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Review Article

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Influence of Drought Stress on Lipids, Root growth, PS2 Activity and Rubisco in Crop Plants

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Abstract Drought stress is a major abiotic factor that limits agricultural production more importantly in the rain-fed areas of the world. Drought stress affects 40 to 60% of the world's agriculture lands. Along with proteins, lipids are the most abundant component of membranes and they play a role in the resistance of plant cells to environmental stresses. Strong water deficit leads to a disturbance of the association between membrane lipids and proteins as well as to a decrease in the enzyme activity and transport capacity of the bilayer. Photosynthetic carbon reduction and carbon oxidation cycles are the main electron sink for PS2 activity during mild drought. It was shown that PS2 functioning and its regulation were not quantitatively changed during desiccation. The CO_2 molar fraction in the chloroplasts declines as stomata close in drying leaves. As a consequence, in C3 plants RuBP oxygenation increases and becomes the main sink for photosynthetic electrons.

Keywords ABA, proteins, Nutrient

Introduction

Drought stress is a major abiotic factor that limits agricultural production [1-2], more importantly in the rain-fed areas of the world. Drought stress affects 40 to 60% of the world's agriculture lands [3]. Breeding for drought resistance is complicated by the lack of fast, reproducible screening techniques and the inability to routinely create defined and repeatable water stress conditions when a large amount of genotypes are to be evaluated efficiently [4]. The relative yield performance of genotypes in drought stressed and more favorable environments seems to be a common starting point in the identification of traits related to drought tolerance and the selection of genotypes for use in breeding for dry environments [5].

Drought stress and lipids

Along with proteins, lipids are the most abundant component of membranes and they play a role in the resistance of plant cells to environmental stresses [6]. Strong water deficit leads to a disturbance of the association between membrane lipids and proteins as well as to a decrease in the enzyme activity and transport capacity of the bilayer [7]. Poulson et al. (2002) established that for *Arabidopsis*, polyunsaturated trienoic fatty acids may be an important determinant of responses of photosynthesis and stomatal conductance to environmental stresses such as vapour pressure deficit. When *Vigna unguiculata* plants were submitted to drought the enzymatic degradation of galacto- and phospholipids increased. The stimulation of lipolytic activities was greater in the drought-sensitive than in drought-tolerant [8-9].

Root growth

A developed root system is constitutive feature in many environments. The roots help the plants to absorb water and minerals for their better use. Roots are also important component of drought tolerance at the various growth stages of plant [10]. The maximum accumulated water in the root zone depends on the anchorage of roots in the soil volume. Under the limited supply of water resource allocation pattern changes; root tissues gain more assimilates as compare to leaf tissues. If drought stress prevails at the early seedling stage the root-shoot changes [11] and commonly increases [12]. Investigation work showed that root weight enhance while shoot weight reduce with the application of water deficit stress [13]. It was found that drought reduced fresh and dry shoot and root weight by 40 and 58 %, respectively. Drought stress decreased the length and fresh weight of shoot in maize [14].

Drought Stress and PS2 Activity

Photosynthetic carbon reduction and carbon oxidation cycles are the main electron sink for PS2 activity during mild drought. It was shown that PS2 functioning and its regulation were not quantitatively changed during desiccation. The CO_2 molar fraction in the chloroplasts declines as stomata close in drying leaves. As a consequence, in C3 plants RuBP oxygenation increases and becomes the main sink for photosynthetic electrons. Depending on the prevailing photon flux density (PFD), the O_2 through photorespiratory activity can entirely replace CO_2 as an electron acceptor or not. Havaux (1992) has investigated the impact of various environmental stresses (drought, heat, strong light) applied separately or in combination on the PS2 activity [15]. The existence of a marked antagonism between physicochemical stresses (e.g. between water deficit and HT) was established, with a water deficit enhancing the resistance of PS2 to constraints as heat, strong light. Similar results were obtained on bean plants [16].

Nutrient Relations

Decreasing water availability under drought generally results in limited total nutrient uptake and their diminished tissue concentrations in crop plants. An important effect of water deficit is on the acquisition of nutrients by the root and their transport to shoots. Lowered absorption of the inorganic nutrients can result from interference in nutrient uptake and the unloading mechanism, and reduced transpirational flow [17]. However, plant species and genotypes of a species may vary in their response to mineral uptake under water stress. In general, moisture stress induces an increase in N, a definitive decline in P and no definitive effects on K [17]. As nutrient and water requirements are closely related, fertilizer application is likely to increase the efficiency of crops in utilizing available water. This indicates a significant interaction between soil moisture deficits and nutrient acquisition. Studies show a positive response of crops to improved soil fertility under arid and semiarid conditions. Currently, it is evident that crop yields can be substantially improved by enhancing the plantnutrient efficiency under limited moisture supply [17].

Rubisco, Specific Proteins and Drought Stress

The mechanism by which Rubisco may be downregulated in the light due to tightbinding inhibitors could be pivotal for tolerance and recovery from stress and may be central to integrating the midday depression of photosynthesis [18]. Additionally, enhanced rates of oxygenase activity and photorespiration maintain the ET rate in response to drought and are quantitatively much more important than the Mehler reaction [19-20]. Kanechi et al. (1995) found a close relationship between Rubisco content and maximal O_2 evolution rate measured at high photosynthetic photon flux density (PPFD) during leaf dehydration [21]. It was established that below –2.0 MPa inhibition of photosynthesis in two maize cvs is in part attributed to stomatal conductance but mostly to the decreased activities of carbonic anhydrase, phosphoenol pyruvate carboxylase and Rubisco [22]. As mentioned above, the primary site of limitation of maximal O_2 evolution rate, measured at high PPFD, seemed related to significantly reduced RuBP content, not to the amount of Chl or Rubisco. But as mentioned above, Rubisco is not a prime target of water deficit and is not limiting net CO_2 assimilation of leaves submitted to desiccation [23]. Decreased supply of CO_2 to Rubisco under both mild and severe water deficit is primarily responsible for the decrease in CO_2 fixation [24]. Specific proteins display particular structural features such as the highly conserved domain predicted to be involved in hydrophobic interaction leading to macromolecular stabilization [25]. The majority of new proteins belong to dehydrin-like proteins, which are abundantly induced during embryo maturation of many higher plants as well as in water stressed seedlings [26]. Dehydrins are synthesized by the cell in response to any environmental influence that has a dehydration component such as drought, salinity or extracellular freezing [27]. Dehydrins may stabilize macromolecules through detergent and chaperone like properties and may act synergistically with compatible solutes [28-29]. The steady state levels of major PS2 proteins, including the Dl and D2 proteins in the PS2 reaction center, declined with increasing water deficit possibly as a result of increased degradation. The effects of WD on PS2 protein metabolism, especially on the reaction center proteins may account for the damage to PS2 photochemistry [30].

Accumulation of proteins and ABA under water stress

Some proteins are up-regulated under water stress while others are degraded or down regulated. According to Ashraf et al. (2003) accumulation of proteins in leaves under water stress conditions might be an adaptive mechanism [31]. Abscisic acid (ABA) is a plant stress hormone that is observed to accumulate under drought stress and mediates many stress responses. ABA also expresses the gene encoding enzymes that participate in the repair of spontaneous protein damage [32]. Moreover, ABA induced increase in the osmolyte might also help in stabilizing the proteins under water stress [33].

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