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Amminocyclopropane-1-carboxylate (ACC) Utilization and Indole-3-acetic Acid (IAA) Production by *Sesbania rostrata* rhizobial isolates

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ABSTRACT: In present ere agriculture is facing challenges due to low nitrogen availability therefore high amount of chemical fertilizers are used. Symbiotic association occurs by *Rhizobium* that causes the growth of shoots and roots nodules in legumes and nitrogen fixation for improving fertility of soil. Therefore, selection of the appropriate strain is significant for enhancing biological nitrogen fixation. The current study was intended to isolate and characterize rhizobial strain from root and shoot nodule of *Sesbania rostrata* plants on selective yeast extract mannitol agar (YEMA) medium. On the basis of morphological properties, 26 isolates were recognized as rhizobia. These possessed a smooth texture and convex slope and were spherical, milky white, mucoid in shape. All microbial isolates were identified as Gram-negative, rod-shaped, and motile upon microscopic analysis. Biochemical depiction of rhizobia showed that all rhizobia were able to produce IAA however, 65% of rhizobial isolates could utilize ACC. These rhizobia have plant growth promoting traits so used as a biofertilizer and use of chemical fertilizer is reduced.

Keywords: ACC, Symbiotic, Rhizobia, *Sesbania rostrata*, Indole-3-acetic acid (IAA).

INTRODUCTION

For sustainable agricultural practices symbiotic associations between legume and rhizobia are very essential. In this view, the phytohormone ethylene plays a vital function in inhibiting the nodulation process during nodule formation (Schaller, 2012). In addition it also influences several other plant developmental cues, together with a variety of stress responses that prevent plant growth. Gaseous plant hormone ethylene formed endogenously by every bigger plants and is known being among the best crucial molecules for regulating plant development (Bleecker and Kende 2000 and Lin *et al*., 2009). Ethylene is produced from the ACC present in the root exudates by the enzyme ACC oxidase. It is key phytohormone, however more formed ethylene in stressful situation can effect in the inhibition of plant growth or death, particularly for seedlings. When ethylene is produced in the high concentration produces defoliation and other cellular activities, resulting in a decline in crop performance (Bhattacharyya and Jha, 2012). It is involved in a number of phases of symbiosis too, together with the early reaction to nodule development, bacterial nod factors, abscission and senescence (Csukasi *et al*., 2009 and Patrick *et al*., 2009). Though, a number of bacteria can reduce harmful effect of ethylene levels through act of the enzyme ACC deaminase, which degrades ACC to ammonia and α-ketobutyrate, both of which the microbe or the plant can metabolize (Glick, 2014). ACC deaminase not acting an essential function in the nodulation procedure however can adapt the persistence of nodules (Nascimento *et al*., 2016). An inducible enzyme, ACC deaminase's synthesis, is stimulated by the presence of its substrate (Singh *et al*., 2015). Adding of ethylene precursor ACC to plant roots barren nodulation in *Medicago truncatula* (Penmesta and Cook, 1997), whilst the adding of the ethylene inhibitor AVG (L-α-aminoethoxyvinyl-glycine) improved the quantity of nodules in pea (Nukui *et al*., 2000). Bacteria exhibiting 1-aminocyclopropane-1-carboxylic acid (ACC) deaminase activity, which inhibits the biosynthesis of ethylene in higher plants, promote plant growth through the degradation of ethylene precursors, such as ACC (Sarapat *et al*., 2020). The ACC deaminase bacteria offer drought tolerance by adaptable plant ethylene levels. In addition to plant adaption mechanisms, plant growth-promoting rhizobacteria (PGPR) can enhance salt tolerance in plants via ion homeostasis, production of antioxidants, ACC deaminase, phytohormones, extracellular polymeric substance (EPS), volatile organic compounds, accumulation of osmolytes, activation of plant

antioxidative enzymes, and increase of nutrients uptake (Riseh *et al*., 2021).

