INNOVATIVE RESEARCH IN AGRICULTURE, FOREST AND WATER ISSUES



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DUVAR

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TABLE OF CONTENTS

Chapter 1.....5
The Effects of Some Climate Parameters on
Yield and Quality of Siirt Pistachio Variety (*Pistacia vera*, L)
Grown in Semi-Arid Climate Conditions
Ali Beyhan UÇAK

Chapter 2.....25
Pea Production Statistics in the World and in Turkey
Duygu USKUTOĞLU, Leyla İDİKUT

Chapter 3.....39
Rural Migration and Woman: Case Study of Adana, Turkey
Feyzan GÜRSESLİ, Dilek BOSTAN BUDAK

Chapter 4.....53
Investigation of Biological Stress in Plants Specific to Drought Stress
Birol TAŞ

Chapter 5.....69
Biochemical Compositions and Molecular Weight Profiles of Macroalgae
Mehmet NAZ

Chapter 6.....105
Enhanced Screw Withdrawal Strength of Polyurethane (PU)
Composites for Wood Sandwich Panel Core Layer
Süheyla Esin KÖKSAL, Orhan KELLECİ

Chapter 4

Investigation of Biological Stress in Plants Specific to Drought Stress

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ABSTRACT

Stress, in its true sense, is basically a mechanical concept and has been defined as "the force applied to an object per unit area". However, it is difficult to define the word stress in a biological sense as it is in both a mechanical and psychological sense. Therefore, in a biological sense, stress has been defined by researchers in two ways. The first of these is "everything in the ecosystem that negatively limits all kinds of development, especially the reproduction of the plant", and the second is "an adverse force or effect that tends to prevent the functioning of normal systems". The ability of the plant to survive against unfavorable environmental conditions is "stress endurance" or "stress resistance"; The fact that the organism comes to thermodynamic equilibrium with stress is defined as "stress tolerance". The effects of water deficiency in plants on plants can be examined under five main headings. To these. Membranes and Water Stress, b. Photosynthesis and Water Stress, c. Stomas, Wind and Water Stress, d. Osmotic Regulators and Water Stress e. Root Growth and Water Stress

Key words: water stress, biologicsl stress, stress tolerance, photosynthesis**,** stomatal stress

INTRODUCTION

The constant exposure of the biosphere to abiotic stresses such as drought, salinity, temperature extremes, chemical toxicity, oxidative stress, etc. causes disparity in the natural state of the environment. These stress conditions lead to a series of morphological, physiological, biochemical, and molecular changes in plants, which negatively affect their growth and productivity.

Plants strive to survive by fighting against many stress factors throughout their growth cycle. The loser of this battle dies, while the winner continues to live by further developing the traits (s) that helped them win that battle. For example, trees and shrubs in northern temperate latitudes can survive extremely low temperatures in winter, alpine plants can survive cold, dry winds and high levels of UV radiation, and agriculturally important plants can survive prolonged periods of drought. Today, in addition to the stress factors caused by existing natural phenomena, soil, water and air pollutants caused by human activities have been added to the "environmental stress parameters" that plants must cope with. Excess levels of these parameters create stressful conditions that can have significant effects on plant survival. Therefore, the study of plant responses to environmental stress has long been a major research topic for physiologists and ecologists studying plant-environment interactions.

What is stress?

In daily life, stress is always used to express a negative situation. However, when taken literally, it is basically a mechanical concept and has been defined as "the force applied to an object per unit area." Another form of expression is "tension." Stress, as we use in our daily lives, refers to a situation that occurs in conditions that trigger the development of certain biological, physical, and cognitive reactions in the body, which exposes the person to a momentary threat or a problem that requires struggle. In the biological sense, it is difficult to define the word stress as precisely as it is in its mechanical and psychological definition. Nevertheless, J. Levitt argued that this physical terminology could also be used and applied to living organisms (Levitt, 1972; Turner and Kramer, 1980). The concept of stress has more general connotations in biology. For example, "anything of environmental origin that negatively limits all kinds of development, especially the reproduction of the plant in the ecosystem" can be accepted as stress (Grime, 1979; Shabo et al. 2008), " is an adverse force or effect that tends to prevent the functioning of normal systems. " (Jones and Jones, 1989). Because environmental stress is also mentioned in the definition of biological stress, the issue becomes slightly more complicated. It is difficult to evaluate stress originating from the environment. Studies have shown that the responses of plants

to changes in environmental conditions differ by at least as much as plant diversity. For example, are the conditions encountered in deserts or Arctic tundra that are not normal for many plant stress conditions for plants that grow and live and even reproduce there, or is it impossible for these plants to survive elsewhere without those conditions? Therefore, there is no single correct answer for the negative effects of environmental stress factors on plants in scientific studies, and the results of these studies have not received the support of all scientists working in the field of stress physiology (Jones and Jones, 1989). The ability of a plant to survive under unfavourable environmental conditions has been defined as "stress endurance" or "stress resistance" (Levitt, 1980). In short, even this definition has its problems, as it is highly subjective and varies between species and ecotypes.

