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A Review on Plant Growth Promoting Bacteria Ameliorating Salinity Stress

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ABSTRACT
Salinity is a biotic stress which is constraint for the plant growth and development, putting agriculture productivity and food security under stress globally. Potential use of plant growth promoting bacteria (PGPB) ameliorating the salinity stress through number of mechanisms evoking multipronged physiological, biochemical and molecular responses. By developing the novel inoculum for saline soil based on the recent studies concepts can be a sustainable approach in ameliorating productivity of affected agricultural land and food by simultaneously remediating salinity affected agricultural land. The metabolic and genetic properties of the PGPB have direct role in eliminating the harmful effect of salinity. Various mechanism of PGPB includes modification in cell wall/cell membrane, development of various enzymes, production of protein performing various metabolic function, production of osmolytes, siderophore production, improving the level of phytohormones (auxin, ethylene, cytokinin, abscisic acid, gibberellin), Exopolysaccharide (EPS) production. In spite of overwhelming advantages exact mechanism of PGPB ameliorating saline stress is not known so it is field to further investigate.

KEYWORDS: *Exopolysaccharides, Osmolytes, Phytohormones, PGPB, Salinity stress, Siderophore*

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1. INTRODUCTION:

Salinity is factor which negatively impacting on plant growth and crop productivity (Allakhverdiev et al.,2000).Soil salinity cause plant stress in two ways I.water uptake difficult II.plant toxicity by accumulation of high salt concentration (Munns and Tester ,2008)For agriculture, saline stress is the most serious threat because salt deposition on arable land turns cultivable land into unproductive area. The 10% of land surface and 50% of the arable land are salt affected globally (Ruan et al., 2010).The potential application of the PGPB in agriculture is based on their ability to increase plant growth and stress amelioration without having any harmful effect to the environment. The complex and dynamic interaction between microorganism and plant roots under a biotic stress like salinity, affects not only plant growth, but also soil. PGPB inoculation mediates physiological and anatomical changes in the plants, which play an important role during environmental stress. However ,most plants possess various mechanisms to decrease the negative effect of the salinity which includes regulation and compartmentalization of ions, synthesis of compatible solutes , induction of anti oxidative enzymes, induction of plant hormones and changes in photosynthetic pathways(Cheeseman 1988; Parida and Das , 2005).Several strategies have been developed in order to restrict the toxic effect resulted by salinity by use of plant growth promoting bacteria (PGPB)(Dimkpa et al., 2009).

2. SALINITY STRESS AMELIORATINGENZYMES:ACC DEAMINASE AND ROS SCAVANGING ENZYMES

Ethylene at higher level is detrimental for plant growth and development (GLICK 2005). Activity of ACC-deaminases enzyme that degrade the ACC, the precursor of ethylene is stimulated by IAA produced by bacteria(Glick et al., 2005)under salt affected soil condition, ACC-deaminase activity of bacteria can be helping for better growth and yield of crops. Positive effect if such phytohormones producing PGPR have been documented in different crops such as wheat (Egamberdieva, 2009) and rice (Mirza et al., 2006).

Salinity induce to reactive oxygen species (ROS) like hydrogen peroxide(H_2O_2), hydroxyl radical (OH^-), super oxide(o_2^-) etc. (Scandalios 2002).PGPB adopt to the antioxidant system to eliminate the negative effect of on plant growth and development and on bacterial cells(Wang et al., 2009;Jebara et al.,2005, 2010;Farrisi et al.,2013;Amudha, et al., 2011). PGPB promotes higher production of antioxidant enzymes in plants than plant without PGPB treatment (Nautiyal et al 2008; Chakraboarty et al 2013). Example of antioxidant enzymes are guaiacol peroxidase, ascorbate peroxidase(APX), superoxide dismutase(SOD), catalase(CAT), glutathione reductase(GR) which are secondary metabolites(Ghoulam et al.,2002).APX and CAT enzyme eliminate the negative effect of the hydrogen peroxide by converting hydrogen peroxide to the H_2O and O_2.(Scandalios et al.,1997)