Growth phytohormone indole-3-acetic acid (IAA) being considered the most significant agent of auxin class (Ludwig-Muller *et al*., 1993 and Serban *et al*., 2017). Tryptophan and indole derivatives are familiar precursors for usual biosynthetic pathways. The rhizosphere region isolated microorganisms of different crops have capability to generate IAA as minor metabolites because of plentiful supply of substrates. As a regulator of many biochemical functions, such as cell division, elongation, selectivity and tropic responses, fruit maturity, and senescence, IAA plays a critical role in the development and proliferation of plants. They can also prevent abscission of leaves, flowers and fruits. IAA synthesis by microorganism has been recognized from prolonged period. IAA produced by bacteria contributes to circumvent the host defense by derepressing the IAA signaling in the plant. IAA in addition has a straight consequence on bacterial survival and its resistance to plant defense (Spaepen *et al*., 2007). Eighty percent of the microbes from various crops' rhizosphere can synthesize and produce auxins as secondary metabolites (Patten and Glick, 1996). IAA formation via indole-3-acetic aldehyde and indole-3-pyruvic acid is found in a majority of bacteria like saprophytic species of the genera "*Pseudomonas* and *Agrobacterium*; *Erwinia herbicola*; certain representatives of *Rhizobium*, *Bradyrhizobium*, *Klebsiella*, *Azospirillum* and *Enterobacter*" (Ahemad and Khan 2012). The production of indole-3-acetic acid (IAA) is an essential tool for rhizobacteria to stimulate and facilitate plant growth (Lebrazi *et al*., 2020)

MATERIALS AND METHODS

Isolation of native rhizobia. Big sized, healthy, intact and pink nodules were chosen for separation of bacteria from *Sesbania rostrata* root as well as stem. An aseptic rod was used for crushing every apparent outside nodule in a Petri dish. YEMA medium enriched with 0.0025 percent (w/v) Congo red as an indicator was spread on Petri plates with a single loopful of the nodule suspension and cultured at 28±2°C for four days. At the end of incubation stage, the rhizobial colonies showed slight or no Congo red absorption appears white and mucoid. They were chosen out by a sterilized inoculating loop and were supplementary purified via streak plate method. The most important isolates were maintained on YEMA slants at 4°C in refrigerator for additional description (Vincent, 1970).

Amminocyclopropane-1-carboxylate (ACC) utilization. Some of the bacteria can utilize the substrate 1-amminocyclopropane-1-carboxylate as sole nitrogen resource by using enzyme ACC deaminase. The ACC utilization of different bacteria can be checked on minimal medium plates supplemented with 3mM ACC (Dworkin and Foster 1958). Actively growing log phase cells of different rhizobia were spotted on such medium plates. The expansion of different rhizobia on ACC enriched media plates was observed after 3-5 days of incubation at 28±2°C. The different rhizobia showing superior expansion on ACC supplemented medium plates were characterized as ACC utilizers and presumed to have ACC deaminase activity. The expansion on minimal medium plates was used as control to compare the growth on plates supplemented with ACC.

Production of indole-3-Acetic Acid (IAA)

Estimation of Indole-3-acetic acid was done by Salkowski's method (Mayer, 1958).

Reagents

(1) Salkowski's reagent- 1 ml of 0.05M $FeCl_3$ in 50 ml of 35% of perchloric acid ($HClO_4$).

(2) Indole-3-acetic acid stock solution- 100 mg ml^{-1} in 50% ethanol.

Rhizobia were grown in flasks with 25 ml of yeast extract mannitol broth enriched by 0.1 g L^{-1} DL-tryptophan. These flasks were incubated at 28±2°C. Fourth days, two ml of culture broth was centrifuged at 7,000 rpm for 2 min. and IAA was determined in culture supernatant using following procedure:

Salkowski's reagent was added to 2 ml of culture supernatant, mixed, and shaken, then let to stand at room temperature for 30 minutes to acquire a pink color, which was measured on spectrophotometer at 530 nm. Standard was pure indole-3-acetic acid.

