

Influence of drought stress on photosynthetic enzymes, antioxidation and chlorophyll content

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Abstract

The data on water stress induced regulation of the activity of photosynthetic enzymes other than Rubisco are scarce. The activity of several photosynthetic enzymes under progressive water stress in two different cultivars of *Morus Alba*. Unlike Rubisco, which is highly stable and resistant to water stress, the activity of some enzymes involved in the regeneration of ribulose-1,5-bisphosphate (RuBP) are progressively impaired from very early stages of water stress. Drought stress is accompanied by the formation of ROS such as O₂, H₂O₂, and OH, which damage membranes and macromolecules. Plants have developed several antioxidation strategies to scavenge these toxic compounds. Enhancement of antioxidant defense in plants can thus increase tolerance to different stress factors. Antioxidants (ROS scavengers) include enzymes such as catalase, superoxide dismutase (SOD), ascorbate peroxidase (APX) and glutathione reductase.

Keywords: antioxidation, Stomatal conductance, Chlorophyll

1. Introduction

Food productivity is decreasing due to detrimental effects of various biotic and abiotic stresses; therefore minimizing these losses is a major area of concern to ensure food security under changing climate. Environmental abiotic stresses, such as drought, extreme temperature, cold, heavy metals, or high salinity, severely impair plant growth and productivity worldwide. Drought, being the most important environmental stress, severely impairs plant growth and development, limits plant production and the performance of crop plants, more than any other environmental factor (Shao *et al.*, 2009) [7].

Activity of photosynthetic enzymes

The data on water stress induced regulation of the activity of photosynthetic enzymes other than Rubisco are scarce. Thimmanaik *et al* (2002) studied the activity of several photosynthetic enzymes under progressive water stress in two different cultivars of *Morus Alba*. Unlike Rubisco, which is highly stable and resistant to water stress, the activity of some enzymes involved in the regeneration of ribulose-1,5-bisphosphate (RuBP) are progressively impaired from very early stages of water stress. Thus, these results present the possibility that some enzymes involved in the regeneration of RuBP could play a key regulatory role in photosynthesis under water stress. During water stress induced by polyethilen glycole, Rubisco activity significantly increased in young potato leaves, while decreased in mature leaves (Bussis *et al.*, 1998) [4]. But NADP-GAPDH and PRK activities have been decreased and this change became faster in the course of drought. While decreased Rubisco activity may not be the cause of photosynthetic reduction during water stress, its down-regulation may still be important because it could preclude a rapid recovery upon rewatering (Ennahli and Earl, 2005). Similarly, somereports have shown strong drought-induced reductions of Rubisco activity per unit leaf area (Maroco *et al.*, 2002) and per mg showed that the decrease of Rubisco activity in vivo was not connected with the protein content. It occurs because of CO₂ concentration decrease in the

carboxylation center in consequence of the partly closing of stomata (Flexas *et al.*, 2006). But it is known, that enzyme regulation occurs not only in transcription, but also in posttranscriptional level. Activities of the tested enzymes are regulated by light as well as by the concentration of photosynthetic metabolites (Raines, 2006). Reductions of more than 50% in the levels of NADP-GAPDH, FBP, PRK, and plastid aldolase were also needed before photosynthetic capacity was affected (Stitt and Schulze, 1994) [9].

Antioxidation strategies

Drought stress is accompanied by the formation of ROS such as O₂, H₂O₂, and OH (Moran *et al.* 1994; Mittler 2002), which damage membranes and macromolecules. Plants have developed several antioxidation strategies to scavenge these toxic compounds. Enhancement of antioxidant defense in plants can thus increase tolerance to different stress factors. Antioxidants (ROS scavengers) include enzymes such as catalase, superoxide dismutase (SOD), ascorbate peroxidase (APX) and glutathione reductase, as well as non-enzyme molecules such as ascorbate, glutathione, carotenoids, and anthocyanins. Additional compounds, such as osmolytes, proteins can also function as ROS scavengers (Bowler *et al.* 1992; Noctor and Foyer 1998). The antioxidant defenses appear to provide crucial protection against oxidative damage in cellular membranes and organelles in plants grown under unfavorable conditions (Al-Ghamdi, 2009; Kocsy *et al.*, 1996) [1].

Chlorophyll content

Severe drought stress also inhibits the photosynthesis of plants by causing changes in chlorophyll content, by affecting chlorophyll components and by damaging the photosynthetic apparatus (IturbeOrmaetxe *et al.*, 1998). Ommen *et al.* (1999) [6] reported that leaf chlorophyll content decreases as a result of drought stress. Drought stress caused a large decline in the chlorophyll a content, the chlorophyll b content, and the total chlorophyll content in all sunflower varieties investigated (Manivannan *et al.*, 2007). The decrease in chlorophyll under

drought stress is mainly the result of damage to chloroplasts caused by active oxygen species (Smirnov 1995). The decrease in chlorophyll under stress condition can be attributed to the sensitivity of this pigment to increasing environmental stresses, especially to salinity and drought, which has been reported by several researchers (Mekliche *et al.*, 2003; Younis *et al.*, 2000).

Stomatal conductance

Plants grown under drought condition have a lower stomatal conductance in order to conserve water. Consequently, CO₂ fixation is reduced and photosynthetic rate decreases, resulting in less assimilate production for growth and yield of plants. Diffusive resistance of the stomata to CO₂ entry probably is the main factor limiting photosynthesis under drought (Boyer, 1970). Certainly under mild or moderate drought stress stomatal closure (causing reduced leaf internal CO₂ concentration (C_i)) is the major reason for reduced rates of leaf photosynthesis (Chaves, 1991). Varieties significantly differed in photosynthetic activities, but these differences could only be expressed under the control conditions. In many experiments it has been shown that A decreases when g_s decreases (e.g., Tenhunen *et al.*, 1987; Nilsen and Orcutt, 1996).

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