Role of PGPR to improve potential growth of tomato under saline condition: An overview

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Abstract: Salinity is an important and potential abiotic stress that caused reduction in yield and potential of crop plants throughout the world. It has been reported from various studies that as salinity is increased, the morphological trait like leaf length, leaf weight, number of leaves, leaf surface area; physiological traits, like transpiration rate, stomata conductance, photosynthetic rate, leaf temperature; chemical (anthocyanin, Chlorophyll-a, Chlorophyll-b, carotenoids) and biological (gene expression) are mostly effected that cause the death of the crop plants. Findings of results show that PGPR exhibits a pondering effect on tomato plants and targets the plant growth by its constraints. Various strains of *Bacillus megaterium* has been used by different researchers with different concentrations of salt. It's an elicit swapper which enhances via hormones to plunk in salt stresses. Research says PGPR is an admirable and diverse model system, instead of using artificial fertilizers using PGPR is momentous eco-friendly and upholds safe agriculture resulting in improved yield crop because of phytohormone production (organic acids) and their biocontrol nature. Therefore *Bacillus megaterium s*trains can be used in saline condition to make plants tolerant.

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1. Introduction

Environmental problems are encroaching day after day in, raising interest in environment friendly agricultural practices. Agriculture had a vital share of national income. Salinity is one of those factors which deteriorate the position of a country. It vitally affects the agricultural land, economic development and also the nutritional standards which by the end result in increased expenditure to manage (Ezlit *et al.,* 2010). Saline soil solution may contain cations of potassium, sodium, calcium magnesium, etc. and anions of carbonate, bicarbonate, nitrate and sulphates, etc. In urge of improvement in salinity tolerance worldwide many strategy advancements are made. However molecular biology bends are pursued currently with intense tactics to maintain the resistance potential in the plant against salinity. In recent times, salinity is given more importance as soon it will be not remain only an option to deal but a problem to deal, realizing and accepting the fact that salinity is affecting the economy and also the environment. Productive usage of resources and fruitful attempts should be made (Dasti, 2013).

In arid and semi-arid regions, like Pakistan, this is a matter of concern because such areas are vulnerable to salinity. Nature of plants vary, some of the plants can grow in saline conditions. If soils are not irrigated the salts are not leached out properly, for that reason, large amount of salt in the soil wreck the soil quality and crop growth. Therefore, designing of irrigation system and such tolerant plants can be used to recover the salinity, which is cost effective and can contribute to national income by adding production of crops. Examples of such halophytic (salt loving) plants are kallar grass, Rhodes grass, frash, tomato and other fodder species. The best part is our Pakistan is best area for such plants as salt tolerant species grow best in arid regions (Qureshi *et al.,* 2007). When we talk about salinity there are many inter and intra specific levels which makes us unable to identify a single criteria for effective targeting but can be possible if physiological and biochemical factors are taken into most concern indicators. There is a difference in crops pattern of growth when they are interacted to saline soils and by the time the salts can mount up in their tissues contributing to the food chain. Saline stipulations can impinge on the nutrients uptake by antagonistic effects. Other premium thing we can do for such crops is to build tolerance at generic level or by using bio-indicators. PGPR are the best remediation for treating saline soil (Figueiredo *et al.,* 2010). At present, worldwide in the field of biofertilizer technology there is a considerable progress useful for soil enrichment or fertility (Yang *et al.*, 2008 and Amin Yang *et al.*, 2015).

In 1970 research on PGPR started and in 1980 *Bacillus* was in consideration for research including screening, isolation and antagonistic effects. PGPR is a proficient way to swap fertilizers, pesticides etc. By the time PGPR flourishes and its connotation delve into colonization, seedling germination, mineral uptake (ion fixation) helps plant to stand out growth yield (height & weight), nutrient uptake. Maneuver that PGPR promote includes; nitrogen fixation in legumes by promoting free-nitrogen living bacteria, producing plant hormones, controlling fungal and bacterial diseases and insect pests. They augment plants by two means i.e., direct and indirect profess (Korneli *et al.*, 2012). Cost for bringing overall a new crop protection merchandise to the market requires eight to nine years and approx. 200$. By 2005 the zenith of plant science companies has spent US 2.25billion dollars (Crop life Australia, 2008). Research industry should now look outside the customary line up as challenges of future such as climate change and human demands are also mounting day by day. Innovative farming, crop protection can conserve agriculture (Dasti, 2013).