RESULTS AND DISCUSSION

A total of 26 rhizobia were isolated from *Sesbania rostrata* (Root as well as stem nodules) and stored at 4°C for further studies. Enzymes such as ACC deaminase are formed via the variety of strains and its production is typically associated to free-living bacteria/rhizobacteria, a few fungi and members of Stramenopiles. Bacteria and fungi that convey ACC deaminase can lesser the impact of a range of diverse stresses that influence plant enlargement and progress. ACC deaminase considered as important PGP traits for rhizobacteria and endophytic bacteria (Glick, 2014). ACC deaminase making may be beneficial in the nodulation practice thus enhance the nitrogen supply for legume plants because of an added efficient nodulation. The enzyme ACC deaminase lowers plant ethylene levels is one of the key mechanisms employed by plant growth promoting bacteria to help plant development under stress conditions. Screening of all *Sesbania rostrata* rhizobia for ACC utilization was carried out on minimal medium plates supplemented with 3mM ACC. Log phase actively grown cells were spotted on the ammonium sulphate (2 gL^{-1}) as control medium plate and on ACC (3 mM) supplemented medium plate. These plates were incubated for 3-4 days at 28±2°C and compared the development of rhizobia on plates supplemented with both N source i.e. ammonium sulphate and ACC. It was observed that all rhizobial isolates tested showed development on

minimal medium supplemented with ammonium sulphate as compared to ACC supplemented plates which showed growth of 65% rhizobia, indicating that only these rhizobial isolates have ACC deaminase activity (Table 2, Plate 1 and Fig. 1). Likewise, Singh *et al*. (2017) reported that forty nine percent of the rhizobia from pigeon pea showed growth on ACC supplemented plates. On ACC-supplemented plates, 38.9% of *Pseudomonas* strains exhibited good growth, according to Khandelwal and Sindhu's (2013) research. To reduce drought stress in *Vigna mungo* L. and *Pisum sativum* L., Saikia *et al*., (2018) investigated the effects of the consortium with three rhizobacteria that produce ACC-deaminase: *Ochrobactrum pseudogrignonense* RJ12, *Pseudomonas* spp. RJ15, and *Bacillus subtilis* RJ46. The consortium treatment considerably enhanced the treated plants' dry weight, dry shoot length, and seed germination %. According to Saleem *et al*., (2018), inoculated velvet bean plants with plant growth promoting rhizobia (PGPR) that included the ACC deaminase enzyme during a drought environment grew more quickly than untreated plants. Compared to uninoculated plants, ethylene emission from the roots and foliage of inoculated velvet bean plants was noticeably lower. Therefore, PGPR that exhibit ACC deaminase activity shield plants against growth suppression caused by drought, excessive salt, nematodes, bacterial and fungal diseases, flooding, anoxia, metals, and organic pollutants (Gamalero and Glick, 2015). Endophytic bacterial strains of *Bacillus subtilis* LK14 has revealed major scenario of ACC deaminase (448.3 ± 2.91 nM α-ketobutyrate mg^{-1} h^{-1}) (Khan *et al*., 2016). Many researchers reported that around 50-55% of abiotic stress tolerant rhizobial isolates obtained from diverse legumes like pigeonpea, guar, mungbean and mothbean have been found to be good ACC deaminase producers (Kuldeep, 2013; Dhull *et al.,* 2016 and Mondal *et al.,* 2017). Belimov *et al.* (2019) also reported that *R. leguminosarum* bv. viciae 1066S exhibiting ACC deaminase activity increased shoot biomass, nodulation, nitrogen fixation, water use efficiency (WUE), and nutrient uptake in pea plats exposed to water deficit conditions.

Table 1: Details of rhizobial isolates of *Sesbania rostrata* species.