3. NUTRIENT UPTAKE FACIATION BY PGPB

Salinity make difficult the uptake of nutrients because of increased level of the Na^+/K^+, Na/Mgratio (Grattan and greive 1999). Plant growth promoting bacteria which grow in, on, around plant tissues are promising alternative to ameliorate plant stress caused by salinity through various mechanism. (Fu et al., 2010; Mayak et al., 2004; Shilev et al., 2010; Yao et al., 2010). These mechanisms and their effects can be classified as direct or indirect .The direct mechanisms are biological nitrogen fixation (BNF)(Graham and Vance,2000),phosphate solubilization and mineralization (Rodriguez et al.,2007).Crop production is decreased due to salinity stress because of effect on nutritional uptake and translocation of nutrients(Nautiyal et al.,2008; Shi-Ying et al.,2018)Inoculation of plant growth promoting bacteria help in nutrient uptake through various mechanism(Jaiswal et al., 2016). Nitrogen, Phosphorus, potassium is vital elements for plant growth. The addition of plant growth promoting bacteria help to increase the uptake of nitrogen symbiotically or Non symbiotically along with plants (Santi et al., 2013). salt tolerant *Azotobacte*r can fix nitrogen at higher concentration (Zahran 1997).Naturally the phosphorus is present in both organic and inorganic form but these forms cannot be taken up by them. To make them in available from which can be taken up by the plant. Processes like chelation and acidification by PGPB make the plants. Monobasic ($H_2PO_4^-$) and dibasic (HPO_4^{2-}) are forms of phosphorus that can be taken up by plants (Etesami et al.,2014).To getthe maximum production K is required in optimum quantity but K is not directly available from K-solubilizing bacteria(KSB) make them available. The NPK content of the wheat leaves are high due to inoculation of *Bacillus aqamaris*under salinity stress (Upadhyay and Singh2015). Plants also requires some mineral elements likeFe, Zn,Cu, etc. Siderophores, Low molecular weight iron chelators, produced by various PGPB, bind $Fe^{3+}$and make it available for own growth and plant growth. The production of siderophore by PGPR enhance the iron uptake of plants (Kotasthane et al.,2017;Priyanka et al.,2017).Zinc is important microelement for the growth and development of plants by governing several physiological processes. Use of zinc solubilizing ability of ACC deaminase containing PGPR was evaluated on the Tris-minimal plates supplemented with insoluble zinc complex $NZnSo_4$and only ACCO2 was found to be categorized as zinc solubilizing bacteria. The production of ammonia by microbes helps the in both direct and indirect manner. Ammonia production by diazotrophic bacteria is one of the important character of PRPB which benefit the crop (Perez-Montano., 2014; Richard et al., 2018). This accumulation of ammonia in soil may increase in the pH creating alkaline condition of soil at pH-9-9.5.It suppresses the growth of certain fungi and nitrobacteria as it has potent inhibition effect. (swamy et al.,2016).

4. SECONDARY METABOLITES PHYTOHORMONES BY PGPB

Plant hormones are naturally occurring small organic molecules produced within the plants which influence the plant growth and development. at very low concentration. Plants growth promoting bacteria produce plant growth promoting compounds including phytohormones; auxin, cytokinin, abscisic acid, and Gibberellins (Garcia de Salamone et al., 2001.)

A. auxin

Auxin synthesis occurs through various pathway in bacteria.along with plant's endogenous IAA pool,auxin signaling pathway is provoked and it cause the cell growth, Patten and Glick (1996)reported that about 80% of the plants growth promoting bacteria posses the ability to produce in dole acetic acid. Plants inoculated with such plant growth promoting bacteria help in increasing root growth, lateral root formation, root hairs that help them to survive against abiotic stress like salinity. Several strains of genus *Bacillus, Azatobacter, Psuedomonas* were reported to produce IAA (Cassan et al., 2014; Verma et al., 2018).The evaluation of bacterial isolates, ACC02 and ACC06 for production of IAA revealed that both are significant producers of IAA suggesting that they could be used as PGPB.

B. ethylene

Ethylene is involved growth and development such as seed germination, root hair development and elongation, fruit ripening, leaf abscission, and organ senescene (Ahmad et al.,2011), through regulation of several stress-related genes. However ethylene is essential for plant growth and development but at higher concentration of the ethylene is detrimental for plants and resist the plant growth. Plants synthesize 1-aminocyclopropane-1-carboxylic acid (ACC), an ethylene precursor, used by bacteria having ACC deaminase potential as a source of nitrogen to prevent ethylene production. Ethylene production is having two peaks; first peak and second peak. First peak is small and important for the defense mechanism of the plant while second pic is high which is detrimental for the plant growth and development which is prevented by the ACC deaminase induced by the PGPB.

