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Review Article

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Impact of Environmental Stress on the Physiology of Plants

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Abstract

Stress causes a plant to develop in a suboptimal or terrible state, compromising its capacity to grow, produce crops, develop, or even die if the stress level exceeds the plant's tolerance limitations. It is made up of a diverse set of variables that may be divided into two categories: environmental stress factors (abiotic stress factors) and biotic stress factors (biological stress factors). While biotic stress factors are biological threats (pathogens and pests) that a plant faces during its life, abiotic stress factors include any number of environmental issues that impede plant growth, such as light, waterlogging, temperature, salt, drought, and heavy metal toxicity. Due to continued climate change and deteriorating circumstances, human activity has caused an imbalance in the level of food security. This research looks at the broad views of the various types of plant stress, their effects, and how plants react to these different types of stress. To cope with the stresses they face, plants usually exhibit a range of defensive mechanisms in response to stress.

Keywords: Plants stress, abiotic and biotic, plant response, Heavy metal stress, Physiology

1. Introduction

A plant may experience stress from any external factor that affects its growth, yield, or any other part of its life cycle. Any changed physiological condition caused by environmental factors might disturb homeostasis. Environmental perturbations in this homeostatic condition are referred to as biological stress. The rapid change from certain normal environmental circumstances upsets this initial at-home feeling, and the plant suffers as a result. A system deviates from its usual state due to a recognized situation termed stress, which results in strain—a physical or chemical alteration. Numerous causes contribute to decreased agricultural output, including these environmental stresses. Along with their negative impacts on the existing crop, they also create obstacles to the entry of new species into the ecosystem, which prevents the use of such species for agriculture.

Plants are subject to environmental and unfavorable limitations, which have been described using the stress concept that Hans Selye first introduced in 1936. However, the meaning of stress in plants differs greatly from that of stress in humans and animals.

The quantity of research articles on plant stress and plant stress detection that can be found in journals of botany, plant physiology, ecophysiology, and plant biochemistry has increased dramatically during the last ten years. This process is still ongoing and might pick up even more speed in the future. The state of the art in stress research is demonstrated by several recent books, including Stress and Stress Coping in Cultivated Plants by McKersie and Leshem, Plant Adaptation to Environmental Stress by Fowden et al., Proceedings of Symposia or Plant Stress Reviews by Larcher and Lichtenthaler, and the recently published Vegetation Stress, edited by Lichtenthaler. The latter contains more than 90 original contributions on stress detection and stress effects in plants. Stress bei Pflanzen, an enticing new textbook written in German, has also been edited[1–9].

2. Methodology

The overall design of this study was exploratory. The research paper is an effort that is based on secondary data that was gathered from credible publications, the internet, articles, textbooks, and newspapers. The study's research design is primarily descriptive.

3. Literature Review

3.1 Stress Factors

Under normal conditions, plants can only develop and reproduce more efficiently, yielding high-quality products, as we have previously discussed. However, plants are subject to different levels of biotic and abiotic stresses, which change the environment in which they thrive. Another name for these components is stressors. Plants respond to these pressures by activating defence mechanisms and adaptation processes, which we will discuss later in this chapter. This section discusses several important biotic and abiotic stresses and how they affect plant development (Fig. 1).

Principal types of Abiotic Stress have been mentioned below:

1. Drought or Water Stress
2. Salt-induced stress
3. Thermal stress
4. Light stress.
5. Stress due to heavy metal

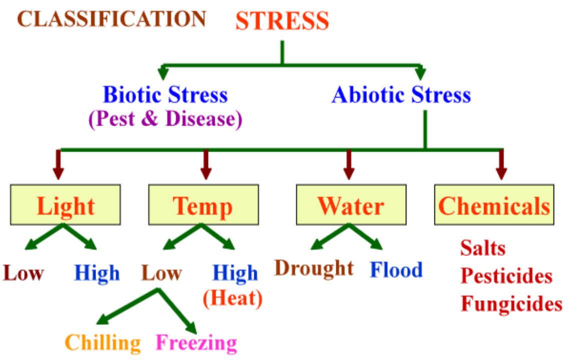

Figure 1. Various Stress factors

3.2. Drought or water stress

Drought is defined as a lack of water that is severe enough to prevent plants from growing. Drought is classified into two primary categories: soil drought and atmospheric drought. An air-dry spell is caused by dry soil. The combination of high temperatures, strong winds, and low atmospheric humidity causes a plant to lose the majority of its water during an atmospheric drought. Abiotic stressors that affect a plant's overall health and growth include flooding, too much salt, insufficient rainfall, too much light, and temperature fluctuations. Plants suffer from a water deficit when transpiration rates rise or when root water absorption is impeded. Wilting is the first response to drought stress because of the decrease of turgor pressure, which makes plant cells swell and stay rigid[10].

Compared to non-resistance cultivars, drought-tolerant sesame cultivars produce more seeds, have higher levels of carotenoid content in their leaves, and have higher levels of proline in their roots. Furthermore, by generating more of these metabolites, the plant was able to withstand the drought stress condition. The height, number of leaves, leaf area, number of pods, pod dry matter, and total plant weight of two bean cultivars all significantly decreased under drought stress. Under drought stress, proline level rises but protein content may fall[11].

3.3. Salt Stress

The accumulation of too much salt in the soil is referred to as "salt stress" and can sometimes lead to plant mortality by impeding plant development. In dry regions, it is one of the primary abiotic factors that reduces agricultural productivity. Salinity has several detrimental effects on agricultural output, seed germination, and plant productivity, to name a few. Ion toxicity, membrane disruption, oxidative stress, water potential, and decreased cell development and division are other ways that high salt levels can damage plants. Each of these effects harms plant growth and crop yield. Senescence, growth inhibition, and fast growth were among the adverse consequences that plants under salt stress encountered. It may lead to death because of the extended exposure to the salt. Salt stress affects a wide range of plant characteristics, such as physiology, morphology, anatomy, chemical composition, and water content of plant tissues.

