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Influence of drought stress on molecular responses on crop plants

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Abstract The crop growth and development are constantly influenced by environmental conditions such as stresses which are the most important yield reducing factors in the world. Drought stress is considered as one of the crop performance limiting factors and a threat for successful crop production. Drought tolerance is important trait related to yield. A better knowledge of the effects of water deficit and salt excess on plant biochemistry has a primary importance for improved management practices, breeding programmes and for predicting plant growth and product quality. To improve this trait, breeding requires fundamental changes in the set of relevant attributes, finally emerging as something named drought tolerance. Stress treatment caused an increase in activity of antioxidant enzymes like superoxide dismutase (SOD), CAT and peroxidases that allow this species to present a high degree of drought tolerance characters. Acclimation of plants to drought and salinity is often associated with increased levels of reactive oxygen species (ROS), such as superoxide anion (O_2-), hydrogen peroxide (H_2O_2), hydroxyl radical (HO.) and singlet oxygen ($1O_2$), which are toxic for the cells.

Keywords Acclimation, Catalase, superoxide dismutase, reactive oxygen species

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Introduction

Drought Stress

The crop growth and development are constantly influenced by environmental conditions such as stresses which are the most important yield reducing factors in the world [1]. Drought stress is considered as one of the crop performance limiting factors and a threat for successful crop production. Drought tolerance is important trait related to yield. To improve this trait, breeding requires fundamental changes in the set of relevant attributes, finally emerging as something named drought tolerance [2]. Drought, one of the most important environmental stresses that in many parts of the world, especially in warm and dry areas of crop yield are limited [3]. International Maize and Wheat Research Center researchers believe that the stiffness on wheat growth stages occur in three ways. In the first case, which is specific to the Mediterranean climate, the rainfall occurs during the winter and transplant only after the flowering stage drought are faced. The stiffness of about 6 million hectares of land occurs wheat [4]. This article and review and the aims are influence of drought stress on molecular responses on crop plants.

Molecular Responses to Drought

In drought conditions, reduced water potential and increased cell content of ABA, regulate the metabolism of cells. Increase substances such as proline, glycine and betaine can be one of the major molecular responses to drought stress [5]. Accumulation of solutes in cells under stress conditions, in order to maintain cell volume against the loss of water, called the osmotic adaptation [6]. Drought stress induced free radicals cause lipid peroxidation and membrane deterioration in plants [7].

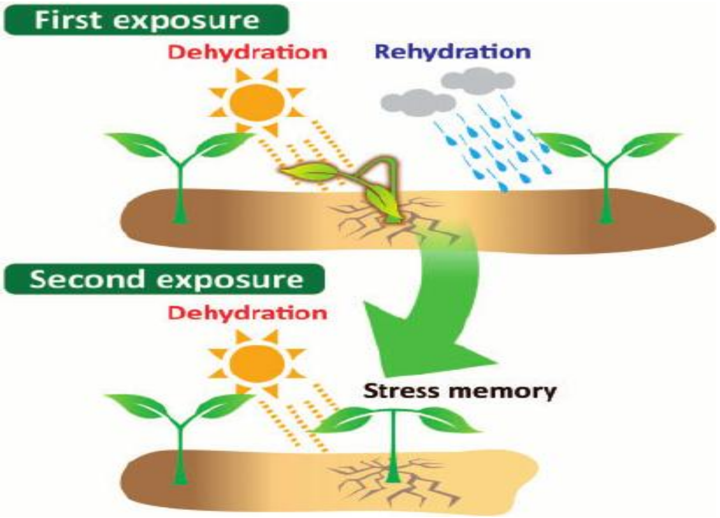

Figure 1: An example of stress memory in plants.

Plants have elaborate mechanisms for stress memory. For example, a plant that experiences a period of drought wilts under the dehydration stress and then re- covers after rehydration (upper panel); during a second drought stress, the plant 'remembers' the past drought experience, allowing it to achieve better resistance to dehydration and improve its survival pro- spects (lower panel)

Antioxidant enzymes

Stress treatment caused an increase in activity of antioxidant enzymes like superoxide dismutase (SOD), CAT and peroxidases that allow this species to present a high degree of drought tolerance characters. In another drought-tolerant species (*Jatropha curcas*), leaf CO_2 assimilation rate and carboxylation efficiency parameters decreased progressively as the water deficit increased. In this species, leaf H_2O_2 content and lipid peroxidation were inversely and highly correlated with CAT activity, indicating that drought-induced inhibition of this enzyme might have allowed oxidative damage.

Catalase (CAT)

It is known that photorespiration makes oxygenic photosynthesis possible by scavenging its major toxic by-product, 2-phosphoglycolate, but also leads to high losses of freshly assimilated CO_2 from most land plants [8]. Considering the key role of CAT in photorespiration, many authors focused on the role of CAT catalysis pathway under both drought and salt stress. Indeed, the maintenance of CAT activity in leaves of drought-stressed plants likely allowed the removal of photorespiratory H_2O_2 produced when plants are subjected to water deficit of salinity, especially under severe degrees of stress. In these conditions, photorespiration works as energy sink preventing the over-reduction of the photosynthetic electron transport chain and photoinhibition [9]. On this basis, photorespiration and CAT pathway cannot be considered wasteful processes but are nowadays increasingly appreciated as a key ancillary component of photosynthesis and important parts of stress responses in green tissues for preventing ROS accumulation [10]. Severe drought stress and salinity predispose the photosynthetic system of leaves to photoinhibition, resulting in a light-dependent inactivation of the primary photochemistry associated with photosystem II, which often persists after rewatering [11]. Indeed, photosynthesis is one of the key processes to be affected by water deficits and high salt contents, via decreased CO_2 diffusion to the chloroplast and metabolic constraints [12]. The relative impact of those limitations varies with the intensity of the stress, the occurrence of superimposed stresses, and the species we are dealing with. Total plant carbon uptake is further reduced due to the concomitant or even earlier inhibition of growth. Leaf carbohydrate status and hormonal ratios are also deeply altered directly by water deficits or indirectly via decreased growth.

