# Drought Stress: Effects and Causes

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**Abstract**

Expansion of agriculture to semi-arid and arid regions with the use of intensive irrigation will increase secondary salinization as a result of changes in the hydrologic balance of the soil between water applied (irrigation or rainfall) and water used by crops (transpiration). Moreover, the faster-than-predicted change in global climate and the different available scenarios for climate change suggest an increase in aridity for the semi-arid regions of the globe and the Mediterranean region in the near future. Together with overpopulation this will lead to an overexploitation of water resources for agriculture purposes, increased constraints to plant growth and survival and therefore to realizing crop yield potential. Understanding how plants respond to drought, salt and co-occurring stresses can play a major role in stabilizing crop performance under drought and in the protection of natural vegetation.

## Introduction

Water is an increasingly scarce resource given current and future human population and societal needs, putting an emphasis on sustainable water use (Rosegrant and Cline, 2003). Water stress is the major environmental stresses that affect agricultural production worldwide, especially in arid and semi-arid regions. Thus, an understanding of drought stress and water use in relation to plant growth is of importance for sustainable agriculture. Scarcity of water is a severe environmental constraint to plant productivity. Drought-induced loss in crop yield probably exceeds losses from all other causes, since both the severity and duration of the stress are critical. Here, we have reviewed the effects of drought stress on the growth, phenology, water and nutrient relations, photosynthesis, assimilate partitioning, and respiration in plants. This article also describes the mechanism of drought resistance in plants on a morphological, physiological and molecular basis. Various management strategies have been proposed to cope with drought stress. (Farooq*et al*., 2009).

Changes in the global production of major crops are important drivers of food prices, food



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security and land use decisions. Average global yields for these commodities are determined by the performance of crops in millions of fields distributed across a range of management, soil and climate regimes. For wheat, maize and barley, there is a clearly negative response of global yields to increased temperatures. Based on these sensitivities and observed climate trends, we estimate that warming since 1981 has resulted in annual combined losses of these three crops representing roughly 40 Mt or $5 billion per year, as of 2002. While these impacts are small relative to the technological yield gains over the same period, the results demonstrate already occurring negative impacts of climate trends on crop yields at the global scale. (Lobel and Field, 2007)

The mid-20th century brought a new agricultural revolution, first in industrialized countries, and then in the tropics, where it came to be known as the Green Revolution. New crop varieties and livestock breeds, combined with increased use of inorganic fertilizers, pesticides and machinery, together with better water control, led to sharp increases in food production from agricultural systems. Many staple crops and livestock show productivity changes over time over this period. Agriculture accounts for 70 % of global freshwater use, even though 80 % of global agriculture is primarily rainfed (FAO, 2011a). In coming decades the share of global freshwater available for agriculture is likely to decline as a result of increasing demands from industry, power generation and domestic use. In addition, competition between different agricultural uses, changing dietary patterns (e.g. the increased consumption of meat and sugar) and the changing structure of the global energy mix (Gerbens-Leenes*et al*., 2012) will also have a direct bearing on the availability of water for food production.

Water deficit is the commonest environmental stress factor limiting plant productivity. The lack of water, drought, is one of the major constraints that limit crop production and quality (Chandler and Bartels, 2003). The drought phenomenon is a chemical – physical complex, intervene in the organization of a number of large and small bio-molecules, such as nucleic acids, proteins, carbohydrates, fatty acids, hormones, ions, and nutrients (Dhandha*et al*., 2004 and Chaves*et al*., 2003). The stress is usually associated with a variety of other stresses, including salt, cold, heat, acidity and alkalinity. The ability of plants to tolerate water deficit is determined by multiple biochemical pathways that facilitate retention and/or acquisition of water, protect chloroplast functions, and maintain ion homeostasis. Essential pathways include those that lead to synthesis of osmotically active metabolites and specific proteins that control ion and water flux, support scavenging of oxygen radicals, or may act as chaperones. The ability of plants to detoxify radicals under conditions of water deficit is probably the most critical requirement. Many stress-tolerant species accumulate methylated metabolites, which play a crucial dual role as osmoprotectants, and as radical scavengers. Their synthesis is correlated with stress-induced enhancement of photorespiration. However, transfer of individual genes from tolerant plants only confers marginally increased water-stress tolerance to stress-sensitive species: tolerance engineering will probably require the transfer of multiple genes. (Bohnert and Jensen, 1996)

In response to drought brought about by soil water deficit, plants can exhibit either drought escape or drought resistance mechanisms, with resistance further classified into drought avoidance (maintenance of tissue water potential) and drought tolerance (Levitt, 1980; Price *et al.*, 2002). Drought escape is described as the ability of plants to complete the life cycle before severe stress sets in. Drought avoidance is by maintenance of high tissue water potential despite a soil water deficit. Mechanisms such as improved water uptake under stress and the capacity of plant cells to hold acquired water and further reduce water loss confer drought avoidance.

It is believed that when a plant is subjected to water stress, it reacts by producing a range of reactive oxygen species (ROS) during photosynthesis, photorespiration and dark respiration, causing damage to cells that suffer from water deficit (Taylor et al., 2003). Such ROS are toxic to plant cells and can be combined with vital molecules, such as fats, proteins, nucleic acids, causing lipid peroxidation, protein denaturation and DNA mutation (Quiles and Lopez, 2004).

Numerous recent studies have shown the negative effect of water stress on cellular membranes and organelles such as mitochondria and chloroplasts (Chandan and Tarhan, 2003), causing cellular content leakage outside the cell (Karabal*et al.*, 2003). Root growth maintenance under moderate water stress was also identified as an important mechanism to avoid dehydration by maximizing water uptake through an increase in root absorption area (Pe´rez-Ramos *et al.*,





2013).Water stress lead to growth reduction, which was reflected in plant height, leaf area, dry weight, and other growth functions (Kriedemann and Barrs, 1981 and Fischer, 1980). Water deficit is the commonest environmental stress factor limiting plant productivity.

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In conclusion water stress strongly affects photosynthesis, growth and survival of plant species growing in semi-arid climates, such as the Mediterranean. In the field water deficits do not act alone, but are normally associated with high temperature and high light stresses. Therefore, plant responses to drought during summer also involve adjustments to the stresses associated with drought. While trees and shrubs have developed a 'strategy' of stress tolerance and stress avoidance, herbs and annuals rely mostly on rapid growth to escape summer stresses as well as on fast responses of the photosynthetic and Carbon metabolism machinery to early signs of stress, including storage of reserves in the stem or roots (Chaves*et al*., 2002).

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