2. Salinity affects on crop plants

Survival of the plants confront spate occurrence of unfavorable conditions. From many of other traumas salt and water is one of the anxiety plants suffer when water is not available up to the required limit. Studies are being conducted in this regard for developing breeding strategies. Tomato plants are being used in research for agriculture and research (Nadeem *et al.,* 2006). Over a 1000 scientific papers per year have been published linked to the research of tomato, since 2000 (Passam *et al.,* 2007 and Khan *et al*., 2015). Estimated production of tomato globally is 120 million metric tons; it's a foremost horticulture crop. From 1960 – 2000 ratios of population and arable land turn down about 40% percentage arable land internationally is UK 24%, Australia 6.6%, and France 34%. In some countries more than the half of the irrigated land is saline. Total land of world`s 6% world irrigated areas are 20 % affected by salinity (FAO, 2007).

Soil salinity is one of the vital harass for crops. It is been projected globally that the cost of saline irrigated soils is US$11 billion per year. The main toxic component of salinity is sodium (Na^+). It is estimated that water scarcity will be in countries as population will reach to 1.8billion people. 20% (450,000sqkm) of irrigated land is salt affected results in 2500-5000sqkm production loss (Crop life Australia, 2008).

Facts say Pakistan has 24.44% arable land, 0.84% permanent crops and irrigated land is 198,700sqkm (CIA World Factbook for Pakistan, 2008) At present irrigated land internationally suffers 20% of the salinity which may increase more by the upcoming 20 years. Due to salinity this year Pakistan suffers the loss of crop yield which is apprehending to the 880 million rupees ($28.5 million) whereas estimation says that the economic damage's total leads to 300million dollars. Saline soil is a social problem as its effects the agricultural strength which is the vital supplement for humans. In Punjab a survey is conducted which proclaims the statement "saline soil is a social problem" as people who live in affected areas of salt had shoddier living standard. Some of the halophytic plants can survive even in 0.5% soluble salts by weight (Dasti, 2013).

In abiotic stress condition plants give response commonly as altering water transportation, ROS (reactive oxygen species) and osmolyte production (Maggio *et al*., 2007; Rodriguez *et al.*, 2008). Endurance of plants depends on antagonistic strain of environment. In control of crops production water is the basic control. When plant is in stress the hormone ABA is activated (catabolized by hydroxylation and conjugation) other factors of Bzip transcription as ABFs/AREBs, phosphoinositides and IP3 have been identified. Secondary messangers (Ca^{+2}, phospholipase and phosphatidic acid) in stress condition the stomatal response communicates the activities of numerous ion channels generalized at the tonoplast and plasmalemma. Some of the genes induced by drought, salt, or cold as RD29A, KIN1, KIN2, COR47 but in an independent manner. To identify the positive transgenic lines PCR is apllied using genomic DNA from segregating primers (Turan *et al*., 2012 and Mohamed *et al*., 2015). Salt contaminated soils are classified as: Saline soils, sodic soils and acid soils (Qureshi *et al.,* 2007) Salt glands are there in some plants also in some halophytes salts are excluded by plant roots for regulating the contents of salt. Salinity can be increased in the root zone of soil when salt is not leached after the irrigation from the root zone (Ezlit *et al.,* 2010). When salts in soil are in high concentration they hinder the roots potential to haul out the water. At the same time it results in physical and biochemical toxicity of plant such as assimilation and nutrient uptake etc. (Hasegawa *et al.,* 2000; Munns *et al.,* 2008).

Table 1.1: Salinization risk in comparison with its limitation (Posthumus, 2006)

Salt concentration (g/l)	Less than 0.5g/l	0.5 – 2 g/l	More than 2 g /l
Risk of saline soil	No risk	Slightly to risk	High risk
Limitations	No limitation	Appropriate management practices for water applied	Specialist analysis required

Table 1.2: Salinity and plants response of different growth (Posthumus, 2006)

Concentration of salt g/l	0 – 1.5	3-5	5-11	More than 11
Salinity	Salinity None	faintly saline	average saline	extremely saline
Plants reaction	minor	Growth of many plants restricted	Tolerant plants can grow suitably	a small number of tolerant plants can grow suitably