C. cytokinin

The exact mechanism of cytokinin in the PRPB is still unknown due to less researches toward this *Pseudomonas* strains(*P.aurantiaca* TSAU20,*P.extremorientalis* TSAU6 and *P.extremorientalus* TSAU20) enhanced growth up to 52%,compared to control plant and alleviated salinity(100Mm NaCl)induced dormancy of wheat seeds(Egamberdieva,2009).

D. abscisic acid(ABA)

Abscisic acid plant hormone play important role in seed development, and maturation, in synthesis of protein and compatible osmolytes, which enable plants to tolerate abiotic stress like salinity and as a general inhibitor of growth and metabolic activities.ABA secreted by Bacillus amyloliquefaciens H-2-5 supress the Nacl induced stress in soya bean enhancing the plant growth (Kim et al.,2017)

Protective effect of the ABA is major in plant growth as it influence the stomatal closure to decrease the water loss and mediates stress damage through activation of various stress-responsive genes, which collectively increase the plants stress tolerance (Zhang et al., 2006).However effect of ABA varies among different class of the microorganisms and plant species (Evelin et al., 2009; Yang and Crowley 2000)

E. gibberellin

Gibberellin is plant growth promoting hormone. Gibberellins are a group of diterpenoid group of hormones strongly associated with the plant growth. Rice roots colonized by *Rhizobium* show more production of gibberellin which results in increase of plant growth and development (Bottini et al., 1989). Endophytic bacteria *(Sphingomonas* sp.LK11) and gibberellin can improve *Solanum lycopercium* growth and oxidative stress under salinity (Halo et al., 2015). The secretion of gibberellins (GA_4, GA8, GA9 and GA_{20}) by Bacillus amyloliquefaciens H-2-5 and their phosphate solubilizing activity help in increasing plant growth(Kim et al.,2017).

5. OSMOLYTES PRODUCED BY PGPB

Osmatic adjustment is effective aspect of stress tolerance. Here osmolytes can be define as osmoprotectants like glycine, betaine, polyamide and various sugars which stabilize the osmotic difference between cytol and cell surroundings. Along with this they also help against oxidative stress by restricting detrimental (reactive oxygen species) ROS like super oxide, hydrogen peroxide and other free radicals. Bacteria can synthesize compatible solute (sugar, amino acids or derivatives) that act as osmolytes and help organism to survive when there is extreme stress (Bacilio et al., 2004; da costa et al., 1998; parida and Das, 2005). *Pseudomonas fluorescens* MSP-393 is proven biocontrol agent for many of the crops grown in saline soils of coastal ecosystem. Studies have revealed that the root colonization potential of the strain was not hampered with higher salinity in soil. As means of salt tolerance, the strain de novo-synthesized, the osmolytes Ala, Gly ,Glu , Ser, Thr, and Asp in their cystol.

PGPB Producing exopolysaccharides:

Different biopolymers are secreted by the microbial cell (polysaccharide), polyesters, polyamides) intoits surrounding .EPS produced by PGPB make slime and it make protective sheath around soil aggregates, and when plants are inoculated with EPS producing bacteria they ameliorate plant salinity stress. (Ashraf et al., 2004; Naseem and Bano, 2014). Exopolysaccharides forms sheath around foots and bind with the cations like Na+ in less bio available concentration and also play role as signaling molecule and help to survive in saline condition .EPS-producing *Azotobacter chrococcum* improve the shoot growth and root system under salinity stress (Awad et al.,2012).

6. DISCUSSION

The potential microbes are beneficial to improve the plant growth, nutrient uptake during abiotic stress like salinity (Egamberdiyeva and Hoflich 2003; Berg et al 2013; Vardharajula et al 2011). But still for more clearity of interactions between microbes (PGPB) and plant to ameliorate biotic stress like salinity more researches are required.

CONFLICT OF INTEREST

The authors have no conflict of interest in preparing this article

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