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Editorial Open Access

What makes Chloroplast an Inclusive Sensor of Environmental Stresses?

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Chloroplast that converts solar energy into chemical energy also senses the environmental stresses accurately, transmits appropriate signal(s) and responds effectively for adaptation to the stressful condition. All though these two processes are quite different and independent mechanisms, these are accomplished by the same organization, the photosynthetic apparatus (PSA).

The PSA in green plants and algae may be grouped into three basic structural components: the light energy harvesting system (energy source), the electron transport chain through a series of redox reactions and utilization of energy for the formation of stable organic compounds (energy sink). These components work harmoniously to drive photosynthesis and a balance between the rate at which electrons are released and injected into electron transport chain due to absorption of light energy by photosynthetic pigments associated with photosystem (PS) II (source) and the rate at which the electrons are consumed by assimilating processes (sink) (called photostasis of photosynthesis) is maintained. A balance in the rate of electron transfer amongst different components of the chain between the source and the sink (called redox homeostasis) is also a necessary condition for optimum photosynthesis. Additionally, the energy sink through an elaborate combination of metabolic and respiratory processes maintains a cellular sugar level that modulates the growth, development and regulatory processes.

Environmental stresses are known to perturb the photostasis of photosynthesis, redox homeostasis and the cellular sugar status primarily by disrupting different components of chloroplasts. The perturbation in either of these processes and/or damage of any components of the PSA may lead to the generation of reactive oxygen species (ROS). These changes are signalled from chloroplast to the nucleus (retrograde signalling) for nuclear gene expression which develop defence, repair and acclimation and bring about changes in other metabolic processes. Although a significant change in photostasis may result in the cell death, plant strives to restore photostasis of photosynthesis by modulating at the level of the source, the sink or both. An imbalance in the activity of the source and the capacity of the sink generates a signalling system for the expression of specific genes leading to modification in cellular metabolism for photosynthetic adaptation. Likewise, an imbalance in the distribution of energy between PS I and PS II creates an excitation pressure that activates/deactivates a LHC-specific kinases leading to mobilisation of LHC II for redistribution of energy between two photosystems. The loss in cellular redox homeostasis, on the other hand, generates signal for a possible gene expression to regulate the ROS metabolism. The PQH2, (reduced PQ that plays a major role in maintaining redox homeostasis) and ROS trigger the link between the stress-induced excitation pressure and gene expression for adaptation. The cellular sugar level also modulates gene expression and enzyme activities; however the mode of signalling in sugar-limiting condition is different from the enhanced-sugar level condition. The energy deficiency condition as aroused from the loss in photosynthesis (sugar limitation) is sensed by SnRK1 which in turn initiates many energy-generating and/or suppresses many energy-utilizing processes. The increase in sugar level, on the other hand, activates hexokinase (HXK) to suppress photosynthetic gene and hence photosynthetic sugar production.

Perusal of relevant literature indicates that the mode of perception and transmission of signals for different environmental stresses at different phases of chloroplast development are different. The adaptational mechanisms of chloroplasts are also different at different phases of development and to different stress factors. Probably, this multiplicity in differences and intricacy in the structural organisation of chloroplast sprovide the organelle scopes to serve as an inclusive sensor of environmental stress.

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