Sr. No.	*Sesbania* species	Name of rhizobial isolates	No. of rhizobial isolates
1.	*Sesbania rostrata* (root nodulating)	SRKe(i)/r, SRKe(ii)/r, SRTn/r, SRMa/r, SRUd/r, SRPr/r, SRKr(i)/r, SRKr(ii)/r, SRKr(iii)/r, SRSn/r	10
2.	*Sesbania rostrata* (stem nodulating)	SRKe(i)/s, SRKe(ii)/s, SRKe(iii)/s, SRTn/s, SRMa/s, SRMa(i)/s, SRUd/s, SRPr/s, SRKr(i)/s, SRKr(ii)/s, SRKr(iii)/s, SRHn/s, SRMg/s, SRHs/s, SRSn/s, SRHg/s	16
		Total	26

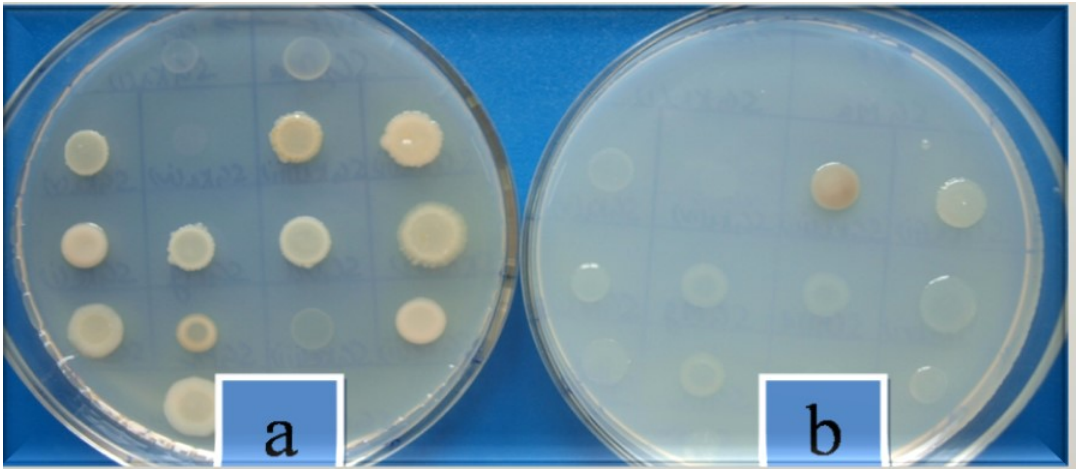

Plate 1: ACC deaminase activity by some of the *Sesbania rostrata* rhizobial isolates on minimal media plate (a) and ACC supplemented plate (b).

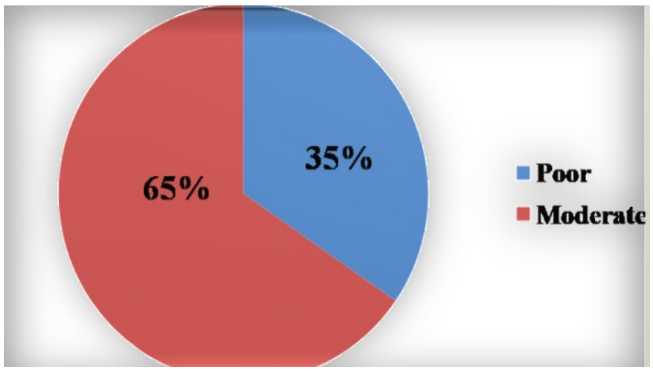

Fig. 1. Categorization of *Sesbania rostrata* rhizobial isolates for ACC utilization.

