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Role of Stress tolerant microbes in Sustainable agriculture

Dr. Archana Yadav Amity Institute of Biotechnology, Amity University, NOIDA

Renu Yadav Amity Directorate of Science and Innovation, Amity University, NOIDA

ABSTRACT

Beneficial aspect of PGPR is their ability to survive in stress conditions. These aspects have been rigorously utilized to promote plant growth. Increasing burden on the environment has resulted in diversified intense conditions which do not seek to promote plant growth naturally. Conditions like high salinity, alkaline soils and high temperature constitute an unfavorable habitat for the growth and multiplication of microbes. Apart from limiting the crop productivity, high salt, pH, and temperature stress in tropical alkaline soils also affects the efficiency of the plant beneficial microbes by retarding their growth. This could further promote reliance on chemical fertilizers which is not an eco-friendly agricultural practice. Thus, PGPR can be used to regulate plant growth in such stressed conditions. Stress tolerant PGPR can be used as potential abiotic stress tolerant inoculums for the tropics to rehabilitate degraded ecosystem.

KEYWORDS abiotic stress, PGPR, temperature, drought, osmotic

Introduction:

Agriculture contributes to a major share of national income and export earnings in many developing countries, while ensuring food security and employment. But the modern agriculture is severely modifying and polluting the natural environment due to the widespread application of chemical fertilizers, herbicides and pesticides. Alkalization of soil is one of the most serious forms of land degradation. Increased alkalization of land is expected to have devastating global effects, resulting in 30% land loss within next 25 years and up to 50% by the middle of 21st century (Mahajan and Tuteja, 2003). Saline and alkaline soils constitute an unfavorable habitat for the growth and multiplication of microbes which further leads to soil degradation. Recently there has been a great interest in eco-friendly and sustainable agriculture. PGPR are known to improve plant growth in many ways when compared to synthetic fertilizers, insecticides and pesticides. They enhance crop growth and can help in sustainability of safe environment and crop productivity.

Soil microflora

Soil is replete with microscopic life forms including bacteria, fungi, actinomycetes, protozoa and algae. Of these different microorganisms, bacteria are by far the most abundant (~95%). Soil hosts a large number of bacteria (often 10^8 to 10^9 cells/ gms of soil). Soil microflora is influenced by the type of soil and soil conditions like temperature, moisture, presence of salts, chemicals and the type of plants persisting in that soil. In addition, the distribution of bacteria is also not even in soil. Higher concentration of bacteria exists around the roots of plants than rest of soil.

PGPR (Plant Growth Promoting Rhizobacteria)

The term rhizobacteria is used to describe a subset of rhizosphere bacteria which are able to colonize the root environment (Ryu et al, 2004). Rhizobacteria that exert beneficial effects on plant growth and development were termed as PGPR. Rhizobacteria responds to root exudates by means of chemotaxis towards the exudates source: and in such scenario, competent bacteria tend to modulate their metabolism towards optimizing bacteria and tend to modulate their metabolism towards optimizing nutrient acquisition (Van Overbeek et al 2008) PGPRs either may inhabit root surface (exo-root) or penetrate into root cortex (endo-root). Thus, they may be ePGPR those found in the rhizosphere, on rhizoplane or within apoplast of root cortex or iPGPR that enter the plant cells and produce specialized structures, so called nodules. The rhizospheric soil contains diverse types of PGPR communities, which exhibit beneficial effects on crop productivity. Several research investigations are conducted on the understanding of the diversity, dynamics and importance of soil PGPR communities and their beneficial and cooperative roles in agricultural productivity. PGPR are known to affect plant growth by different direct and indirect mechanisms (Glick 1998). They aid in improving plant stress tolerance to drought, salinity, and metal toxicity, increasing mineral solubilization and nitrogen fixation, nutrients assimilation, repression of soil borne pathogens by producing hydrogen cyanide, siderophores, antibiotics, and/or competition for nutrients, production of phytohormones such as indole-3-acetic acid (IAA) . Moreover, some PGPR have the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase, which hydrolyses ACC, the immediate precursor of ethylene in plants. By lowering ethylene concentration in seedlings and thus its inhibitory effect, these PGPR stimulate seedlings root length. The bacteria presenting one or more of these characteristics are known as PGPR – PGPR (Kloepper et al, 1980). Some common examples of PGPR genera exhibiting plant growth promoting activity are: *Rhizobium, Pseudomonas, Azospirillum, Azotobacter, Bacillus, Burkholdaria, Enterobacter, Erwinia, Mycobacterium, Flavobacterium,* etc.