Salinity refers to the presence of ions in water. Salinity can be natural or induced. Common salt NaCL, sodium sulfates, potassium, calcium, magnesium are dominant in saline soils. Knowing the degree of salinity we can evaluate the type of plants, soil characters, water quality and the extent of problem (Ashraf, 2004). Salt concentrated soil act as growth inhibiters because first it decreases the water absorbance ability and declines the transpiration by damaging the transpiration stream leaves. In saline soil water is trapped by ions. (Aranda *et al.,* 2001) To combat the salinity issues lot of research work is done to seek the tolerant cultivators for abiotic constraints, i.e. salinity (Korneli *et al.,* 2012 Butt *et al.,* 2015). Salt tolerance can be measured by increase or reduction in the yield of plant (Maggio *et al.*, 2007). Gene analysis contributed a lot to identify the determinants of salt tolerance and analyses the response in stress adaptation (Hasegawa *et al.*, 2000; Munns *et al.,* 2008). Whenever saline water is used for irrigating tomato plants there's a decrease in the development and uptake of water, physiological traits effected by these changes can be measured in a relative way by gauging the biochemical characteristics, gas exchange parameters, leaf are, dry and fresh weight, Chlorophyll content and sodium. There`s a feedback behavior in plants to salinity as they decreased fruit production and less dry weight is produced. Riot in water balance persuaded by the salts made costs leaf turgor reducing the photosynthesis area of the plans by leaf expansion (Aranda *et al.,* 2001; Salam *et al.,* 2011).

In saline environments plants adapt themselves by physical and biochemical mechanisms leading to the effective mechanism of homeostasis, both ion and water (Hasegawa *et al.*, 2000). Tomato was names as `Apple of Love` in France and Italy, they were first raised by Thomas Jefferson in 1871 but was not cultivated commonly until 1835 in united states because of the myth at that time that tomatoes are poisonous. Tomato is diploid having 2n = 24 chromosomes, having short life cycle. Largest genera of angiosperm are *Solanum* which includes plants that are perrinnial and annual with diversified habitats. For tomatoes 1 – ½ inch of water is required to make healthy growth of plants. Tomatoes are rich in nutrients and are low in calories. one medium sized tomato provides 35 calories while it provides 25 % RDA of vitamin A, 57 % of the RDA vitamin C, 8 % of RDA iron at the same time. Genetic makeup and the temperature synchronizes the ripening and color of tomato i.e., above 86 ^{o}F red color does not develop and yellow pigment continues (Tam *et al.,* 2007; Peralta *et al.,* 2007). Tomato (*Lycopersicon esculentum*) is significant crop in semi-arid regions of Mediterranean countries (Ferrandino, 2012).

North Americans are accustomed to call it "tomati" (Gao *et al.,* 2010). More than 4000 varieties of tomato are there. Garden tomatoes divides into determinate; small compact plants having the 12 - 18 inches long stem , semi- determinate; slightly larger having 18 – 24 inches, indeterminate; suitable for stalking , also have wide range viens. Tomatoes grow best in ph of 5-5 – 7.5 of soil. Tomato is a solar influenced sugar workshop (Amor *et al.,* 2001). A deep loamy soil supplied with organic matter and nutrients and also well drained is suitable for the healthy growth of the tomato plants (Gao *et al.*, 2010).

Tomato shows high salt stress forbearance succeeding treatment with inducer of resistance against as adipic acid mono ethyl ester and (DAAME) 1-3-diaminepropane. DAAME based tolerance in stress condition reduces the transpiration. *Lycopersicon esculentum* shows the classic glycophytic reaction with a prejudiced absorption of K over Na. When exposed to high salt the ethylene content in tomato plant reduces (Yang *et al.,* 2008). Salinity hinders the growth of plants and their production and affects the plants physiology, biochemistry and also reduces yield (Cuartero *et al.,* 2006). One of the abiotic stress plant suffer is salinity. Plants use osmotic tolerance, Na^{+} exclusion and tissue tolerance for combating the salt tolerance. High salt tolerant crop plants are tomato, cotton, sugar beet, date palm, barley spinach, etc. (Salam *et al.,* 2011).

