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## Effect of drought stress on carotenoid and chlorophyll contents and osmolyte accumulation

Mohsen Arabshahi\*, Hamid Reza Mobasser

Department of Agronomy, Islamic Azad University, Zahedan Branch, Zahedan, Iran

**Abstract** Crop plant experiences water stress either when the water supply to roots becomes difficult or when the transpiration rate becomes very high. Available water resources for successful plant production have been decreasing in recent years. Furthermore, in view of various climatic change models scientists suggested that in many regions of world, plant losses due to increasing water shortage will further aggravate its impacts. In many observed cases chlorophyll content declines under drought stress conditions. Potato leaves show a significant decline in chlorophyll content with increasing drought stress. Under water stress, the maintenance of leaf turgor may also be achieved by the way of osmotic adjustment in response to the accumulation of proline, sucrose, soluble carbohydrates, glycinebetaine, and other solutes in cytoplasm improving water uptake from drying soil. The process of accumulation of such solutes under drought stress is known as osmotic adjustment which strongly depends on the rate of plant water stress.

**Keywords** Stomatal density, Heat shock proteins, Drought

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### Introduction

#### Drought stress

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 [1]. Plant experiences drought stress either when the water supply to roots becomes difficult or when the transpiration rate becomes very high. Available water resources for successful crop production have been decreasing in recent years. Furthermore, in view of various climatic change models scientists suggested that in many regions of world, crop losses due to increasing water shortage will further aggravate its impacts. Drought impacts include growth, yield, membrane integrity, pigment content, osmotic adjustment water relations, and photosynthetic activity [2-3]. Drought stress is affected by climatic, edaphic and agronomic factors. The susceptibility of plants to drought stress varies in dependence of stress degree, different accompanying stress factors, plant species, and their developmental stages [4]. Acclimation of plants to water deficit is the result of different events, which lead to adaptive changes in plant growth and physio-biochemical processes, such as changes in plant structure, growth rate, tissue osmotic potential and antioxidant defenses [5]. This article is review and the aims and scope is effect of drought stress on carotenoid and chlorophyll contents and osmolyte accumulation.

#### Carotenoid and chlorophyll contents

Wang *et al.* (2001) [6] reported that the carotenoid content in leaves of winter wheat increased under drought stress. The major role of carotenoid through direct quenching of triplet chlorophyll prevents the generation of singlet



oxygen and protects from oxidative damage. Chlorophyll and carotenoid absorb radiant energy, which is used for photosynthesis. In many observed cases chlorophyll content declines under drought stress conditions. Potato leaves show a significant decline in chlorophyll content with increasing water stress. Chlorophyll is one of the major chloroplast components for photosynthesis, and relative chlorophyll content has a positive relationship with photosynthetic rate. The decrease in chlorophyll content under drought stress has been considered a typical symptom of oxidative stress and may be the result of pigment photo-oxidation and chlorophyll degradation. Photosynthetic pigments are important to plants mainly for harvesting light and production of reducing powers. Both the chlorophyll a and b are prone to soil dehydration [7]. Decreased or unchanged chlorophyll level during drought stress has been reported in many species, depending on the duration and severity of drought [8-9]. Drought stress caused a large decline in the chlorophyll a content, the chlorophyll b content, and the total chlorophyll content in different sunflower varieties [10]. Exposure of two olive cultivars to reduced irrigation led to lower Chl (a + b) contents. These reductions were 29 and 42% for Chemlali and Chetoui, respectively [11]. Loss of chlorophyll contents under water stress is considered a main cause of inactivation of photosynthesis. Furthermore, water deficit induced reduction in chlorophyll content has been ascribed to loss of chloroplast membranes, excessive swelling, distortion of the lamellae vesiculation, and the appearance of lipid droplets [12]. Low concentrations of photosynthetic pigments can directly limit photosynthetic potential and hence primary production. From a physiological perspective, leaf chlorophyll content is a parameter of significant interest in its own right. Studies by majority of chlorophyll loss in plants in response to water deficit occurs in the mesophyll cells with a lesser amount being lost from the bundle sheath cells.