Cross-protection against abiotic stress

The non-specificity of plant perception of abiotic stress can lead to a general response, the basis of cross-protection, for eg: synthesis of quaternary amines increases plant's resistance towards drought and salinity and production of SOD (Superoxide dismutase). There occur a number of such responses in plants. More interestingly, the beneficial effects of inoculation with plant growth promoting root zone bacteria have been reported to be most significant under unfavourable conditions such as drought, metal toxicity (**Zhuang et al., 2007**) or nutrient deficiency (**Egamberdiyeva 2007**). The survival rate of introduced rhizobaqcteria in any given microbial community is an important factor determining the degree of plant stimulation. Because competition for limited resources is crucial, and baqcteria are also susceptible to environmental stressors, the most prominent beneficial effects of inoculation with potential PGPR is to be expected in poor soils. Inoculation with non-pathogenic root zone bacteria can trigger signaling pathways that lead to higher pathogen resistance of the host- the so called induced systemic resistance.

Changing environment and increasing stress:

Most plants complete their life cycle in a single location and are therefore plagued by challenges such as nutrient acquisition, pathogen attack and environmental stresses. External conditions adversely affect growth, development and productivity. Stress triggers a wide range of plant responses- altered gene expression, cellular metabolism, changes in growth rate and crop yields. Thus there is need for stress tolerant bacteria which can combat these changes and can increase the plant yield at the same time.

High temperature stress

In most environments, bacteria experience fluctuation in temperature that is both regular and random. Temperature tolerance in bacteria varies widely among different species and is influenced by a variety of factors as heating at sub lethal temperature; viral infections; presence in the media of chemical compounds such as methanol, methylating agent, antibiotics (e.g. nalidixic acid), and amino acid restriction and acid shock **(Kjelleberg et al., 1993)** have reported that starvation of some bacteria enhanced their resistance to temperature stress. Heat resistance increased with dehydration of bacteria and spore formation.

Tolerance to high temperature is a desirable property for PGPR inoculants to be used in the tropic, where high temperature during transportation and storage of the inoculants and at planting time is not usual. The surface temperature in soil of tropics and sub tropic often rises at 50^0C (Abdel Gadir and Alexander, 1997). Such high temperature may partially or wholly eliminate PGPR especially if the exposure period is long. Therefore it is important to have isolates resistant to high temperature. Kulkarni and Nautiyal (1999) have isolated 17 different (on the basis of SDS-PAGE) temperature tolerant rhizobia isolated from Prosopis. Besides, these cellular activities, heat stress is also known to change cell morphology in rhizobia. Heat shock proteins have been found in PGPR . The synthesis of heat shock proteins was detected in both heat-tolerant and heat sensitive bean-nodulating bacterial isolates at different temperatures. An increased synthesis of 14 heat shock proteins in heat-sensitive isolates and of 6 heat shock proteins in heat-tolerant isolates was observed at 40 and 45^0C, respectively (Michiels et al., 1995).

Drought Stress

Drought stress limits the growth and productivity of crops, particularly in arid and semi-arid areas. But as compared to host plants, bacterial isolates are quite resistant to soil desiccation and can survive in water films surrounding soil particles (Williams and deMallorca, 1984). Growth and movement of PGPR bacteria in the soil however could decrease under soil dehydration conditions .(Zahran 2001) showed that exposing PGPR to drought stress resulted in alteration of PGPR membrane polysaccharides, which are involved in the PGPR host plant recognition process. PGPR strain not producing exopolysaccaharide are more prone to dessication and temperatute than those producing exoplolysaccahride.

Osmotic stress

Soil alkalinity is a significant problem facing agricultural production in many areas of the world (Correa and Barneix, 1997). Alkalinity can develop from saline soils with low calcium reserve. On lowering the water table, soluble salts are washed down the profile and exchangeable calcium is replaced by sodium. Soil carbon dioxide form carbonate and bicarbonate ions and these react with sodium to raise the pH. Thus, tolerance to salt stress is an important part of saprophytic competence and competitiveness in PGPR spp.Intracellular accumulation of low molecular weight organic solutes called osmolytes has been a mechanism of adaptation to saline conditions by many species of bacteria. PGPR utilise this mechanism of osmotic adaptation that counteract the dehydration effect of low water activity in the medium but not to interfere with macromolecular structure or function (Zahran, 2001). In the presence of high levels of salt (up to 300 to 400 mM NaCl), the levels of intracellular free glutamate and/or K^+ were greatly increased (sometimes up to six fold in a few minutes) in cells of R. metiloti . The Na^+, K^+ and Mg^{2+} concentrations are increased in cells of cowpea PGPR under salt stress. These organic osmolytes (amino acids) and the inorganic minerals (cations) may play a role in osmoregulation for this PGPR strain.

Conclusion:

As our understanding of the complex environment of the rhizosphere, of the mechanisms of action of PGPR, and of the practical aspects of inoculant formulation and delivery increases, we can expect to see new PGPR products becoming available. The success of these products will depend on our ability to manage the rhizosphere to enhance survival and competitiveness of these beneficial microorganisms. Rhizosphere management will require consideration of soil and crop cultural practices as well as inoculant formulation and delivery. The use of multi-strain inocula of PGPR with known functions is of interest as these formulations may increase consistency in the field. They offer the potential to address multiple modes of action, multiple pathogens, and temporal or spatial variability.

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