Pure Appl. Bio., 3(4): 167-174, December- 2014

Review Article

Role of plant growth promoting rhizobacteria as ameliorating agent in saline soil

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Citation
Nazima Batool, Noshin Ilyas and Armghan Shahzad. Role of plant growth promoting Rhizobacteria as Ameliorating agent in saline soil. Pure and Applied Biology. Vol. 3, Issue 4, 2014, pp 167-174

ABSTRACT
Abiotic stress factors severely affect the crop plant growth, yield and productivity in the semiarid areas. Though, salt stress is one of the important reasons to reduce crop growth and productivity. High salt in soil is reason to produce critical conditions for plant survival. A number of scientists focus their research to identify tolerance mechanisms in plants under saline soil, although utilization of this information limited to improve crops. In recent years, number of scientist identified tolerance mechanism induced by Plant Growth Promoting Rhizobacteria (PGPR) in crop plants under saline conditions. PGPR Identification and exploitation is proving to be new alternatives against salt stress. Although, PGPRs mechanism of action is not understood. PGPRs application increases water and nutrient uptake and improve phytohormone production. The main aim in this review is to illustrate role of PGPRs as ameliorating agent in crop plant under saline soil.

Keyword: PGPR; saline soil; plant survival

Introduction
Cultivated soils throughout the world sever affected from marginal irrigation desertification processes and excessive water. Salt stress is a rigorous dilemma in tropical, arid and temperate agriculture system **[1]**. In current years about 800 million ha of land is affected due to salt worldwide **[2]** and in Pakistan about 6 million ha area **[3]**. Pakistan is located in arid and semiarid region. In this region high evaptranspiration that causes deposition of salts on the soil surface. Saline condition is main factors which limit food production as a result; it decreases crop plants productivity **[4-6]**. High salt concentration may exacerbate other stress factors such as oxidative stress and protein denaturation in plants. Plant adapted a number of strategies to overcome harmful impacts of salinity by developing salt resistant varieties, leaching excess soluble salts from upper to lower soil depths and salt accumulation by aerial plant parts **[7]**.
High salt concentration interferes with plant growth because it causes osmotic stress, toxic ion accumulation and nutrient

imbalance. Salt stress may be due to high levels of Na+, K+, Mg+, or Ca2+ of salt; however NaCl is the major reason [5, 6, 8]. When salt stress condition prevails for a long time it may induce in plants accumulation of osmolytes, stress protein production and reactive oxygen species scavenging systems. In recent years, the number of scientists tries to enhance plant tolerance in the salt stress situation. Plant tolerance either through chemical treatments such as plant hormones, minerals, amino acids, quaternary ammonium compounds, polyamines, vitamins, biofertilizers treatments; Asymbiotic nitrogen fixing bacteria, symbiotic nitrogen fixing bacteria, mycorrhiza and enhanced tolerance by using genetic modification [9].

Plant growth promoting bacteria (PGPB) are inoculated in seed and seedlings of crop plant this helps to alleviate salt stress effect. Crop production decrease as a result of the severity of abiotic stresses, particularly high salt condition, so tolerance mechanism to stress provided by PGPB inoculants becomes more significant. Rhizosphere is soil surrounded directly from the root system, whereas bacteria colonizing in the root environment are referred as rhizobacteria. PGPB in saline condition related to hydraulic conductance, compatible solute addition, confiscate toxic sodium ions and higher stomatal conductance. In saline environments PGPRs may increase plant growth and development by direct and indirect mechanisms. Plant hormones such as auxin, cytokinin and gibberelin produce by promoting bacteria indirect mechanism [10]. PGPRs can also stop the harmful effects of one or more phytopathogenic organisms and stresses from the environment [11]. ACC deaminase activities in PGPRs have been used to decrease the harmful effects of salt stress because PGPRs slow down ethylene production in plant roots [1]. Bacteria isolated with PGP activities from physically salt affected help to ameliorate the harmful effect on wheat plants [12]. Numerous genera such as *Pseudomonas, Bacillus, Arthrobacter, Azospirillum*, *Klebsiella*, *Enterobacter*, *Azotobacter*, *Herbaspirillum*, *Burkholderia*, *Rhizobium*, *Gluconacetobacter*, *Alcaligenes*, and *Serratia* have been isolated from the rhizosphere of different crops [13, 10]. These bacterial strains have the ability to produce non enzymatic antioxidants [14]. Exopolysaccharides produce by bacterial strains help to bind cations such as calcium, potassium and sodium. Approximately fifty percent organic forms of phosphorus are synthesized by plants and microorganisms in the soil. In recent studies six phosphobacteria strains were identified from the rhizosphere of *Lolium perenne*, *Trifolium repens*, *Triticum aestivum*, *Avena sativa* and *Lupinus luteres* [15]. PGPRs can avoid the detrimental effects of stress factor from the environment. Besides this, the beneficial and suitable PGPRs identification, selection and application can increase the options to compete with increasing harmful effects of abiotic factor. In this review, we discuss plant growth promoting bacteria role in saline soil.

