CYANOBACTERIAL STRESS ACCLIMATION UNDER ENERGY DEPLETED CONDITION

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Abstract: Cyanobacteria show different adaptations under various salt stress conditions, which facilitate their survival. Pyrophosphate works as an energy donor while energy depletion in the cyanobacteria during salt stress condition. Alternative glycolytic reaction can bypass Pi dependent (ATP dependent) pathway of glycolytic cycle in cyanobacteria, through which these organisms are acclimated to salt stress.

Keywords- Acclimatization, Adaptation, Cyanobacteria, Glycolytic cycle, Salt stress

INTRODUCTION

Human population increases endlessly, enhancing water crisis, potential global change leading to need for increase in worldwide food production. More use of water for irrigation has resulted in soil salinization and depletion of ground and surface water Rosegrant (1997, Postel (2001). Developing countries face more soil and water degradation problem.

Salt Stress: Salinity is one of the severe environmental factors that may impair crop productivity. Most of the water on planet earth containing approximately 30g of sodium chloride L-1. Salinity is affecting the land which is used for the crop production. Excessive soil salinity is a severely increasing agricultural problem in arid and semi arid regions and also an important constraint limiting the distribution of plants in natural habitats Lauchli and Epstein (1990). This has made researchers to study the physiological and biological mechanisms supporting salt tolerance, with the aim of improving crop plants. Salinity affects osmotic stress, decreasing water availability, ionic stress, changes in the cellular ionic balance Krist (1989).

Nutrient Availability under Salt Stress: Crop production is dependent on the future global use of N, P, and water sustainability. N and P both are nonrenewable resources. P is second to N as limiting element for plant growth Vance (2001). Bound P is found in many soils, It is not available for uptake Schactman *et al.* (1998). To establish incessant availability of P requires an understanding of mechanisms in plants that enhance P acquisition and ways to increase availability of soil dissolved orthophosphate ($H_2PO_4^-$ and HPO_4^{2-}).

Biological nitrogen fixation constitutes an important potential source of N for crop growth and protein production in many soils and ecosystems. Renewable sources of nitrogen, biologically fixed, with enhanced P acquisition and conserve use are imperatives for future sustainability.

Various reports are available on role of cyanobacteria at increasing P availability in saline soil Kaushik and Subhashini (1985) but reports on cyanobacterial features responsible for this property are lacking. During cyanobactrial growth P assimilated by cells is released by decomposition in the form of soluble organic phosphate compounds and mineralized to orthophosphates resulting in an increase in available P Mandal *et al.* (1999).

Adaptation under Salt Stress: The reaction under salt stress is a physiological adaptation. It starts with destabilization of the cellular metabolism, loss of semipermeability, denaturation of proteins, changes in metabolic balance, formation of radical's etc. leading to growth inhibition. This is followed by an acclimation phase initiated by the synthesis of low molecular osmoprotective substances (glucosylglycerol, disaccharides sucrose and trehlose and quaternary ammonium compounds glycine and glutamate betaine) Mackay *et al.* (1984, Reed *et al.* (1984) which modify the membrane composition and induce certain transport processes (intracellular homeostasis) or lead to appropriate metabolic changes or processes which require a lot of energy expenditure.

ENERGY ACCLIMATIZATION UNDER SALT STRESS

It has been noted that one of the most important factors for the reduced growth and inability of plants and cyanobacteria to grow and survive under salinity is energy limitation to meet the adaptation. Pi starvation further deregulates the physiology of cells and cause ATP over consumptionPlaxton (2004). Plant metabolic flexibility allows the preferential utilization of inorganic pyrophosphate (PPi) as an energy donor, particularly when cellular ATP pools become limited during stresses and nutritional Pi starvation. PPi permits and microbes to conserve ATP Stitt (1998).

Use of PPi (a byproduct of secondary metabolism and anabolism) as an energy donor helps to conserve limited ATP pools. Concentration PPi in the cytosol is upto about 0.5 mM which is remarkably insensitive to abiotic stresses Stitt (1998). These large amounts may be employed to enhance the energetic efficiency of cellular processes. During salt stress, there is marked decline in cytoplasm Pi levels that follow large reductions in intracellular levels of ATP. During stress conditions, PPi would continue to generate (albeit at a lower rate) as a byproduct of the synthesis of essential macromolecules. PPi-powered processes may be crucial facet of the metabolic adaptations of plants to environmental stress that cause depressed ATP (but not PPi) pools Dobrota (2006). However, this aspect has not been worked out especially in the case of salt stress.

