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Mini Review

Drought stress mitigation in *Vigna radiata* by the application of root-nodulating bacteria

Diksha Kumari and Dipjyoti Chakraborty*

Department of Bioscience and Biotechnology, Banasthali Vidyapith, Rajasthan, 304022, India

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Correspondence
Dipjyoti Chakraborty
cdipjyoti@banasthali.in

Abstract

Plant growth promoting rhizobacteria (PGPR) facilitates plant growth and are of potential use as bio-fertilizer. Pulses are an important protein source in the vegetarian diet and being legumes harbour members of the Rhizobiaceae that form symbiotic relationships and nodules involved in nitrogen fixation. *Vigna radiata* is one such pulse crop popular in India. Nodulating bacteria were also found to mitigate biotic and abiotc stress and may be used as an alternative to chemical fertilizer for a sustainable agriculture. Here, we review rhizobial species isolated from *V. radiata* that have offered an efficient drought stress tolerance.

Keywords

drought stress; nitrogen fixation; Rhizobiaceae; sustainable agriculture; *Vigna radiata*

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Introduction

Mungbean (*Vigna radiata* L. Wilczek) is one of the most important "kharif" pulse crops in India. It belongs to leguminosae family. It is extensively grown in tropical and subtropical Asia because of its ecological adaptability. Mungbean is an important source of easily digestible proteins (up to 24%) and iron (40–70 ppm) for nutritionally balanced cereal-based diets in South and Southeast Asia. It is quite a versatile crop grown for seeds, green manure and forage and it is also considered as Golden Bean because of its nutritional values and suitability for increasing the fertility of soil, as a source of nitrogen. Because of its short life-cycle, it fits well in crop rotation and mixed cropping systems. Actually, the per capita share of pulses in nutrition supply in India with respect to energy, protein and fat is 117.4 K cal, 6.9 g and 1.0 g per day, respectively.

Plant growth-promoting Rhizobacteria (PGPR)

Microorganisms, like plant growth promoting rhizobacteria, play an important role in agricultural systems. Plant growth promoting bacteria are a heterogeneous group of bacteria that can be found in the rhizosphere, at root surfaces and in association with roots, which facilitates the establishment of diverse interaction mechanisms responsible for promoting the quality of plant growth directly and/or indirectly. In the last few decades, a large array of bacteria including species of *Pseudomonas*, *Azospirillum*, *Azotobacter, Klebsiella, Enterobacter, Alcaligenes, Arthrobacter, Burkholderia, Rhizobium, Flavobacteriaum*, *Bacillus* and *Serratia* have been reported to enhance plant growth (1,2).

PGPR are widely studied because of their potential in increasing plant growth and yield. They act as biofertilizers (3,4) and some provide nitrogen via nitrogen fixation, which can subsequently be used by the plants. They exude phytostimulators (5) that can directly promote the growth of plant, usually by the production of plant hormones. They are also potential biological control agents and can protect plant via root system from phyto pathogenic organisms (6). Application of PGPR is also reported to confer abiotic stress tolerance (7,8). The application of PGPRs in agriculture as inoculants is very attractive since it can substantially reduce the use of chemical fertilizers and pesticides (9).

Root nodulating bacteria as PGPRs

Biologically active product more appropriately called as “microbial inoculants” contains active strength of selective microorganisms like bacteria, algae, fungi; alone or in combination which helps in increasing crop productivity by biological nitrogen fixation. The rhizobia are a group of Gram-negative bacteria that form species-specific symbioses with legume plant. Nitrogen fixation, the reduction of atmospheric dinitrogen (N_2) to ammonia (NH_3), by rhizobia only occurs during symbiosis and provides a significant proportion of available nitrogen in the biosphere. In addition to having nitrogen fixing capacity, some rhizobial inoculants show enhanced nodulation, produce plant growth promoting hormones like indole acetic acid (IAA), secrete siderophores and solubilise phosphates etc (2,10,11).

Drought stress and its mitigation by *Rhizobium* species

Roots play an important role in water stress tolerance by reduction in leaf expansion and promotion of root growth. Root length at seedling stage provides a fair estimate about the root growth in field (12,13). Roots have a major role in improving crop adaptation to water stress conditions. In general, deeper and more profuse root systems are able to tap extra water from the soil profile and alleviate drought effects. Root traits like root length, number and root depth, have long been seen as important traits to improve crop adaptation to water stress. The plant growth promoting effects of *Rhizobium* sp. on *V. radiata* are represented in Table 1.

In a study, root nodules from healthy seedlings of *Vigna radiata* from farmer’s field and yielded three bacterial strains viz., RP1, RP2 and RP3 (14). It was demonstrated that all these strains show growth promoting activities, but RP1 was found to be the most effective in enhancing the growth of plant compared to the other two strains (RP2 and RP3). Several rhizobial species were isolated from the varieties of *V. radiata* (PM-2, PDM-54, K-851, and PM-5) but only six isolates were short listed on the basis of plant growth promotion and increased plant biomass, maximum nodule numbers and higher nitrogenase activity (15). Maximum range of fresh weights of nodule per plant was shown by R0132, was able to grow at slightly higher temperature (32°C) and slightly acidic (pH 6.0) and alkaline (pH 8.0) conditions.