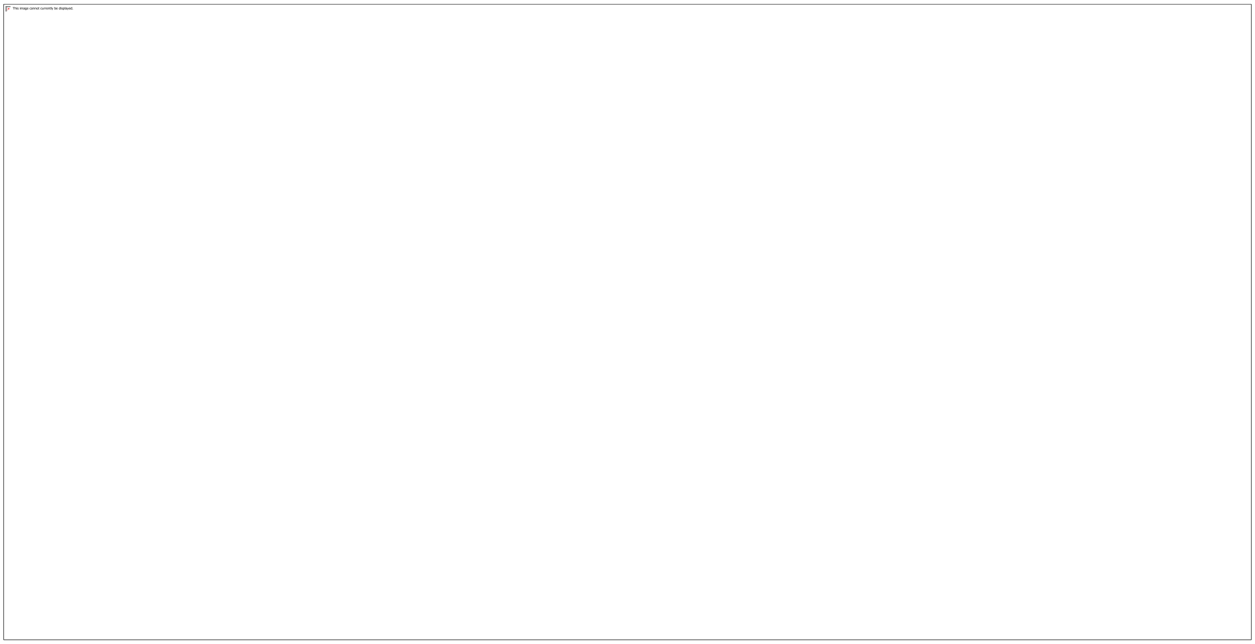

Fig.1. Illurtation of PGPRs role in salt stress harmful effects alleviation.

Plant Growth Promoting Rhizobacteria role in water homeostasis:

The salinity negative effect is to disturb water uptake and reduce plant yield, so water homeostasis is essential. As salt stress has induced changes in turgor potential of plant cells if PGPRs plant shows osmotic adjustment to salt stress **[16]**. PGPRs can affect root hydraulic conductance of *Phaseolus vulgaris* plants under salt stress than un-inoculated plants **[17, 18]**. Likewise, *Zea mays* plant's roots were inoculated with *Bacillus megaterium* in high salt levels as result plant able to sustain with stress condition **[19, 20]**. In stressed plant proline synthesis increases due to application of Burkholderia, Arthrobacter and Bacillus [21]. Though proline synthesizes mechanism is not clear, on the other hand proBA gene derived from *Bacillus subtilis* and introduces into *Arabidopsis thaliana* as a result of this induction increased proline production **[22, 23, 24]**. In an experiment 7200 expressed sequence tags from plants inoculated with strains over expressing the trehalose-6-phosphate synthase gene revealed upregulation of genes involved in stress tolerance **[25]**. *Glomus fasciculatum* colonize crop plant roots as a result increased soluble sugar production. Though, carbohydrate accumulation should be also considered in relation to its production in source leaves and its transport and use in actively growing sink tissues. This has an important implication for biomass reallocation, plant adaptation, photosynthesis, and growth **[26]**.

Plant Growth Promoting Rhizobacteria Role in Ion Balance:

A number of metabolic and physiological changes in plants under salt stress related to plant tolerance and mostly ion exclusion from the leaves, thus ions toxic effects are avoided or delayed **[5]**. PGPRs role in maintaining toxic ion concentration in Plant growth under salt stress it must be beneficial. Sodium and chloride accumulation decrease due to PGPRs ion transporter expression that can adjust toxic ion uptake and alter rhizosheaths produced by bacterial exopolysaccharides.

Rhizosphere pH changes are caused by microbes increase the availability of macro and micronutrients to plant [27]. Sodium accumulation decreased due to *Glomus intraradices* in *Lotus glaber* root and shoot [28]. *Glomus clarumand* improve growth and development of *Vigna radiata* plant in salinity. Correspondingly, other scientist's findings also show that PGPRs increase growth, development and yield in crop plants [29]. Recent results show that PGPRs can increase uptake of potassium, magnesium and calcium and decrease sodium uptake. PGPRs this role helps to maintain internal potassium and sodium levels. Uptake of toxic ions could more or less lessen harmful effects of salinity on crop plants [30].

Sodium accumulation decreased by bacterial exopolysaccharides because PGPRs bind with sodium ion in the roots therefore avoids transfer to leaves and stem of plant [31]. Besides, PGPRs with 1-aminocyclopropane-1-carboxylic acid (ACC) deaminase enhance absorption of nitrogen, phosphours and potassium in *Zea mays* [32] and Phosphours, potassium and calcium accumulation increased in tomato plant under salt stress condition [1]. Microbes not only delay uptake of sodium but also promote sodium extrusion from the shoot [32]. High affinity potassium ion transporter differentially regulated sodium and potmassium levels depending on the plant species and plant tissue. Number of scientists observes that the induction of AtHKT1 decreased sodium accumulation and improved tolerance mechanism. Salt stress phenotype and inhibited growth observed when exposing an AtHKT1 mutant to bacterial volatile organic compounds [33]. Nonetheless, [34] findings demonstrate that PGPR in salt stress play an important role in the alleviation of osmotic stress effects by maintaining higher stomatal conductance and photosynthetic activities [26].

Plant Growth Promoting Rhizobacteria Role in Phytoharmone Production

In the rhizosphere microbial community present has been identified and recognized in auxin synthesis. In recent year's research, scientist discovered 80% microorganisms hold the ability to synthesize and release auxins. Plant auxin level variations due to PGPRs auxin level in soil, but sometime auxin produced by rhizobacteria that delay various plant developmental processes [35, 36]. Auxin play important role in plant growth as well as in plant defense system. [37] explain auxin synthesis, transport and signaling mechanism with auxin function. Indole aceic acid (IAA) play important role in seed germination, root cells growth and development and adventitious root formation. IAA3 directs shoot growth towards light, root growth under gravity, regulates chlorophyll synthesis, enhance photosynthesis and help plant withstand stress condition. PGPRs auxin enhances root formation, root area and root hairs and gives the plant roots large area to absorb maximum nutrients. [36] describe rhizobacterial auxin slacken plant cell walls facilitates an increasing amount of root exudation that provides additional nutrients to support the growth of rhizosphere bacteria. Therefore, Spaepen and Vanderleyden [35] recognized auxin as the key molecule in plant microbe interaction.