Acclimation of plants and reactive oxygen species (ROS)

Acclimation of plants to drought and salinity is often associated with increased levels of reactive oxygen species (ROS), such as superoxide anion (O_2-), hydrogen peroxide (H_2O_2), hydroxyl radical (HO.) and singlet oxygen ($1O_2$), which are toxic for the cells [13]. ROS are by-products of aerobic metabolism and their production is enhanced during stress conditions through the disruption of electron transport system, and oxidizing metabolic activities occurring in chloroplasts, mitochondria and microbodies [12]. Under non-stressful conditions, ROS are efficiently eliminated by non-enzymatic and enzymatic antioxidants, whereas during drought and saline conditions, the production of ROS exceeds the capacity of the antioxidative systems to remove them, causing oxidative stress [14]. In this context, catalase (CAT) isoforms are iron porphyrin enzymes that serve as an efficient ROS scavenging system to avoid the oxidative damage induced to these two stressors [15].

Ascorbate Peroxidase (APX)

A better knowledge of the effects of water deficit and salt excess on plant biochemistry has a primary importance for improved management practices, breeding programmes and for predicting plant growth and product quality. In this regard, a major hydrogen peroxide detoxifying system in plant cells under abiotic stressors is the ascorbate-glutathione cycle, in which ascorbate peroxidase (APX) isoenzymes play a key role in catalyzing the conversion of H_2O_2 into H_2O, using ascorbate as a specific electron donor [16], particularly in the chloroplast. Mutant plants *APX* genes showed alterations in growth, physiology and antioxidant metabolism revealing those enzymes involvement in the normal plant development. The expression of *APX* genes is strictly regulated in response to drought and salt stresses as well as during plant development [17]. The genes encoding APXs are particularly important in maintaining the homeostasis of ascorbate (AsA) and glutathione (GSH), two non-enzymatic antioxidants within the context of cellular redox homeostasis and redox signaling, and directly or indirectly involved in maintaining high photosynthetic rates in plants under adverse environmental conditions [18]. For instance, in saline soils and/or when drought limits the CO_2 fixation, the excess excitation energy is dissipated in the light harvesting antennae as heat by zeaxanthin, that is formed by successive de-epoxidation of the xanthophyll cyclepigments violaxanthin and antheroxanthin. The deepoxidase, which is bound to the lumen side of the thylakoid membrane, is dependent on AsA as a cofactor [19]. Etelib *et al.* (2012) [20] found that transgenic tobacco plants accumulating greater amounts of AsA have an enhanced tolerance to salt stress. In addition, AsA is involved in other functions such as plant growth, gene regulation, modulation of some enzymes, and redox regulation of membrane-bound antioxidant compounds in plants under both drought and salt stress.

Physiological drought stress

In terms of of plant physiology, dryness causes of stress in plant growth, yield 50-30% reduction in drought stress due to low humidity in plant growth occurs as a result of the high evapotranspiration, temperature high intensity of sunlight [21], high temperature caused by the drought stress of increased respiration, photosynthesis and enzyme activity in the plant. Drought in the sun, the light reaction of photosynthesis and continued production of free radicals of oxygen leading to plant death is light and oxidation. Absorb nutrients from the upper soil horizon, which is found in most foods, the drought reduced [22]. The increase in drought conditions, accumulation of salts and ions in the upper layers of the soil around the root cause osmotic stress and ion toxicity. The first response to stress is a biophysical response. In fact, with increasing drought stress, cell wall wizened and loose, with a decrease in cell volume, pressure decreases and the potential for the development of the cell, depending on the potential pressure decreases and growth is reduced. These factors are the size and number of leaves in plants [22].

Particular small RNA molecules

In order to identify and study factors involved in stress responses, by using mutants, it was found that particular small RNA molecules, are involved. These elements of RNA metabolism participate in the regulation of different pathways linked to environmental stress conditions, including drought and salinity [23]. In particular, in the context of antioxidant defence, the role of these small regulatory non-coding microRNAs (miRNAs) has been recently established, also in the regulation of antioxidant enzymes during the plant response to drought and salinity stresses. For example, some miRNAs identified in cotton plants (miR156-SPL2, miR162-DCL1, miR159-TCP3, miR395-APS1, and miR396-GRF1) and their predicted targets were found to be differentially expressed under dose- and tissue-dependent salinity and drought. Very recently, in the same plant, others miRNAs were identified, of which at least 18 and 27 are salt specific and drought specific, respectively. Salinity and drought stresses were able to up-regulate and down-regulate, respectively, miRNAs expression, miR395 being the most sensitive to both stress levels, also in French bean seedlings [24].

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