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POLYAMINES IN RESPONSE TO ABIOTIC STRESS TOLERANCE IN CROP PLANTS

Rakesh Sil Sarma[1*], Jyoti Chauahan[1]

Department of Plant Physiology, Banaras Hindu University, Varanasi, India.

Email of corresponding author - sarmarakesh24@gmail.com

Introduction: Plant development and productivity are negatively affected by environmental stresses. The major abiotic stress factors limiting crop productivity and plant growth are soil salinity, exposure to high and low temperatures, and drought. In the past decade, the average yields of major crops have been reduced up to 70% due to abiotic stresses. On the other hand, the increasing world population has added more pressure on the demand for increased crop yields, creating an urgent need to cultivate stress-tolerant crops with increased productivity. Agriculture around the globe is facing great challenges due to climate change with more erratic climate and with it, an increasing effect of abiotic stress factors. Plants are able to sense environmental changes, to respond to them, adapt and survive. Such changes under stress occur at cellular, physiological, biochemical, and molecular levels (Munns and Tester 2008). The expression of a variety of genes is induced by different stresses in a wide diversity of plants. However, the stress-tolerant plants can alter their cellular mechanism and metabolic pathways to counteract the created imbalance under environmental stresses. PAs are low molecular weight, non-protein polycations at physiological pH with a strong binding capacity to negatively charged DNA, RNA, and different protein molecules, and the ability to stabilize membrane structures. They regulate many physiological, growth, and developmental processes in organogenesis, embryogenesis, flower initiation and development, leaf senescence, fruit development and ripening, and abiotic and biotic plant stress responses (Gosal *et al.*, 2009).

Abiotic Stress In Plants—Assessment of The Situation:

Abiotic stress exposure in plants can be divided into three arbi- trary stages:stress perception, stress response and stress outcome . Depending on the nature of stress, it perception can be localized to a specific group of cells, tissues and organs or it could be widespread. Additionally, stress could arise suddenly or slowly. For example, exposure of roots to a heavy metal in fertilizer or saline water or to flooding is likely to be different from that if the plant started its life in the presence of the sestres- sors. On the other hand, drought due to lack of programmed irrigation and excessive transpiration, or a gradual increase in ozone concentration in the air, are examples of slow exposure to stress. (Gill and Tuteja 2010).

Transgenics and Stress Tolerance:

In reviewing the literature on the improvement of stress tolerance in transgenic plants over-expressing a homologous or a heterolo- gous gene encoding a PA biosynthetic enzyme, a few conclusions stand out:

(1) Every one of the PA biosynthetic enzyme genes has been expressed as a transgene in several plant species; in most cases a constitutive promoter controls the transgene expression.
(2) Experiments with transgenics have typically involved short- term treatments with stress followed in many cases by removal of the treatment to study recovery from stress. Only in a few cases have the plants been brought to maturity and analyzed for total biomass or yield of the desired product (seeds, fruit, or leaf biomass) or its quality (e.g., nutritional properties).
(3) Measurements of stress response have included visual symp- toms of water loss or wilting, changes in fresh weight, dry weight, ion release, gene expression and analysis of enzyme activities and cellular metabolite, *etc.*
(4) Transgenic manipulations of *ADC* or *ODC* in plants have resulted in a significant increase in Putresine content (typically3– 10-fold) with relatively smaller (<2-fold) changes in Spermidine and Spermine. Transgenic manipulation of *SPDS*, *SPMS*, and *SAMDC* causes smaller (compared to Putresine) increase of Spemidine and Spermine contents (2–3 fold).
(5) The fold increase in Putresine content often varies with the plant species,homologous or heterologous gene sources, nature of the promoter, developmental stage of the plant and the tissues analyzed.

Exogenous Application of Polyamines for Enhanced Abiotic Stress Tolerance:

Large number of evidence suggested that exogenous application of PAs (di- and tri- and tetra-amines) were shown to stabilize plant cell membranes, protecting them from damage under stress conditions an endogenous PAs are also suggested to participate in sustaining membrane integrity. Exogenous application of Putresine reduced the net accumulation of Na+ and Cl ions in different organs of *Atropa belladonna* subjected to salinity stress. Put alleviated the adverse effect of NaCl during germination and early seedling growth and increased the alkaloids as well as endogenous Put of *A. belladonna*. It suggested that this positive effect was associated with an increase in ethylene biosynthesis through an increase in ACC content and a suppression of NaCl-induced inhibition of ACC conversion to ethylene and suggested the involvement of Put in salinity tolerance in rice. reported the protective effect of exogenous Polyamines application on *Changchun mici* (chilling-resistant) and *Beijing jietou* (chilling-sensitive) cv. of cucumber against chilling injury. They noted a remarkable increase in free Spd, Spm and Put in the leaves of cv. *Changchun mici* upon chilling treatment after1 day of treatment but the induction of Put declined thereafter, whereas, Spd and Spm levels increased steadily. Whereas, in the leaves of cv. *Beijing jietou*, Put content was increased onlyat 1 day after chilling while Spd content decreased significantly upon chilling treatment. It was noted that chilling reduced the soluble protein content, activities of antioxidant enzymes (SOD, POD, CAT and APX) only in *Beijing jietou.* Scientists found a close relationship between cellular PA levels and their Put:Spd ratio with in vitro morphogenetic capacity in indica rice and suggest that the cellular PAs and Put:Spd ratios are important determinants (biomarkers) of plant regeneration ability in indica rice, and the improvement/induction of plant regeneration in morphogenetically poor and recalcitrant species could be achieved by modulating PA metabolism. (Marais, and Juenger 2010)

Conclusions:

Considerable evidence indicates that polyamines are involved in a wide array of plant processes, including DNA replication, transcription of genes, cell division, organ development, fruit development and ripening, leaf senescence and abiotic stresses. Despite ample evidence of their involvement in these processes, their precise role in these specific processes remains to be established. The polyamine pathway is now amenable tomodulation by genetic approaches because it has been elucidated molecularly and biochemically in plants. Reverse genetics has identified an Arabidopsis knockout mutation of ADC2 gene which reveals inducibility by osmotic stress. Generally, genetic manipulation of single steps located upstream of the PA pathway (i.e. ODC or ADC) lead to elevated levels of Put, but no changes occur in the higher PAs, Spd and Spm. By contrast, overexpression of genes located downstream of the pathway (i.e. SAMDC or Spd synthase) generally leads to increased levels of Spd and Spm, indicating that the levels of Spd and Spm are under a tight homeostic cellular control. Phenotypic analyses of mutants and transgenic plants affected in polyamine metabolism further support previous physiological evidence, but the molecular mechanisms underlying PA effects on plant growth and development remain to be elucidated. The best-case scenario for such genetic manipulation will be that PA metabolism can be controlled in a transient and cell/tissue/organ specific manner in response to the earliest perception of stress exposure before the stress reaches its peak to cause damage. This would generate plants, which will pro- duce additional PAs to protect themselves from stress only when needed without significant alterations in PA and amino acids metabolism under normal growth conditions.

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