IAA production is prevalent amongst environmental bacteria that inhabit soils. Therefore, all 26 rhizobial isolates were tested for IAA production. All rhizobial isolates were found to be IAA producers, though, their production quantity wide-ranging significantly from 0.45 to 22.77 µg/ml. Out of 26 isolates 23, 31 and 46% were poor, moderate and excellent IAA producers, respectively. Maximum IAA production was observed by the rhizobial isolates SRTn/s (22.77 µg/ml), while the isolate SRHg/s (0.45 µg/ml) showed minimum IAA production (Table 2, Fig 2 and Plate 2). It was observed that all isolates showed IAA production however, their production amount varied considerably. Indole acetic acid was produced by 26 Rhizobial strains isolated from *Sesbania sesban* (L.) Merr. in different zones of Andhra Pradesh, according to Sridevi and Mallaiah (2007), but only five strains produced the most significant amount in YEM broth supplemented with L-tryptophan. Maximum amount (28.0 µg/ml) of IAA was produced by *Rhizobium* strain 13 after seventy two hours of incubation. Mohite (2013) also reported that out of ten IAA producing isolates, five isolates were selected as efficient producers from rhizosphere bacteria. Comparable, outcome were also observed by Khalid *et al.,* (2004) who categorised the in vitro IAA production by rhizobacteria in three major groups: low (1 to 10 µg/ml), medium (11 to 20 µg/ml) and high producers (21 to 30 µg/ml). Compared to control plants, seedlings inoculated by IAA-producing bacteria produced more shoot biomass, longer roots, and more colonization (Etesami *et al*., 2014). Dhull *et al*., (2016) also reported that all the 54 clusterbean rhizobia were found to be IAA producers, though, their production quantity varied considerably. Boora (2016) also reported that most of the abiotic stress tolerant pigeon pea rhizobia were good IAA producer having different levels of IAA production. Similarly, Subha (2018) reported that all the native rhizobial isolates from different legumes crop showed IAA production, however their production amount varied considerably from 1.62 to 12.3 ug/ml. IAA secretion was estimated of the three *Rhizobium* isolates (Rf3, Rf11 and Rf12), the maximum amount of IAA was found in yeast extract mannitol medium supplemented with 500µg/ml L-tryptophan. Lebrazi *et al*. (2020) isolated eighty rhizobial bacteria isolated from root nodules of *Acacia cyanophylla* grown in different regions of Morocco were firstly screened for their ability to produce IAA. Then, IAA production by a combination of isolates and the inoculation effect on the germination of *Acacia cyanophylla* seeds was studied using the best performing isolates in terms of IAA production.

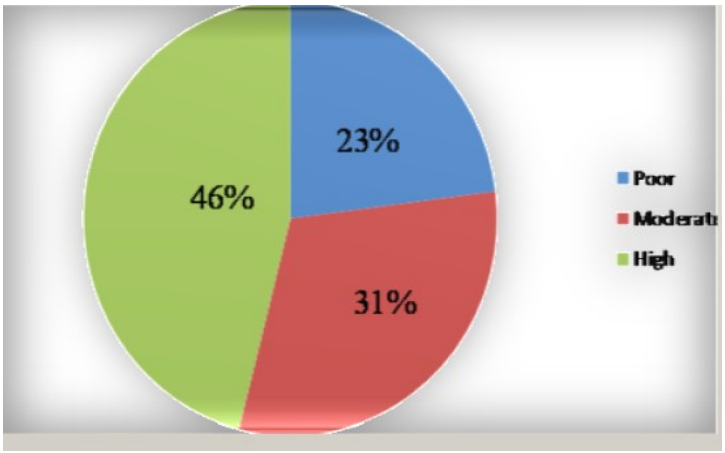

Fig. 2. Categorization of *Sesbania rostrata* rhizobial isolates for IAA production.

Table 2: Characterization of *Sesbania rostrata* rhizobial isolates for plant growth promoting (PGP) traits.

Sr. No.	*Sesbania* species		
		IAA-production (µg/ml)	ACC utilization
***Sesbania rostrata* (root nodulating)**			
1.	SRKe(i)/r	16.80	+
2.	SRKe(ii)/r	7.66	-
3.	SRTn/r	1.84	+
4.	SRMa/r	15.77	+++
5.	SRUd/r	7.96	++
6.	SRPr/r	13.48	++
7.	SRKr(i)/r	22.19	++
8.	SRKr(ii)/r	0.63	+
9.	SRKr(iii)/r	6.75	-
10.	SRSn/r	4.28	+++
***Sesbania rostrata* (stem nodulating)**			
11.	SRKe(i)/s	9.26	-
12.	SRKe(ii)/s	14.72	-
13.	SRKe(iii)/s	15.95	+++
14.	SRTn/s	22.77	-
15.	SRMa/s	9.47	++
16.	SRMa(i)/s	8.38	-
17.	SRUd/s	10.95	++
18.	SRPr/s	12.40	+++
19.	SRKr(i)/s	14.02	+++
20.	SRKr(ii)/s	2.35	+
21.	SRKr(iii)/s	4.37	++
22.	SRHn/s	10.86	+
23.	SRMg/s	5.73	+++
24.	SRHs/s	15.01	-
25.	SRSn/s	7.90	-
26.	SRHg/s	0.45	-

