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MINI REVIEW

# Salinity Tolerant Plant-Growth-Promoting Rhizobacteria (PGPR) to Improve Crop Productivity

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The world population, at present estimated ~7 billion people, is expected to increase to ~10 billion in the next 50 years and to sufficiently feed all these individuals requires an ecological sound management system to sustain crop productivity [1]. The type of soil defines the concentration of salts in the soil and the salt concentration may be different at different soil. Measuring the electrical conductivity of the soil defines salinity of that particular land. When the extract solution of the soil has electrical conductivity 20 mM or more it is considered saline soil or salt affected soil [2]. The main reasons of accumulation of salt in soil are leaching and insufficient drainage of irrigation water. Plants develop with the help of plant growth promoting rhizobacteria (PGPR) various mechanisms for salt tolerance; antioxidant enzyme activation and antioxidant compound synthesis, ion homeostasis, biosynthesis of compatible solutes, nitric oxide generation, ions transport and hormone modulation [3]. Balanced application of chemical inputs including fertilizers, pesticides, fungicides and herbicides have to increase agricultural productivity for the mitigation of food security worldwide. The high uses of chemicals increase the salinity condition in soil and deteriorate the soil texture, soil quality, health and also increase many environmental problems. Nowadays alternative of these, PGPR mitigate the salinity stress in crop production. Thus, remarkable effort is being put on research to develop such rhizobacterial inoculants which have plant growth promoting (PGP) properties under sustainable agriculture [4,5].

Nowadays soil salinity is one of the major problems in agriculture, affected ~20% and ~50% of the total cultivated and irrigated land in the world, respectively, that limits plant growth and causes significant loss of crop productivity worldwide [6]. The shortfall in the availability of fresh water resulted in gradual increase in the use of saline water in agriculture resulted in salt deposits in the crop field. As a result, every year, salt-affected areas are constantly increasing and at the same time considerable area of arable land is being agriculturally unproductive because of salinity [7,8]. Discharge of industrial effluents into irrigation canals is one of the potential sources of salts in agricultural soil. Saline water reduces the transpiration rate of plants by disrupting the evapotranspiration system thus reducing agricultural productivity [9]. A high salt concentration in the root zone affects root density, root turgor pressure, and water absorption, subsequently affects plant growth and development. Reactive oxygen species (ROS), namely, $H_2O_2$, $O^{-2}$, and $OH^-$ generated in salinity stress damages the DNA, RNA, and proteins [10], the root meristem activity [11] and cause chlorophyll destruction. Antioxidant such as superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX) have the ability to scavenge the ROS and maintain them at low levels. Superoxide dismutase is a metallo-enzyme that protects cells from oxidative damage, by catalyzing the conversion of the superoxide radical to $H_2O_2$ [12], which is further breakdown by catalyzing action of ascorbate peroxidase. Catalase reduces ROS levels by catalyzing the breakdown of $H_2O_2$ into $H_2O$ and $O_2$ [10]. ACC deaminase-containing PGPR induces stress tolerance in plants by a variety of mechanisms such as the synthesis of phytohormones, mineral solubilization, nutrient uptake and use efficiency, increased leaf area, increased chlorophyll and soluble protein content, and antioxidant enzyme activities [13] thereby, reduces the harmful effects of environmental stress.

The rhizosphere is the ecologically important zone in soil around the plant root surface and region for the plant-microbes interactions in the vicinity of the plant roots and the soil extend to few millimeters from the root surface, which is characterized by a high concentration of plant exudates and lysates and mediated by intense microbial activity [14], because a multitude of compounds are released into the rhizosphere by plant roots induces more intense microbial activity and larger microbial population which may be beneficial, neutral or detrimental to plants. The PGPR found in the rhizosphere, on the root surface or associated to it, belong to heterogeneous and beneficial group of microbes that are capable of enhancing the growth of plants and also reported to protect them from abiotic stresses [1,15]. The stimulated plant growth mechanisms involve the availability of nutrients originating from genetic processes, such as biological nitrogen fixation (BNF) and phosphate solubilization and mobilization, alleviation of stress through the regulation of ACC deaminase expression, and production of phytohormones and siderophores, among several others. In the last few years, the various genera of PGPR have been identified, like *Pseudomonas, Azospirillum, Azotobacter, Klebsiella, Enterobacter, Alcaligenes, Arthrobacter, Burkholderia, Bacillus* and *Serratia* have been reported to enhance the plant growth and the numbers are increasing every day mainly because the role of the rhizosphere as an ecosystem has gained importance in the functioning of the biosphere [16,17]. The application of salt tolerant PGPRs including genera *Klebsiella*, *Pseudomonas*, *Agrobacterium* and *Ochrobactrum* may enhance plant growth under salinity condition [18]. These PGPRs can promote plant growth by regulating nutritional and hormonal balance, producing plant growth regulators (PGR), nutrients solubilization and inducing resistance against plant pathogens additionally, these PGPR are also evidenced for synergistic as well as antagonistic interactions with other PGPRs in the soil environment. The halotolerant or salt tolerant bacteria have been able to survive high salt concentration due to their efficiency to accumulate various compatible osmolyte which maintained intracellular osmotic balance [19]. However, these PGPRs produced ACC deaminase and catalase enzymes in response to salinity stress to protect plants against different environmental stresses through reducing the ethylene levels and also help in maintaining plant ROS levels [20,21].

Soil-plant-microbes interaction enhances the sustainability of agricultural system. The indigenous salinity tolerant PGPR should be more suitable and play important role in crop production under salinity condition. Furthermore, efficient consortia of salinity tolerant PGPR can be more suitable on agriculture farmer's field for crop production and maintain the soil texture, soil health, decrease environmental pollution and also save the fossil fuel consumption under sustainable agriculture. It is environment eco-friendly and cost-effective technology. The various biotechnological approaches apply for development of salt tolerant transgenic plant might be prominent technique for crop production. However, salt tolerant transgenic plant along with salt tolerant PGPR application show profound effect under salinity condition.

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