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Effect of drought stress on cell membrane stability, relative water content and some characteristics of crop pants

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Abstract Growth is accomplished through cell division, cell enlargement and differentiation, and involves genetic, physiological, ecological and morphological events and their complex interactions. The quality and quantity of plant growth depend on these events, which are affected by water deficit. Cell growth is one of the most drought-sensitive physiological processes due to the reduction in turgor pressure. Under severe water deficiency, cell elongation of higher plants can be inhibited by interruption of water flow from the xylem to the surrounding elongating cells. Severe water deficit stress restricts the photosynthesis by damaging the chlorophyll components (CC) and changing the photosynthetic machinery. Decreased photosynthetic amount under water deficit condition is an outcome of Inhibition of Rubisco enzyme activity and development of ATP. Proline is well known to occur extensively in higher crop plants and accumulates in higher concentration in response to different abiotic environmental stresses specially drought stress. Different types of plant physiological responses have been reported by various Plant physiologists in their findings under drought stress situation.

Keywords Chlorophyll components, Relative water content, Stress

Introduction

Faced with scarcity of water resources, drought is the single most critical threat to world food security. It was the catalyst of the great famines of the past. Because the world's water supply is limiting, future food demand for rapidly increasing population pressures is likely to further aggravate the effects of drought [1]. The severity of drought is unpredictable as it depends on many factors such as occurrence and distribution of rainfall, evaporative demands and moisture storing capacity of soils [2]. 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 [3]. 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 [4]. 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 [5]. 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 [6]. This article and review and the aims are influence of drought stress on molecular responses on crop plants.

Chlorophyll components (CC)

Severe water deficit stress restricts the photosynthesis by damaging the chlorophyll components (CC) and changing the photosynthetic machinery [7].

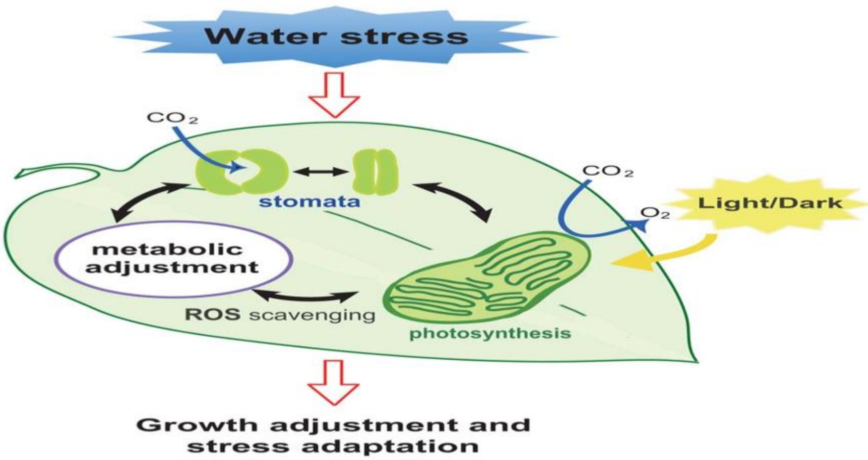

Figure 1: Illustration of the response of plants to water stress. Stomatal response, ROS scavenging, metabolic changes, and photosynthesis are all affected when plants are subjected to water stress. These collective responses lead to an adjustment in the growth rate of plants as an adaptive response for survival.

Decreased photosynthetic amount under water deficit condition is an outcome of Inhibition of RuBisCO (ribulose-1, 5-bisphosphate carboxylase/oxygenase) enzyme activity and development of ATP [8]. Many researchers revealed in their investigations that photosynthesis of higher plants is extremely susceptible to drought stress and Lower amount of chlorophyll cause chlorosis and reduction in crop growth [9]. Higher concentration of chlorophyll is essential for plants because it depicts the low quantity of photo-inhibition of the photosynthetic which prevents the carbohydrates losses and eventually enhances growth [10].

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 [11]. Accumulation of solutes in cells under stress conditions, in order to maintain cell volume against the loss of water, called the osmotic adaptation [12]. Drought stress induced free radicals cause lipid peroxidation and membrane deterioration in plants [13].

Relative water content (RWC)

Relative water content (RWC) of leaves has been reported as direct indicator of plant water contents under water deficit conditions [14]. Drought stress lead to reduction of water status during crop growth, soil water potential and plant osmotic potential for water and nutrient uptake which ultimately reduce leaf turgor pressure which results in upset of plant metabolic activities. Momentous pattern of divergence can be observed in Relative water content (RWC) among diverse genotypes during various plant growth stages. The highest Relative water content (RWC) might be calculated at crop vegetative stage [15]. Under water stress condition decrease in water status and osmotic potential in plants is the ultimate outcome of lower relative water content. Osmoregulation mechanism plays a phenomenal role in preserving turgor pressure which helps in soil water absorption and continue plant metabolic activities for its survival.