Nine different *Rhizobium* sp. were isolated from the root nodules of *Vigna radiata* cultivated in Gujarat and it was observed that isolates AAU-6 and AAU-7 can be used as biofertilizers for a better yield (16). In another study, 140 *Rhizobium* strains were isolated, out of which, six strains (KG-50, WG-57, MG-58, TG-60, MG-64 AND BG-72) were taken for further study. Of them, four isolates showed significant plant growth promotion evidenced by an increase in root and shoot length and number of secondary roots.

Rhizobium phaseoli strains (N1, N2, N4, N10, N11, N13, N20, N22, N25 and N28) were isolated from Mung bean nodules and it was found that N20 isolate offered the best tolerance efficiency to salt stress (18).

In another study, 201 rhizobial strains from were isolated from mothbean, clusterbean and mungbean growing in the arid zones of Rajasthan out of which sixteen showed potential for high PEG and high temperature tolerance under *in vitro* conditions (19). These strains could further be used in greenhouse experiments for their drought tolerance enhancement potential.

The pulses as cash crops have been always of second choice in India. The “Accelerated pulses production programme” launched in 2010-11 improved pulse crops like chickpea, blackgram, greengram and lentils. However, a lot needs to be done to increase the stagnant pulse production and loss in yield due to drought, salinity and diseases. An understanding of the soil microbiota, especially root nodulating bacteria and its association with specific pulse crops to increase its productivity needs to be addressed.

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Table 1: Growth promoting characteristics of *Rhizobium* strains isolated from Mung

No	*Rhizobium* Strain	Growth promoting characteristics	Ref.
1.	WG-57	Gram negative, IAA production, Ammonia synthesis, phosphate solubilisation, Proteolytic enzyme production, amylase activity, cellulase activity.	(17)
2.	MG-58	Gram negative, IAA production, ammonia synthesis, HCN production, phosphate solubilisation, proteolytic enzyme production, amylase activity.	
3.	TG-60	Gram positive, IAA production, ammonia synthesis, cellulase activity, lipase activity, proteolytic enzyme production, amylase activity	
4.	MG-64	Gram negative, Ammonia production, HCN production, phosphate solubilisation, amylase activity.	
5.	BG-72	Gram negative, IAA production, ammonia synthesis, amylase activity.	
6.	RP-1	IAA production, increase in root and shoot length, HCN production, Siderphore production, enhancement in nodulation, urea hydrolysis, ammonia production	(14)
7.	RP-2	IAA production, Phosphate solubilisation, Siderphore production, urea hydrolysis, increase in root and shoot length comparatively less than RP1	
8.	RP-3	Increase in root and shoot comparatively less than RP1, ammonia production enhancement in nodulation.	
9.	AAU 2	Citrate production, nitrate reduction, organic acid production, 122mg/100ml gum production on YEMA broth, good growth on 2%sodium chloride concentration, Melanin and Amylase production	(16)
10.	AAU 3	Nitrate reduction, 106mg/100ml gum production on YEMA broth, good growth on 2%sodium chloride concentration, Melanin and Amylase production	
11.	AAU 4	nitrate reduction, 103mg/100ml gum production on YEMA broth, poor growth on 2% sodium chloride concentration, Amylase production,	
12.	AAU 5	Citrate reduction, nitrate reduction, 100mg/100ml gum production on YEMA broth, good growth on 2% sodium chloride concentration	
13.	AAU 6	Nitrate reduction, organic acid production, good growth on 2%sodium chloride concentration, Melanin production, maximum amount of gum production	
14.	AAU 7	Citrate production, nitrate reduction, poor growth on 2% sodium chloride concentration, melanin production	
15.	AAU 8	Methyl red test positive, nitrate reduction, 98mg/100ml gum production, melanin production, Amylase production	
16.	AAU 9	Methyl red test positive, citrate production, nitrate reduction, 96mg/100ml gum production, Melanin and Amylase production.	
17.	N20	Produce maximum IAA, increase root length, shoot length, pods dry weight, grain nitrogen, number of nodules/plant and number of pods/plant of mung bean at different salinity levels. Maximum visual growth, optical density and population count at high salt concentration	(18)
18.	R0034	Potential to increase plant biomass, higher number of nodules per plant, and higher nitrogenise activity	(15)
19.	R0129	Increase number of nodule per plant, increase fresh weight and dry weight of nodule	
20.	R0132	Maximum increase in nodule per plant, increase in fresh and dry weight of nodule, able to growth at slightly higher temperature and slightly acidic (pH 6.0) and alkaline (pH 8.0) condition.	
21.	R0564	Increase number of nodule per plant, increase fresh weight and dry weight of nodule	
22.	R0789	Show higher plant biomass, maximum nodule numbers, and higher nitrogenise activity	
23.	R1203	Potential to increase plant biomass, higher number of nodules per plant, and higher nitrogenise activity	
24.	AAU 1	Citrate utilization, nitrate reduction, organic acid production, 120 mg/100ml gum production on YEMA broth, good growth on 2% sodium chloride concentration, melanin and amylase production.	

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Conflict of Interest

The authors declare that they have no competing interests.

Authors' Contribution

DK drafted the manuscript with collection of references. DC designed the concept, discussed the findings with scientific justification and over all edited the whole manuscript.

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