Biochemical pathways that expedite the withholding capacity of water determine the tolerance of plant to salinity (Asish *et al*., 2005). It was found that restrained salinity effects size of tomato fruit initiates from a restricted water transport (Grava *et al.,* 2004). We can use gypsum (calcium sulphate) to measure the level of salinity and solubility of salts. Most common salt found in saline soils is carbo0nate. There are patches in saline fields which are termed as "Alkali spots" filled with the high levels of sodium, this leads to the compaction of soil. Due to the presence of salts, EC (electrical conductivity) of soil raises which results in soil dehydration deficiency and mortality of plants (Dasti, 2013). Potassium is essential for the expansion of the cell, homeostasis, and osmoregulation but in case of salinity the potassium role is depressed; as Na^+ depress K^+ uptake. Potassium is involved in many of the reactions of metabolism used for the structural components formation at cellular level. It act as a shield from water loss and also guard freezing in winter (Patel *et al.,* 2008). Salinity raises sodium concentration in roots and leaves of sodium plants. Sodium play role in osmoregulation, signaling and sustaining the uprightness of cell membrane. It also triggers the Na / K selectivity. Ca^{+2} may itigate Na^+ toxicity in plants (Turhan *et al.,* 2009). High levels of magnesium in the root zone are advantageous for tomato plants. Magnesium plays role in enzyme co-factor, cholorophyl structure. In addition to these it also exports photosynthates enhancing the leaves degradation resulting in amplified oxygenase activity (Patel *et al.,* 2008). Phosphorous enhances the pollen performance and influence the efficiency with respect to reproduction (Passam *et al.*, 2007).

Worldwide, more than 1 billion US$ annual economy loss occur due to salinity. Pakistan is located in arid and semi-arid climatic zones. Evapotranspiration cause salt accumulation in surface. Saline water upward movements can cause a salt cover in plant root zone (Qureshi *et al.*, 2007). Plants give responses to salt stress by means of cellular, tissue and whole plant level. When chemical activity of water decreases and turgor loss occurs it indicates that hyperosmotic shock (Nutritional imbalance, hypoxia and hyper osmotic stress) is stirring (Borsani *et al.,* 2003; Goupil *et al.*, 2009). When tomato is irrigate with water having salts growth and water uptake decreases with respect to these declines the physical traits (fresh, dry weight , leaf are, osmotic potentials, gas exchange parameters, leaf chlorophyll, Na+ content etc) are investigated so that the remediation or the level of treatment suggested. Chlorophyll content per unit of leaf area is increased with salinity (Aranda *et al.,* 2001). Abiotic plant Species becomes Stress tolerant because of the cellular proteins that regulate the transport functions. Tomato is one of them which express the HALI gene which reflects tolerance as a result of holding high potassium (Mathur *et al.,* 2008).

Presence of salinity raises the ROS (reactive oxygen species) that can encourage the lethal effects for cell metabolism (Borsani *et al.*, 2003). Salinity can prompt the second metabolic switch which is pragmatic to the plant`s stress adaption scheme (Maggio *et al.,* 2007). Mortality is not affected by salinity but the leaf area develops which turn out to be the decrease of shoot dry matter accumulation (Maggio *et al.,* 2007; Munns *et al.,* 2008). QTLs are linked with specific trait and are sections of genetic material; salt stress tolerant trait is multipart and goes on with response of salt and tolerant producing plants generation (Turan *et al.,* 2012). Salt tolerance is a dense trait in which long catalogues of genes responsive to salt stress are involved. When multiple characteristics are synchronized in a single genotype salt tolerance can be achieved. Conversely, as a single gene will not bring any significant change unless the gene over expression makes the plant salt tolerant as recently observed in Arabidopsis (Zhang *et al.,* 2001). Genes responsible for salt tolerance can be identified by gene expressions regulated by salt stress, the genes that gather organic compounds can be considered as the "salt determinants" (Borsani *et al.*, 2003). Plant growth promoting rhizobacteria is a varied group of colonizing bacteria, rhizosphere which is also diazotrophic. When it is grown with plants, it causes growth stimulation and direct indirect promotions effects also occur (Vessey, 2003; Banchio *et al.,* 2008).