Biological Stress Avoidance, Stress Tolerance, Stress Adaptation and Adaptation Mechanisms

Many plants can resist stress through stress avoidance or tolerance. Stress avoidance mechanisms are provided by modifications that a plant usually creates in its anatomical structure. With these modifications, even if there is stress in the environment, the effect of the stress is reduced. Examples of these modifications are the deep root systems that plants form to better utilize the water in the soil, to keep the water within the plant and to prevent water loss through evaporation, the thickening of the cuticle layer, the hairs they form on the leaves to reduce the effect of the sun's rays, and the formation of fleshy leaves (Salisbury and Ross, 1992).

On the other hand, Stress tolerance occurs when an organism reaches thermodynamic equilibrium with stress. In other words, the internal and environmental conditions of the plant are balanced. For example, drought tolerance allows the protoplasm of an organism to maintain its average growth and development capacity without damage when rehydrated after drying. The vegetative parts of most plants cannot tolerate even moderate dehydration, whereas the leaves of the fern plant can survive up to 7% water content (Figure 1).

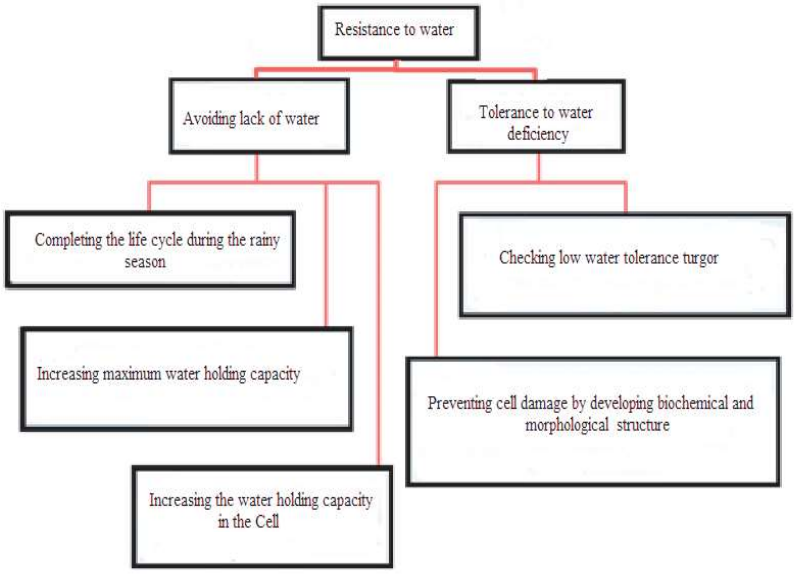


Figure 1. Tolerance and Avoidance in Mechanisms of Resistance to Water Deficiency Stress

The two other terms that require explanation are adaptation and adaptation. Both adaptation and adaptation are means of providing tolerance to a particular stress. Adaptation refers to heritable changes in structure or function that increase an organism's adaptability to stressful environments. Morphological and physiological modifications associated with crassulacean acid metabolism (CAM) in plants are examples of adaptation. Adaptation, on the other hand, refers to the physiological changes that occur in a plant throughout its life, but they are not hereditary (modification). The capacity to adapt is, of course, a genetic trait; however, the specific changes that occur in response to stress are not passed on to the next generation.

Water (Drought) Stress

Drought is the most important source of stress for agricultural production. Drought is one of the most important abiotic stresses affecting plant productivity worldwide, including our country (Oki and Kanae 2006; Osakabe et al.2014). However, many plants have developed morphological and physiological changes that allow them to survive in areas of insufficient rainfall and low soil moisture content. These morphological and physiological changes are planned only for plant survival, and factors such as high yield and quality etc. remain in the background. When water stress is mentioned, the stress caused by an insufficient

amount of water is the first thought that comes to mind. However, water stress can also occur in excess water. Excessive water stress is caused by floods or overflows, and in such a case, the oxygen going to the roots of the plant decreases, and oxygen stress actually occurs. Decreased oxygen levels limit respiration, nutrient uptake, and other critical root functions. Stress from a lack of water, as we generally understand it, is much more common, and this phenomenon, which should be correctly expressed as "water-lack stress," is simply abbreviated as "water stress." Because water stress in natural environments is often caused by a lack of precipitation, it is often referred to as drought stress.