Tryptophans regulate auxin synthesis and tryptophans play important role to change the level of endogenous auxin [38]. Tryptophan stops anthranilate formation by a negative feedback mechanism because anthranilate decrease IAA synthesis, although anthranilate act as precursor for tryptophan biosynthesis [39]. Nevertheless, [35] findings suggest that in rhizobacteria culture if media supply with the tryptophan, PGPRs auxin production increases. **[35]** describe that five different pathways for the synthesis of auxin and (1) explain auxin production through IAA3 and IAA3 aldehyde is found in *Erwinia herbicola*, Agrobacterium, Pseudomonas, Bradyrhizobium, Rhizobium, Azospirillum, Klebsiella, and Enterobacter. (2) In Pseudomonads and Azospirilla tryptophan conversion into IAA3 aldehyde another pathway in which tryptamine formed (3) indole 3 acetamide responsible for auxin formation in *Agrobacterium tumefaciens*, *Pseudomonas syringae*, *Pseudomonads putida* and *pseudomonads fluorescens*. (4) in the *Synechocysti* ssp. tryptophan conversion into indole-3-acetonitrile (5) the tryptophan pathway found in azospirilla and cyanobacteria similar to plants **[40]**.

In salt stress plants root and stem xylem sap show increase in abscisic acid (ABA) levels **[41]**. **[42]** explain that in vitro ABA production mediate by many PGPRs. Even though numerous plant growth promoting rhizobacteria (PGPRs) isolated and recognized from weed species. Weed spp mostly grown in saline soil and them able to produce ABA in vitro. So, PGPRs may enhance growth of soybean seedlings under saline soil **[43]**. *Gossypium hirsutum* seeds dipped in suspensions of *Pseudomonas putida* for 6 h before planting. This practice may increase seedling biomass accumulation about 10% in saline soil **[44]**. Lettuce plants grow in dry soil with PGPR *Bacillus subtilis* producing significant root to shoot cytokinin signaling **[45]**. **[46]** demonstrate that cytokinin production appeared to the relatively common trait of PGPR and mycorrhizal fungi **[42]**.

Phosphorus is present in the soil as an inorganic mineral, but sometime deficiency of phosphorus in soils overcomes by regular applications of phosphate fertilizers in the fields. However, **[46]** explain that plants able to absorb low concentration of applied phosphate fertilizers, but most of rapidly converted into insoluble complexes. Phosphate fertilizers regular application is costly and environmentally hazardous. This has led to search for an ecologically safe and economically reasonable option for improving crop production in low P soils. PSM (phosphate solubilizing microorganisms), have ability solubilize P to accessible forms of plants, so PSM provides a possible alternate to chemical phosphate fertilizers **[47]**. Phosphate solubilizing bacteria (PSB) are considered as promising biofertilizers since they can supply plants with P from insoluble sources **[48]**. **[40]** reported Azotobacter, Bacillus, Beijerinckia, Burkholderia, Enterobacter, Erwinia, Flavobacterium, Microbacterium, Pseudomonas, Rhizobium and Serratiaare mainly important phosphate solubilizing bacteria. In some bacterial strain phosphate solubilization and mineralization can coexist **[49]**. Nevertheless, phosphates solubilizing bacterial strains are normally found play an important role in their establishment and enhance phosphate performances are severely affected by environmental factors, especially under stress conditions **[50]**.

Plant Growth Promoting Rhizobacteria Role in Metabolite Transport:

[26] results explain that *Glomus mosseae* colonized roots of *Zea mays* plant and they accumulate soluble sugars. In stress conditions, plants start to produce osmolytes and they help to enhance the plant water uptake, increase chlorophyll synthesis and photosynthetic ability. *Capsicum annuum* plant shows higher dry matter accumulation when roots inoculated with the *Azospirillum brasilense* and *Pantoea dispersa*. Plants with PGPRs inoculation maintain higher source activity due to increased stomatal conductance and photosynthesis than plants without PGPRs **[34]**.

Conclusions.

In saline conditions PGPRs can induce tolerance mechanism in crop plants PGPRs able to promote plant growth and development. In recent year's number of scientists explains plant microbe interactions help to develop tolerance mechanisms in saline soil, but still need to understand in detail their molecular and biochemical mechanism. On the other hand, PGPRs not play an important role to tolerate stress condition, but they also improve soil fertility.

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