Alternative glycolitic pathways are shown in figure - 1 in which PPi –dependent processes represent a considerable bioenergetic benefit that may extend the survival time of ATP-depleted cells during stresses. Glycolytic reactions can bypass Pi-or ATP-requiring steps of glycolysis under environmental stress conditions Duff et al. (1989, Theodorou et al. (1992), One alternative glycolytic pathway is catalyzed by a PPi –dependent phosphofructokinase (PFP) which, under P deficiency, can bypass the ATP dependent phosphofructokinase (PFK), generating fructose -1,6-bisphosphate Plaxton and Carswell (1999). Another alternative glycolytic pathway found in cyanobacteia is induced by action of non phosphorylaying NADP dependent glyceraldehyade -3P dehydrogenase (NADPG3PDH) that alternate are Pi dependent NAD – G3PDH and phosphoglyceratekinase Duff *et al.* (1989, Theodorou *et al.* (1992). Another bypass of the glycolytic pathway catalyzed by combined activities of PEPC, MDH and NAD – malic enzyme Theodorou and Plaxton (1996). P stress under salt stress condition can severally limit pyruvate kinase (PK), an enzyme requiring Pi and ADP. PEPC, MDH and NAD-malic enzymes bypasses PK and by this maintain the flow of carbon in glycolysis cycle by avoiding the use of ADP but generating free Pi Plaxton and Carswell (1999).

CONCLUSION

Cyanobacteria under salt stress condition use more ATP for their metabolic activities. Due to this, cellular ATP pool of cyanobacteria becomes diminished or cellular Pi level falls to a very low level. For better survival of organism and for energy conservation during salt stress cyanobacteria may bypasses the main glycolytic pathway enzymes by alternative glycolytic pathway enzymes which are ATP or Pi independent and PPi dependent pathway. Level of PPi has been found constant under stress condition.

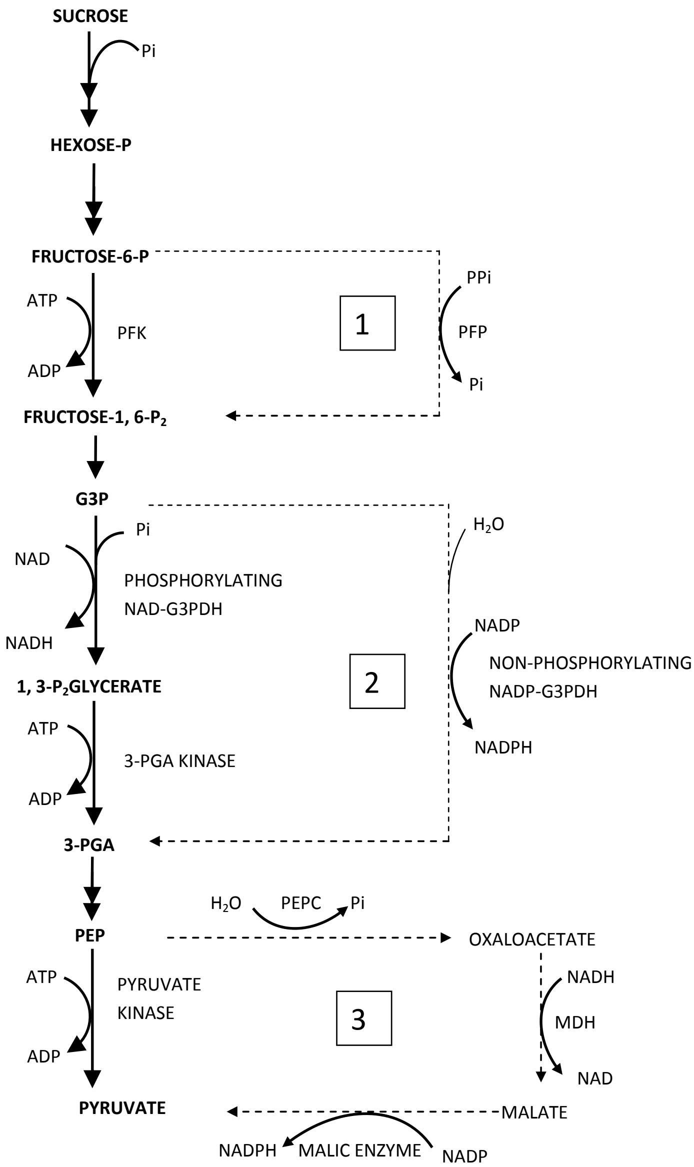

Figure 1: A model suggesting the three salt stress inducible glycolytic bypass pathway in cyanobacteria, 1- representing PPi dependent phosphofructokinase bypass of ATP dependent phosphofructokinase, 2- represent Non-Phosphorylating NADP-G3PDH which bypasses two ATP dependent glycolytic enzymes i.e. Phosphorylating NAD-G3PDH and 3- PGA Kinase third bypass pathway 3- represent combination of three ATP independent enzymes PEPC, MDH and NAD-Malic enzyme which alters ATP dependent Pyruvate Kinase of normal glycolytic pathway (Duff et al. 1989).

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