Water stress negatively affects plant growth and productivity. Therefore, "water use efficiency" (WUE), a parameter of crop quality and performance under water-deficient conditions, is an important selection trait (Yamaguchi-Shinozaki and Shinozaki, 2006; Ahuja et al., 2010; Skirycz and Inze, 2010; Osakabe et al. , 2011; Nishiyama et al., 2013; Ha et al., 2014).

In order for plants to grow and develop in a healthy way, they need to perform a healthy photosynthesis. However, high light intensity (EL) can also cause a decrease in the leaf/water potential and stomatal opening of the plant. Water stress, which leads to the downregulation of photosynthetic genes and reduced CO2 availability, is one of the main factors in EL stress (Osakabe and Osakabe 2012).

a. Membranes and Water Stress

Damage to cell membranes from water stress is determined by the deleterious effects of this deficiency on the protoplasm. For example, the removal of water may lead to a reduction in the protoplast volume and consequently an increase in the solute concentration in the cell, resulting in metabolic dysfunctions in the plant. Although the extent of membrane damage caused by water stress is not yet known, it has been observed that the removal of water from membranes disrupts the normal bilayer structure (cell wall + cell membrane) and makes it highly porous. When extremely porous membranes are rehydrated, they allow large amounts of solutes from the outside of the cell to leak. Due to the loss of membrane selectivity, cellular compartmentalization is generally disrupted and membrane-based enzymes lose activity. The loss of membrane integrity and protein stability can be exacerbated by a high cellular electrolyte consensus, accompanied by dehydration of the protoplasm. As a result, cell metabolism is impaired.

b. Photosynthesis and Water Stress

Photosynthesis, which is the most important factor for the survival of plants, is particularly affected by water stress. This effect occurred in two ways. First, when the plant senses a lack of water, it closes its stomata to prevent evaporation through transpiration, cutting off the chloroplasts' access to atmospheric carbon dioxide. This situation negatively affects the decrease in photosynthesis, and consequently, the growth and development of the plant. Second, there are direct effects of low cellular water potential on the structural integrity of the photosynthetic mechanism. (Lawlor, 2002; Flexas et al., 2006; Chaves et al., 2009). The direct effect of low cellular water potential on photosynthesis is that it reduces both electron transport activity and photophosphorylation. These effects damage the thylakoid membranes and ATP synthetase proteins.

c. Stomas, Wind and Water Stress

Plants often respond to acute water deficits by closing their stomata to allow water lost by transpiration from leaf surfaces to be reabsorbed and replaced by roots. It has been shown that the opening and closing of stomata in all plants examined to date is dependent on ambient humidity (Mansfield and Atkinson, 1990). Stomatal closure is regulated by hydroactive processes. Hydroactive closure occurs metabolically by reversing ion flow under the influence of Abscisic Acid (ABA) and other hormones. Since its discovery in the late 1960s, ABA has been known to play an important role in the closure of stomata due to water stress, with ABA accumulating in water-stressed (i.e., wilted) leaves (Fig. 2)

How ABA controls turgor in guard cells remains to be determined. Evidence suggests that ABA acts on the outer surface of the plasma membrane. Because no plasmodesmata were found to symplastically connect the guard cells to the mesophyll cells. For this reason, it is thought that ABA can reach the guard cells through apoplastic spaces, not symplastic. However, there are strong indications that ABA interferes with plasma membrane proton pumps and consequently K+ uptake and stimulates K+ influx from guard cells. In both cases, the guard cells lose their turgor, causing the stoma to close.

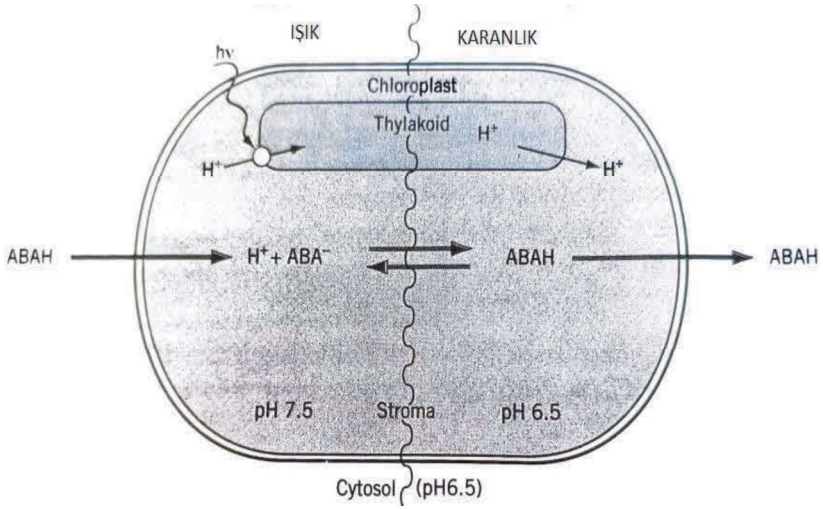


Figure 2. ABA storage in chloroplasts. Photosynthesis in the light creates a pH gradient between the stroma and the cytosol, directing protons into the interior of the thylakoid. The pH gradient favours the movement of ABAH into the chloroplast where it dissociates into ABA. The membrane is less permeable to ABA. In the dark protons leak back into the stroma, the pH decreases and ABAH returns to the cytosol.