3. PGPR role in salinity tolerance

In relationship with plants PGPR is divided into groups i.e., free living as symbiotic. While three are categories exist between the growing plants and rhizobacteria, positive, neutral and negative interactions (Kamilova *et al.,* 2009). PGPR helps in synthesis of particular compounds, uptake of nutrients and act as an antidote for plants (Szczech *et al.,* 2004). PGPR present in rhizospehere soil; area surrounding plant root undergoing intense bio-chemical activities by root exudates and microorganisms feeding on compounds, promotes plant growth, yield, solubilization of nutrients as phosphorous, nitrogen, potassium etc via inoculation (phytoharmones) with PGPR. They act as biocontrol agents via squirting siderophores, capability to fuse anti-fungal metabolites and antagonism for specific niches on root (Singh *et al.,* 2013).

According to Bhattacharyya & Jha (2012), PGPR can be classified into iPGPR and ePGPR. iPGPR are the symbiotic bacteria living with specialized nodular structures while ePGPR live outside and no nodular production is there but still speed up the growth of plants. PGPR are the Substantial techniques in the field of agricultural practices and has been practicised with built-in genetic prospective. The impulse of PGPR is curbed by the bacterial strains now that can aid biocontrol, plant growth stimulation and aggressive colonization (Vessey, 2003). In direct promotion, amalgamated substances are provided to host to ease the solubilization and uptake of nutrients and also synthesize the enzymes or phytoharmones modulating the growth and development of plant (Figueiredo *et al.,* 2010).

While in indirect promotion eradication of deleterious effects of organism occurs (Van Loon, 2007). Recent work shows that Plant growth promoting rhizobacteria (PGPR) provoke 'induced systematic tolerance' towards salt. They are allied to roots of plants and supplement the immunity and productivity of plant. They colonize the rhizosphere and refer constructive effects as disease susceptibility and increased plant growth (Yang *et al.*, 2008). PGPR (*Plant Growth Promoting Rhizobacteria*) are stretched for remediating the contaminated substances. However, phytoremediation is a buoyant attitude for the removal of contaminants. But usage single-handedly can challenge remediation limitations (Zhuang *et al.,* 2007). *Bacillus megaterium* is described over 100 years ago. It is large in size i.e., 10µm, and also capable of sporulation. It can show growth in variety of carbon sources (ecological niches). They are not pathogenic and can degrade many of the persistent insecticides. For expression analysis it proves to be the best, it is also a finest host for manifestation of non-homologous DNA. Recombinant plasmids here are stable in both segregation and structure (Mobitec Molecular Technology, 2012).

Bacillus megaterium is aerobic, spore forming and gram positive bacterium with various habitats i.e., seawater, sediment, soil, dried food, rice paddies, honey and fish. It gives amylase, glucose, penicillin as a product. Multiple plasmid strains are observed in it. It is also known as beast of bioremediation or biotechnology because of its remediating genomic nature (Vary *et al.*, 2007). *Bacillus megaterium* species spores are robust to harsh variety of behaviors i.e., radiation, heat, Y- radiation and the oxidizing agents. DNA spore saturation along with particular binding proteins (SASP) Acid soluble proteins (α/β type) oxidizing agents like H_2O_2 protects the DNA from being damaged (Korneli *et al.*, 2012). *Bacillus megaterium* have digenomic spores having a general radiation resistant characteristic polyploidy bacterium (Ghosh *et al.*, 2011). During germination specific quantities of the dipicolinic acid (DPA) and calcium ions are released by the spores of *Bacillus megaterium*and may responsible for the spores meanwhile communication (Szczech *et al.,* 2004). *Bacillus megaterium* does not produce the toxins that are allied with the outer membrane. About a hundred year ago B*acillus megaterium* was revealed as a gram positive bacterium (Korneli *et al.*, 2012). derived by a Greek word megat(h)erium which means a big animal.(Peralta *et al.,* 2007) Due to gram positive nature hampering of outer membrane protein export is vague. It secretes proteins in growth medium and possesses stable replication, multiplication of plasmids but it does not have alkaline proteases (Korneli *et al.*, 2012). It was found from studies by using PGPR CEMB-22 (*Klebsiella* sp.) and CEMB-15 (*Burkholderia* sp) in rice and Capsicum annuum that yield per plant was enhanced (Dar *et al.*, 2014 and Tariq *et al.*, 2014).

Conclusions

It was concluded from all studies that the tolerance of tomato plants against saline soil may be enhanced through the use of *PGPR.* It was suggested that more research should be conducted to confirm the effective use of PGPR.

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