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 [16]. Considering the key role of CAT in photorespiration, many authors focused onthe 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 [17]. 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 [18]. 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 [19]. 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 [20]. 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.

Proline concentration in crop plant under water deficit condition

Proline is well known to occur extensively in higher crop plants and accumulates in higher concentration in response to different abiotic environmental stresses specially drought stress [21]. Accumulation of higher proline concentration in crop plant under water deficit condition is highly associated with and drought tolerance genotypes depicts its concentration is much higher than drought sensitive genotypes. It has been found by many scientists that in saline stress soil proline are mainly accumulated in leaves of many higher halophytic plant [22] but plants grown under drought stress showed much higher concentration of proline in leaves, shoots, in desiccating pollen and in root apical regions [23]. Accumulation of higher concentration of proline permits plants to keep less amount of water potential which cause accumulation of osmolytes in osmoregulation process which enables the plant to take up water to perform growth and metabolic activities [24]. Under water deficit condition proline perform many functions like act as osmolyte contribute s in the maintenance of membrane and protein, scavenging free radicals. Moreover after the severe damage of stresses proline contents provide adequate reducing agents that assist in mitochondrial oxidative phosphorylation and production of adenosine triphosphate (ATP) for revival from damages of various stresses [25]. The primary site of proline contents accumulation in response to drought stress in crop plant is cytosol [26].

Reactive oxygen species (ROS)

Plants continuously produce ROS and chloroplasts are the major sites of their production in normal condition. This inevitable production of ROS in chloroplasts is through a process called Mehler reaction [27]. When the Fe-S centre in PS I are over reduced and incapable of accepting electrons from thylakoid electron transport chain (ETC), oxygen molecules accept electrons (the Mehler reaction) and it will result in the formation of highly reactive superoxide radicals and H_2O_2**.** Under normal conditions, mitochondrial electron transport chain also generates ROS due to electron outflow and the major sites of electron leak are complex I and III [28]. A reverse electron flow of electrons occur from complex II to complex I when NAD+ supply for complex I are restricted. This leads to ROS production at complex I. In complex III, fully reduced ubiquinone cause the formation of an unstable ubisemiquinone radical which is favorable for the electron leakage to O_2. The normal production of ROS in various sites of plant body (viz. chloroplast, mitochondria, plasma membrane, peroxisomes, apoplast, endoplasmic reticulum, and cell wall) is increased to harmful levels during drought [29]. According to them, increased photorespiration during drought also causes the accumulation of H_2O_2 in peroxisomes. Extensive accumulation of ROS causes oxidative stress in plants through various ways during poor cell water conditions. Decreased rate of C fixation due to closing of stomata will lead to reduction of NADP+ regeneration via Calvin cycle and shortage of NADP+ pool easily cause over reduction of ETC and leakage of electrons to O_2. Thus Mehler reaction is increased over 50% during drought in plants [30].

Physiological Attributes

Different types of plant physiological responses have been reported by various Plant physiologists in their findings under drought stress situation. Zaharieva *et al.* (2001) [31] reported that in globally drought affected areas physiological mechanism is very handy approach in evaluating and screening the extraordinary genotypes having drought resistant mechanism. Comprehensive information of physiological mechanisms permits plant researcher to develop promising genotypes that would be utilized efficiently, continue his growth and production under water deficit stage [32]. In terms 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 [33], 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 [34]. 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 [34].

Cell membrane stability (CMS) under drought stress

Cell membrane stability (CMS) under drought stress depicts the ability of plant tissues to prevent electrolytes leakage by keeping the cell membrane in safe mood [35]. Estimation of Cell membrane stability (CMS) via *in vitro* includes dehydration of leaf tissues by means of polyethylene glycol (PEG) and then assessment of electrolyte leakage from leaves. Leakage of various solutes, such as organic acids, amino acids, saccharides, phenolic compounds and hormones from revealed cell membrane stability (CMS) after subject to dehydration through polyethylene glycol has been reported [36]. CMS Values have immense significance in hybridization programs because these Values predict the drought tolerant varieties [37]. Genotypes having lower CMS value are vulnerable to water deficit condition while the genotypes showing higher CMS values depicts drought tolerant behaviour. The genotypes having less than 50% values are tremendously susceptible to drought while genotypes with 71–80% values are considered to grow with full potential under water deficit. Farshadfar *et al*. (2011) [38] noticed in investigation that under water deficit conditions cell membrane stability (CMS) depicted positively considerable relationship with tillers per plant, grain yield, but negative association 100 kernel weights (TGW). Higher leaves chlorophyll contents is significantly correlated with photosynthesis and regarded as encouraging selection trait in crop productivity [39]. It has been reported in many studies that under drought stress Photosynthesis exhibit direct relationship with wheat grain production because less stomata opening frequency and low amount of CO2 fixation lead to reduction in photosynthetic amount [40].

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