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ABSCISIC ACID *VIS-A-VIS* WATER STRESS IN PLANT

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Abstract: Abscisic acid (ABA) is well known antistress phytohormone which saves the plant from adverse osmotic effects in cell. During stress its biosynthesis accelerated and the increased ABA binds to its receptor to initiate signal transduction leading to cellular responses to water stress. It stimulates stomatal closure, change in gene expression and adaptive morpho-physiological responses. Light regulate stomatal opening and ABA promote partial or complete closure of stomata. The stomatal closure reduces the loss of water by transpiration which accounts approximately 90% through its pore. In the same time stomatal closure prevents the exchange of gases (carbon dioxide and water vapour) through its pore led to inhibition of Calvin cycle and eventually reduction of biomass. Moreover, efflux of water decrease and influx increase in the cell due to synthesis of energetic compatible solutes *viz.* proline, glycine betaine, sugars (sucrose, fructose, trehalose), polyols (sorbitol, mannitol, arabinitol, glycerol) etc. which are induced by ABA. However, proline and glycine betaine prominent among all these compatible solutes. Thus, ABA is the chief regulator of water deficit stress in plants for their survival among the all phytohormones.
Keywords: ABA, Stress, Stomata, Water.

Introduction

The population of world is increasing day by day and it is a great challenge to feed the growing world population in changing climate scenario particularly scarcity of water. The shrinking agricultural land and reducing natural resources affects the quality and quantity of food grain production. It is projected that world population rise by more than one billion by 2030 and over 2.4 billion by 2050. The agricultural food production must be increased by 70 percent by 2050 to feed the increasing population. Fresh water is going to decrease due to excess harness for domestic as well as industrial purposes affect the decrease of water table in earth. The crops under cultivation do not get irrigation at their specific growth stage result in reduction in tiller number as well as duration of crop maturity, eventually led to early flowering and great loss in biomass (Du et al., 2018). The phytohormones have great role in growth and development as well as mitigation of stress. Abscisic acid (ABA) is one of them which is known as antistress hormone due to its counteracting effects of stress in plant (Kuromori et al., 2018).

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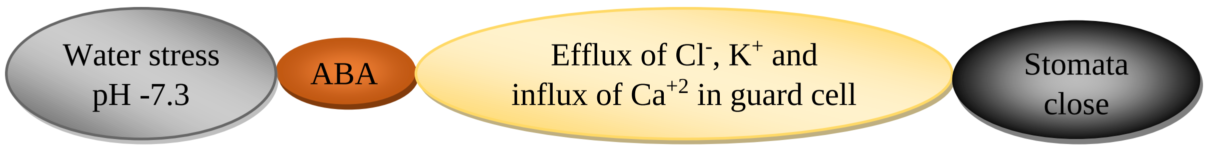
Effects of ABA on morphophysiological trait

ABA production in plant generally regulated by osmotic potential of cell and it is first sensed in roots. The decreasing solute potential (limited to about 0.2 to 0.8 MPa) in roots induce the biosynthesis of ABA in chloroplast/plastids. The deficit of water creates slightly alkaline pH (7.2) in mesophyll cell results in dissociation of ABA and inhibition of its transport through plasma membrane. Hence, it accumulates in guard cell and its concentration dramatically increases during water stress and reaches 50 times more than the well watered condition. Accumulated ABA influenced the signaling molecule for regulating metabolism to cope up the deficit of water in cell (Kuromori et al., 2018). It affects roots architecture *viz.* root length, angle of root, lateral root, etc. led to change in pattern of growth and quiescence in roots. The shoot growth decreases and root length increases as well as expansion and proliferation of roots reduce due to inhibition of ethylene by production of endogenous ABA during water stress (Li et al., 2017). The ratio of root length and shoot length become higher and water flow and ion flux in root tissues increases (Hong et al., 2013). Turgidity is maintained in cell by decreasing transpiration with closure of stomata due to the loss of water followed by the constant efflux of anions (Cl^-) and cations (K^+) and influx of Ca^{+2} through plasma membrane in guard cell (Munemasa et al., 2015). The OST1 (open stomata 1) kinase in epidermal cell of *Arabidopsis*, which mediates ABA-induced stomatal closure by phosphorylation of potassium channel in *Arabidopsis thaliana* 1(KAT1) as well as slow anion channel associated 1(SLAC1) (Merilo et al. 2015). The second messengers, including inositol 1,4,5-trisphosphate (IP3), cyclic ADP-ribose (cADPR) and self amplifying (calcium-induced) Ca^{2+} induce the release of intracellular Ca^{2+} in guard cell by ABA. Nitric oxide (NO) also acts secondary messenger in this pathway which is stimulated and induce closure of stomata in a cADPR-dependent manner by ABA (Aslam et al., 2022).



Effects of ABA on biochemical trait

The accumulation of ions during water stress severely inhibited cytosolic enzymes of plant cells hence they are diverted to vacuole. The solutes which accumulate under the influence of ABA have no adverse effects on activities of enzymes are known as compatible solute/osmolytes. These are organic compounds *viz.* Imino acid proline, sugar alcohols, and a quaternary amine called glycine betaine. During tissue dehydration accumulated ABA induce the synthesis of compatible osmolytes for development of osmotic adjustment in cell. Compatible solute enables the plant to extract more of this tightly held water, but the increase in total available water is small (Camilo et al., 2019). Hence, basal metabolism for survival under water stress uninterrupted under influence of ABA but does not have a major effect on productivity. ABA also regulate phosphoproteins *viz.* ascorbate peroxidase, Ca^{2+}/H^{+} antiporter regulator protein, G protein betasubunit- like protein, glyoxysomal malate dehydrogenase, manganese superoxide dismutase, and triose phosphate isomerase which are supportive in stress mitigation (Sah et al., 2016).

Proline

Proline is a neutral imino acid at pH-7, having rigid structure and highly soluble in water. It stabilizes protein structures and inhibits protein unfolding during water stress. The enzymes of metabolic pathway alleviated by proline particularly ribulose 1, 5 bisphosphate carboxylase that initiate Calvin cycle (Kaur and Asthir, 2015). The oxidative stress is the main factor for membrane disruption and ionic leakage, and these occurs when synthesis of reactive oxygen species (ROS) exceeds their scavenging in the cell. Proline considered as an effective hydroxyl radical scavenger and promoter of enzymatic antioxidants and its biosynthesis in chloroplasts reached upto 80% during stress as compare to 5% in normal which facilitate the electron flow between photosynthetic excitation centers and maintains a low NADPH:NADP ratio in cell. Thus, it protects the plant from photoinhibition and damage to the photosynthetic apparatus because extra electron in the cell is root cause of ROS production. Proline accumulation also increases cellular osmolarity that drives influx of water or reduces its efflux resulting in increase of pressure potential for cell expansion (Bhaskara et al., 2015)

Glycine betaine (GB)

The choline and glycine are the two substrates from which GB synthesized when plant exposed to drought and salinity. It improves Ca^{2+}-ATPase and Hill reaction activities in thylakoid membrane thereby promote photosynthesis and translocation of sucrose. It can protect biological membranes from ROS as well as improving antioxidants defense system under stress (Nawaz and Wang, 2020).

Conclusion

ABA and water deficit stress are interlinked to each other. Deficit of water induces synthesis of ABA for enhancement of osmoprotectants, antioxidants and membrane stability.

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