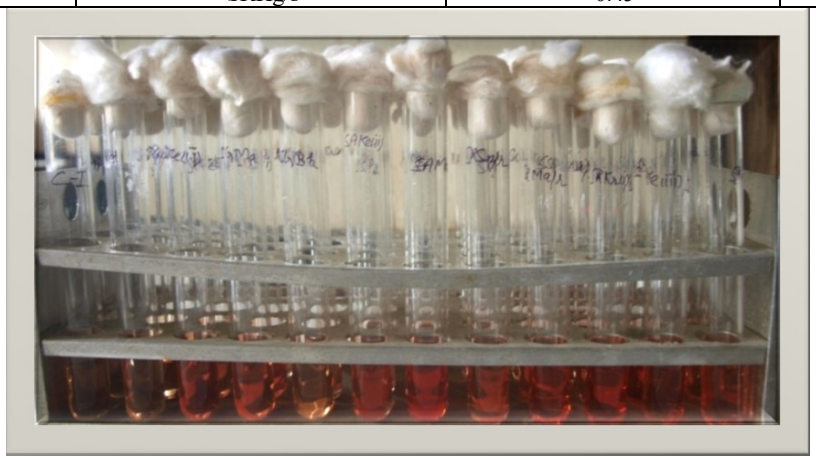

Plate 2: IAA production by some of the *Sesbania rostrata* rhizobial isolates.

CONCLUSION

All *Sesbania rostrata* rhizobial isolates were able to produce IAA and however, 65% of rhizobial isolates could utilize ACC (1-aminocyclopropane-1-carboxylate). So, these isolates have plant growth promoting traits which is useful for present as well as upcoming crops for improving nitrogen.

FUTURE SCOPE

These isolates have tremendous potential in near future to be used as biofertilizers in salt affected, alkaline and waterlogged field conditions, which will not only improve nitrogen availability also having plant growth promoting ability in *Sesbania rostrata* so act as nitrogen reserve for next crop.

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Conflict of interest. None.

REFERENCES

Ahemad, M. and Khan, M. S. (2012). Alleviation of fungicide induced phytotoxicity in green gram [*Vigna radiata* (L.) Wilczek] using fungicide-tolerant and plant

growth promoting *Pseudomonas* strain. *Saudi Journal of Biological Science, 19*: 451-459.

Belimov, A. A., Zinovkina N. Y., Safronova V. I., Litvinsky V. A., Nosikov V. V., Zavalin A. A. and Tikhonovich I. A. (2019). Rhizobial ACC deaminase contributes to efficient symbiosis with pea (*Pisum sativum* L.) under single and combined cadmium and water deficit stress. *Environmental and Experimental Botany*, *167*: 103859.

Bhattacharyya, P. N. and Jha, D. K. (2012). Plant growth promoting rhizobacteria (PGPR): emergence in agriculture. *World Journal of Microbiology and Biotechnology*, *28*: 1327-1350.

Bleecker, A. B. and Kende, H. (2000). Ethylene: a gaseous signal molecule in plants. *Annual Review of Cell and Developmental Biology*, *16*: 1-18.

Boora, S. (2016). Symbiotic effectiveness of abiotic stress tolerant pigeon pea [*Cajanus cajan* (L.) Millspaugh] rhizobia. M.Sc. thesis, CCS Haryana Agricultural University, Hisar.

Csukasi, F., Merchante, D. and Valpuesta, V. (2009). Modification of plant hormone levels and signaling as a tool in plant biotechnology. *Biotechology Journal*, *4*: 1293-1304.

