suppression of charcoal

Table 2. Performance of bacterial isolates against PGPR characteristics

S.No	Name of the isolate	EPS Production (mg/ml)	IAA Positive	ACC Deaminase			PSI	KSI
				Control	Ab/Control	ACC		
1.	**PVAS-1**	5.0	+	+	+	+	2.86	3.40
2.	**PVAS-2**	1.0	+	+	+	+	5.83	3.40
3.	**AGVS**	0.0	+	+	+	+	4.33	2.83
4.	**PCKS**	3.0	+	+	+	+	4.13	3.17
5.	**AKPL**	13.0	+	+	+	+	4.00	2.75
6.	**PCML**	3.0	+	+	+	+	2.40	2.70
7.	**AAAR-1**	2.0	+	+	+	+	4.00	3.20
8.	**AAKR-2**	1.0	+	+	+	+	2.88	2.38
9.	**PKRS-1**	1.0	+	+	+	+	2.71	3.20
10.	**PCKS-2**	1.0	+	+	+	+	2.71	2.64
11.	**PCKR-2**	0.0	+	+	+	+	3.80	3.50
12.	**PVAS**	1.0	+	+	+	+	2.29	2.50

***Note:** "+" Positive, EPS: Exopolysaccharide, IAA: Indole Acetic Acid, PSI: Phosphate Solubilization Index, KSI: Potassium Solubilization Index

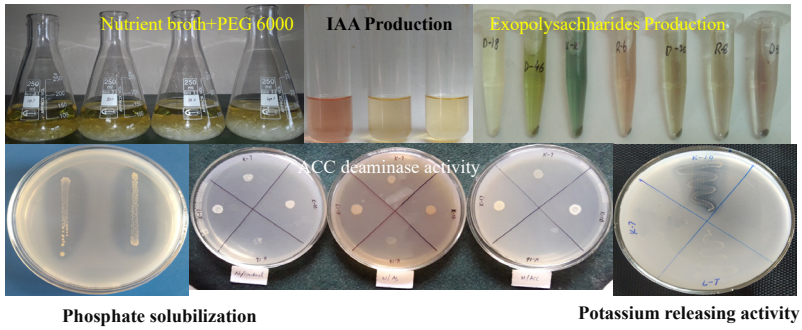

Fig. 4. Plant growth promoting characteristics

rot in groundnut (*Arachis hypogea* L.). They concluded that *Pseudomonas* strains caused variable phosphate solubilization, PS1 (G) and PS2 (G) being the best for phosphate solubilization. Similar results were observed by Sengupta *et al*. (2018) who reported phosphate solubilizing index (PSI) of 17 isolates varied from 1.692-3.033, after seven days of incubation. Tricalcium phosphate solubilization by PSB (309.72-615.28 µg ml^{-1}) and highest with isolate JCA-5.

3.2.6 Potassium releasing activity

Data on potassium solubilization activity show that out of two isolates, PCKR-2 showed the highest solubilization zone (3.50 mm), followed by PCKS (3.17 mm), AGVS (2.83 mm) and PVAS (2.50 mm) (Table 2 and Fig. 4). Norkina and Pumpynaskaya (1956) isolated two strains of *Bacillus* spp. and *Pseudomonas* from rhizosphere soils of different crop plants as mineral potassium solubilizers. The utilization of potassium releasing bacteria to increase the soluble form potassium and has been regarded as a desirable pathway to increase plant yields (Dong *et al*., 2019).

DISCUSSION AND CONCLUSION

In the present study, selected bacterial strains were positive for multiple PGP traits, including exopolysaccharides, IAA, ACC Deaminase, phosphate solubilization and potassium releasing activity, ammonia production and other characteristics revealed drought stress tolerance even under severe stress conditions. The isolation and characterization of stress-tolerant *fluorescent pseudomonad* bacteria are not only essential for understanding their characteristics with in rhizosphere but also understand their utilization in eco-friendly and sustainable agro-technologies. Besides these mechanisms, the inherent PGP traits of individual bacteria may provide an indirect mechanism for water stress alleviation in the tested plants by providing sufficient phosphate, iron, available nitrogen, and cross-protection against pathogen attack. The use of such microbial consortium, which can induce drought stress tolerance and also build up plant growth promotion during the normal condition, might be very much beneficial for sustainable agriculture. All the *fluorescent pseudomonad* isolates are able to grow well under moisture stress condition. The isolates may undergo cellular mechanism of osmotic adaptation through compatible solute and osmolyte productions. Exopolysaccharides possess unique water holding and cementing properties, thus play a vital role in the formation and stabilization of soil aggregates and regulation of nutrients and water flow across plant roots through biofilm formation. The application of efficient isolates exhibits a high tolerance to abiotic stress. The peanut roots will have the source for rhizobacteria that are capable of directly protecting plants from drought stress. Therefore, the screened bacterial isolates can be used as biofertilizers in drought prone areas. The above results suggested that positive ACC deaminase bacterial isolates and EPS-producing bacterial isolates are correlated with groundnut crop could alleviate drought stress. Use of these stress-tolerant *fluorescent pseudomonads* isolates not only essential for understanding their characteristics within rhizosphere but also as biofertilizers which will minimize fertilizer application, increase the available nutrient content in soils, reduce environmental pollution and promote sustainable agriculture. Besides these mechanisms, the inherent PGP traits of individual bacteria may provide an indirect mechanism for water stress alleviation in the tested plants by providing sufficient phosphate, iron, available nitrogen, and cross-protection against pathogen attack. The use of such microbial consortium/consortia, which can induce stress passiveness and also accelerate plant growth promotion during the normal condition, might be very beneficial. The integrative application of such consortium having the characteristics of a suitable stress suppressor is a very important aspect for drought stress alleviation in other crops as well. The *fluorescent pseudomonad* isolates screened from the research work can be studied further under *in vitro* and *in vivo* conditions, the bacterial strain and their consortium formulation require further field evaluation and validation before being confirmed as bio-inoculants to combat various abiotic stresses of different soils with several crops.

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ETHICAL APPROVAL

The authors declare that all the experiments were conducted in accordance with the current laws of the country.

CONFLICT OF INTEREST

The Author (s) declare (s) that there is no conflict of interest.

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