Stomatal closure is not always dependent on the perception of a lack of water and the signals that appear in the leaves. In some cases, stomata appear to close in response to soil drying before there is a measurable reduction of turgor in leaf mesophyll cells (Mansfield and Atkinson, 1990). Several studies have shown that there is a feedforward control system that originates in the roots and transmits information to the stoma (Blackman and Davies, 1985; Zhang and Davies, 1987).

It was determined that the wind movement around the plant also provided closure of the stomata. The reason for this is that the moist air layer surrounding the leaf is reduced by the wind. As the wind speed reaches a certain limit, the amount of water lost from the plant by transpiration also increases. In windless weather and especially in the air layer just above the plant leaves, which are not under the direct influence of the sun, the concentration of water vapor increases. As a result, water loss in the form of steam is also reduced, depending on the difference in concentration of water vapor between the air space of the leaf and the air outside the leaf. By removing the water vapor molecules just above the plant leaf, the wind causes the water vapor concentration difference to increase outward from the leaf and thus the amount of water lost in the form of steam increases. The blowing wind not only drags the air with a high water vapor content just above the leaf and replaces it with dry air, but also causes a large

amount of water lost in the form of steam as it moves the leaves. A light but continuous wind increases the amount of water that is lost in the form of steam more than a sudden and strong wind. Because when the wind suddenly rises and blows fast, the water transferred to the mesophyll cells through the xylem transmission pipes will not be sufficient, so the stomata close and the amount of water lost in the form of steam decreases. On the other hand, the wind causes a significant cooling effect on the leaves and reduces the amount of water lost in the form of steam by reducing the water vapor concentration difference from the leaves to the outside.

Both hydropassive and hydroactive stomatal closure have demonstrated mechanisms that allow plants to anticipate potential water availability problems, either through excessive loss of transpiration from leaves or chronic but non-lethal soil water deficiency.

d. Osmotic Regulators and Water Stress

Another obvious response to water stress in many plants is the reduction in osmotic potential caused by the accumulation of solutes. This process is known as “osmotic adjustment”. Osmotic adjustment creates a more negative leaf water potential, helping to maintain the movement of water towards the leaf, consequently, leaf turgor.

Substances dissolved in the cell slowly accumulate during osmotic adjustment, reducing the rate of osmotic pressure drop created by water loss. Therefore, the decreases in osmotic potential due to osmotic adjustment are relatively small. Osmotic adjustment can play an important role in helping partially wilted leaves regain their turgor after the water problem has been resolved. Osmotic adjustment helps maintain leaf turgor, allowing plants to keep their stomata open and continue to receive CO2 for photosynthesis under moderate water stress conditions. However, osmotic regulators cannot provide the desired success in every plant. For example, while the success rate is high in sugar beet (Beta vulgaris), it is low in cowpea (Vigna unguiadata).

e. Root Growth and Water Stress

One of the early effects of water deficiency in plants is a decrease in vegetative growth. Shoot growth, and especially leaf growth, is more sensitive than root growth. For example, when the maize (Zea maize) plant was not watered, it was observed that there was a significant reduction in leaf expansion when the water potential in the plant tissues dropped to -0.45 MPa and growth stopped completely at -1.00 MPa. However, the same sensitivity was not observed in root tissues, normal root growth continued until the water potential of root tissues

reached -0.85 MPa, and stopped when it dropped to -1.4 MPa (Westgate and Boyer, 1985).

It is not always possible to observe a direct relationship between cell growth and turgor in stressed plants. Therefore, it is necessary to investigate these underlying mechanisms. For example, while the water potential of corn leaves decreased in response to water stress, the water potential of the xylem decreased as well. The movement of water into the leaf depends on the maintenance of the water potential gradient between the xylem and the leaf. The reduced water potential in the xylem will reduce the magnitude of the xylem-leaf gradient, while there will be enough water in the leaf to maintain turgor, and insufficient water will be available to sustain cell growth. Studies have shown that to detect increases in solute concentration in tissues experiencing water stress, the growth rate must first decrease, and this increase cannot be detected until the growth rate begins to decrease (Matthews et al., 1984; Van Volkenburgh and Boyer, 1985). motic Regulators and Water Stress

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