### **Compatible organic solutes**

Osmotic adjustment in terms of accumulating compatible solutes has been considered as an important physiological adaptation for plant to resist drought [13], which facilitate extracting water from dry soils and maintaining cell turgor, gas exchange and growth in very dry environments [14-15]. Soluble sugars and proline are two kinds of the most important compatible solutes in plants [15- 17]. One of the most common stress tolerance strategies in plants is the overproduction of different types of compatible organic solutes [18]. Compatible solutes are low molecular weight, highly soluble compounds that are usually nontoxic even at high cytosolic concentrations. Compatible solutes are accumulated in plants at high concentrations to help in alleviating inactivation of the enzymes or loss in membrane integrity due to a water deficiency [19]. Osmotic adjustment is a mechanism to maintain water relations and sustains photosynthesis by maintaining leaf water content at reduced water potentials. Osmotic adjustment is accomplished with the accumulation of compatible solutes. Of these, proline is one amongst the most important cytosolutes and accumulates in plants during the adaptation to various types of environmental stress, such as drought, salinity, high temperature, nutrient deficiency, and exposure to heavy metals and high acidity [20].

### **Osmolyte accumulation**

Under drought, the maintenance of leaf turgor may also be achieved by the way of osmotic adjustment in response to the accumulation of proline, sucrose, soluble carbohydrates, glycinebetaine, and other solutes in cytoplasm improving water uptake from drying soil. The process of accumulation of such solutes under drought stress is known as osmotic adjustment which strongly depends on the rate of plant water stress. Wheat is marked by low level of these compatible solutes and the accumulation and mobilization of proline was observed to enhance tolerance to water stress [21]. Of these solutes, proline is the most widely studied because of its considerable importance in the stress tolerance. Proline accumulation is the first response of plants exposed to water-deficit stress in order to reduce injury to cells. Progressive drought stress induced a considerable accumulation of proline in water stressed maize plants. The proline content increase as the drought stress progressed and reached a peak as recorded after 10 days stress, and then decreased under severe water stress as observed after 15 days of stress [22]. Proline can act as a signaling molecule to modulate mitochondrial functions, influence cell proliferation or cell death and trigger specific gene expression, which can be essential for plant recovery from stress [23]. Accumulation of proline under stress in



many plant species has been correlated with stress tolerance, and its concentration has been shown to be generally higher in stress-tolerant than in stress-sensitive plants. It influences protein solvation and preserves the quaternary structure of complex proteins, maintains membrane integrity under dehydration stress and reduces oxidation of lipid membranes or photoinhibition [24].

### Stomatal density

Stomatal regulation is one of the key mechanisms allowing plants to optimize CO<sub>2</sub> assimilation versus evaporative water loss [25]. The stomatal density (SD) has been closely related to WUE and drought tolerance [26]. Modification of SD in response to drought is contingent on the severity of drought, which varies among plant species [27]. For instance, drought decreased the stomatal numbers in wheat [28], *Squash cotyledons* [29], and *Phytolacca dioica* [30]. However, increased stomatal density was observed in grass with moderate drought stress [31]. Plants with lower SD have significantly reduced levels of transpiration, and were able to grow continuously under drought condition [32]. The plants with reduced SD were also found to have significantly higher WUE [33]. With *Arabidopsis thaliana* plant lines which have stomatal densities ranging from c. 50 to 250 % of normal levels, Hepworth et al. (2015) [34] found that plants with less than half of their normal complement of stomata, and correspondingly reduced levels of transpiration, conserve soil moisture and are able to avoid drought stress but show little or no reduction in shoot nitrogen concentrations especially when water availability is restricted.

### Heat shock proteins

HSPs, or molecular chaperones, are structurally diverse, but they all share the property of binding other proteins that are in non-native structural states, facilitating many structural processes such as folding, targeting and degradation. They are called heat shock proteins because the proteins were first discovered in abundance after heat stress. It is believed that during high temperature stress, they can prevent irreversible protein denaturation. HSPs are classified in 5 groups according to their approximate molecular masses. This class varies from 82 to 96kD. Proteins that belong to this class function as ATP-dependent chaperones that bind to highly structured folding intermediates, preventing aggregation. HSP90s can act alone or in concert with other proteins, forming for example the cytoplasmic chaperone heterocomplex (CCH). HSP70, HSP90 and an FK506 binding protein (FKBP, a peptidyl prolyl isomerase) have been identified as components of wheat CCH [35]. Another member of the heterocomplex is HOP (HSP70 and HSP90 organizing protein). There are three HOPs in *Arabidopsis* and studies in soybean have shown that HOP is part of the CHH in plants [36]. Studies in *A. thaliana* have shown that HSP90 might have a “buffering” activity regulating the expression of genes, which generates different phenotypes. HSP90 activity was inhibited pharmacologically using geldanamycin (GDA), revealing altered phenotypes in treated plants compared to those grown without GDA in different *A. thaliana* ecotypes and recombinant inbred lines (RI, homozygous in almost all loci). The same altered phenotypes were observed when plants were grown at elevated temperatures.

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