Dhull, S., Yadav, A., Mondal, H. K. and Gera, R. (2016). Evaluation of plant growth promoting (PGP) activity of abiotic stress tolerant rhizobia nodulating Clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.) retrieved from Haryana, India. *The Bioscan*, *11*: 2893-2897.

Dworkin, M. and Foster, J. W. (1958). Experiments with some microorganisms which utilize ethane and hydrogen. *Journal of Bacteriology, 75*: 592-601.

Etesami, H., Mirseyed Hosseini, H. and Alikhani, H. A. (2014). In planta selection of plant growth promoting endophytic bacteria for rice (*Oryza sativa* L.). *Journal of Soil Science and Plant Nutrition*, *14*(2): 491-503.

Gamalero, E. and Glick, B. R. (2015). Bacterial modulation of plant ethylene levels. *Plant Physiology*, *169*: 13-22.

Glick B. R. (2014). Bacteria with ACC deaminase can promote plant growth and help to feed the world. *Microbiological Research*, *169*: 30-9.

Khalid, A., Arshad, M. and Zahir, Z. A. (2004). Screening plant growth promoting rhizobacteria for improving growth and yield of wheat. *Journal of Applied Microbiology*, *96*(3): 473-480.

Khan, A. L., Halo, B. A., Elyassi A., Ali, S., Al-Hosni, K., Hussain, J., Al-Harrasi, A. and Lee, I. J. (2016). Indole acetic acid and ACC deaminase from endophytic bacteria improves the growth of *Solanum lycopersicum. Electron Journal of Biotechnology, 21*: 58-64.

Khandelwal, A. and Sindhu, S. S. (2013). ACC deaminase containing rhizobacteria enhance nodulation and plant growth in clusterbean (*Cyamopsis tetragonoloba* L.). *Journal of Microbiology Research*, *3*(3): 117-123.

Kuldeep (2013). Phenetic and genetic analysis of abiotic stress tolerant pigeon pea (*Cajanus cajan* L.) rhizobia retrieved from south western parts of Haryana. MSc thesis, CCS Haryana Agricultural University, Hisar.

Lebrazi, S., Fadil, M., Chraibi, M. and Fikri-Benbrahim, K. (2020). Screening and optimization of indole-3-acetic acid production by *Rhizobium* sp. strain using response surface methodology. *Journal of Genetic Engineering and Biotechnology*, *18*(1): 21.

Lin. H., Wang. R., Qian. Q., Yan. M. and Meng, X. (2009). DWARF27, an iron-containing protein required for the biosynthesis of strigolactones, regulates rice tiller bud outgrowth. *Plant Cell*, *21*: 1512-1525.

Ludwig-Muller, J., Sass, S., Sutter, E., Wodner, M. and Epstein, E. (1993). Indole-3- butyric acid in *Arabidopsis thaliana*. *Journal of Plant Growth Regulation*, *13*: 179-187.

Mayer, A. M. (1958). Determination of indole acetic acid by the Salkowsky reaction. *Nature*, *182*: 1670-1671.

Mohite, B. (2013). Isolation and characterization of indole acetic acid (IAA) producing bacteria from rhizospheric soil and its effect on plant growth. *Journal of Soil Science and Plant Nutrition*, *13*(3): 638-649.

Mondal, H. K., Mehta, S., Kaur, H. and Gera, R. (2017). Characterization of stress tolerant mungbean rhizobia as pgpr and plant growth promotion under abiotic Stress. *Indian Journal of Ecology*, *44*(4): 38-42.

Nascimento, F. X., Brigido, C., Glick, B. R. and Rossi, M. J. (2016). The role of rhizobial ACC Deaminase in the nodulation process of leguminous plants. Hindawi Publishing Corporation. *International Journal of Agronomy*, pp 1-9.

Nukui, N., Ezura, H., Yuhashi, K. I., Yasuta, T. and Minamisawa, K. (2000). Effects of ethylene precursor and inhibitors for ethylene biosynthesis and perception on nodulation in *Lotus japonicus* and *Macroptillium atropurpureum*. *Plant Cell Physiology*, 41: 893-897.

Patrick, A., Gusti, A., Cheminant, S., Alioua, M., Dhondt, S., Coppens, F., Beemster, G. T. S. and Genschik, P. (2009). Gibberellin signaling controls cell proliferation rate in Arabidopsis. *Current Biology*, *19*: 1188-1193.

Patten, C. L. and Glick, B. R. (1996). Bacterial biosynthesis of indole-3-acetic acid. *Candian Journal of Microbiology*, *42*: 207-220.

Penmesta, R. V. and Cook, D. R. (1997). A legume ethylene-insensitive mutant hyper infected by its rhizobial symbiont. *Science*, *275*: 527-530.

Riseh, R. S., Ebrahimi-Zarandi, M., Tamanadar, E., Pour, M. M. and Thakur, V. K. (2021). Salinity Stress: Toward Sustainable Plant Strategies and Using Plant Growth-Promoting Rhizobacteria Encapsulation for Reducing It. *Sustainability*, *13*(22): 12758.

Saikia, J., Sarma, R. K., Dhandia, R., Yadav, A., Bharali, R., Gupta, V. K. and Saikia, R. (2018). Alleviation of drought stress in pulse crops with ACC deaminase producing rhizobacteria isolated from acidic soil of Northeast India. *Scientific Reports*, *8*(1): 35-60.

Saleem , A. R., Brunetti, C., Khalid, A., Rocca G. D., Raio, A. and Emiliani, G. (2018). Drought response of *Mucuna pruriens* (L.) DC. Inoculated with ACC deaminase and IAA producing rhizobacteria. *Plos One*, *13*(2): e0191218.

Sarapat, S., Songwattana, P., Longtonglang, A., Umnajkitikorn, K., Girdthai, T., Tittabutr, P., Boonkerd, N. and Teaumroong, N. (2020). Effects of Increased 1-Aminocyclopropane-1-Carboxylate (ACC) Deaminase Activity in Bradyrhizobium sp. SUTN9-2 on Mung Bean Symbiosis under Water Deficit Conditions. *Microbes and Environments*, *35*(3): ME20024.

Schaller, G. E. (2012). Ethylene and the regulation of plant development. *Biology and Medicene, 10*(9): 1-3.

Serban, E. A., Diaconu, I., Ruse, E., Totu, E. E. and Nechifor, G. (2017). Studies on the transport of indole-3-acetic acid through bulk liquid membranes. *Revue Roumaine de Chimie*, *62*(6-7): 505-509.

Singh, K., Rani, A., Padder, S. A. and Gera, R. (2017). Plant growth promoting (PGP) attributes of stress tolerant rhizobial isolates from root nodules of pigeon pea [*Cajanus cajan* (L.) Millspaugh] growing in Haryana, India. *International Journal of Current Microbiology and Applied Science, 6*(12): 461-473.

Singh, R. P., Shelke, G. M., Kumar, A. and Jha, P. N. (2015). Biochemistry and genetics of ACC deaminase: a weapon to "stress ethylene" produced in plants. *Front Microbiology*, *937*(6): 1-14.

Spaenpen, S., Vanderleyden, J. and Remans, R. (2007). Indole-3-acetic acid in microbial and microorganism plant signaling. *FEMS Microbiology Review*, *31*: 425-448.

Sridevi, M. and Mallaiah, K. V. (2007). Bioproduction of indole acetic acid by *Rhizobium* strains isolated from root nodules of green manure crop, *Sesbania sesban* (L.) Merr. *Iranian Journal of Biotechnology*, *5*(3): 178-182.

Subha (2018). Development of promiscuous and effective rhizobia nodulating kharif legumes. PhD thesis, CCS Haryana Agricultural University, Hisar.

Vincent, J. M. (1970). A Manual for the practical study of root nodule bacteria IBP handbook No. 15, Blackwell, Edinburgh, U.K. pp.73-97.

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