Under salinity stress, mineral ion absorption may be diminished. The phenomenon known as decreased ion transit rate under salt stress circumstances is caused by poor root absorption rate or low xylem sap efficiency. Under stressful circumstances, either too much NaCl soaked into the spaces between cells or a poor nutritional supplement caused a reduction in cell division or growth. When plants experience osmotic stress, they are forced to relocate away from salt-accumulating regions and grow roots that are adapted to the saline environment. Salt stress for an extended period decreases the quantity of water and nutrients that the roots can absorb[12].

3.4. Temperature stress

Heat limits a plant's ability to grow and function. Cool-season plant growth is restricted by the hot summers in many places of the world. According to several studies, the optimal temperature range for C_3 plant development is 15–25°C. During the warm season, high temperatures prevent photosynthesis and the accumulation of carbohydrates. Additionally, C_3 plants experienced increased cell membrane damage, which led to protein folding and even cell death. Warm-season plants, or C_4 plant species, have been shown to sustain winter harm. Furthermore, because the C_4 species absorbed less water, they needed to self-modify to be able to absorb nutritional components with poor solubility[13].

C_3 plants can slow down their growth and survive the high-temperature stress situation by using less nitrogen fertilizer throughout the summer. The plants would develop faster and use all of their stored carbohydrates if there were more nutrients available in the root zone during the high-temperature stress, leaving them with no reserves to resist the winter's low temperatures[14].

Mesophyts need a relatively narrow temperature range of about 10°C for optimal growth and development. Outside of this range, the extent of damage is determined by the duration and intensity of the temperature shift. The tissues of higher plants that are actively developing can tolerate both short-term exposure to temperatures of 55°C or more and long-term exposure to temperatures over 45°C. However, nongrowing cells or dried tissues (such as seeds and pollen) continue to function at extremely high temperatures. Certain species' pollen grains can withstand temperatures as high as 70°C, while some dry seeds can withstand as high as 120°C.

3.5. Light Stress

Light stress is another stressor that negatively impacts plants and their growth. Light is a vital environmental factor for plant growth and development and one of the most important components of photosynthesis as an energy source. However, photo-destruction and photo-inhibition, which are harmful to plant functions, can also result from the changed quantity and quality of light. Variations in light intensity, whether high or low, impair a plant's capacity to maintain equilibrium and perform its normal metabolic functions.

Being photoautotrophs, plants benefit greatly from visible light because they use photosynthesis to maintain a positive carbon balance. Higher wavelengths of electromagnetic radiation, especially those in the UV range, can damage membranes, proteins, and nucleic acids, which can impair biological processes. However, even in the visible spectrum, exposures considerably over the light saturation threshold for photosynthesis cause a great deal of light stress, which can damage chloroplast structure and reduce photosynthetic rates (a process known as photoinhibition)[15].

3.6. Heavy Metal Stress

Heavy metals interfere with morphological, physiological, biochemical, and molecular processes in plants. Environmental Pb and Cd have a major effect on plant development and production. Conversely, plants need zinc from the soil for vital functions. Zn aids in the transport and accumulation of Pb and Cd in the aerial parts of maize plants. Moreover, Zn, Pb, and Cd interaction hinders the absorption and translocation of additional divalent metals. This study shows how histone acetylation and DNA methylation affect metal stress tolerance through Zn transporters and caution against overusing zinc fertilizers in metal-polluted soil. Cerium dioxide (CeO2) nanoparticles are pollutants of increasing concern since they are seldom immobilized in the environment[16].

4. Critical Analysis

The review by Hasan et al.[17] explores the effect of O_3 on stomatal regulation via phytohormone-mediated guard cell communication. By considering several physiological systems, the authors of this review updated our existing knowledge of ozone-induced stomatal regulation. The insights presented will improve our understanding of the molecular mechanisms associated with the O^3 stress response, especially as they affect stomatal regulation, MAPK activity, and phytohormone signaling. Abiotic stresses disrupt K^+ transport and homeostasis.

A review by Viudes et al.[18] suggests that the production of a polysaccharide mucilage upon water imbibition of myxodiasporous species' seeds (myxospermy) or fruits (myxocarpy) may play a part in how plants react to environmental stressors. The understudied topic of myxodiaspory development was the main focus of this review. A detailed characterization of the molecular actors led to the discovery of the mucilage secretory cell (MSC) toolbox, which aids in the production of seed mucilage in *Arabidopsis thaliana*[19].

Ahmadi et al.[20] found that mild stress increased the activity of the enzyme catalase (CAT) whereas severe stress lowered it when maize was grown under different nitrogen levels and drought stress. Additionally, they discovered that CAT activity was significantly increased when nitrogen fertilizer was administered at its highest dosage. Furthermore, drought stress significantly increased the activity of Superoxide Dismutase (SOD). At the mild water stress level, peroxidase (POD) activity rose; however, at the severe water stress level, it decreased and even fell below the control level.

The review by Hasan et al.[21] explores the effect of O_3 on stomatal regulation via phytohormone-mediated guard cell communication. By considering several physiological systems, the authors of this review updated our existing knowledge of ozone-induced stomatal regulation. The insights presented will improve our understanding of the molecular mechanisms associated with the O_3 stress response, especially as they affect stomatal regulation, MAPK activity, and phytohormone signaling. The review by Monder and colleagues emphasizes the main negative impacts of the contemporary environment on grape quality and, by extension, wine quality. Abiotic stresses disrupt K^+ translocation and homeostasis. The main electrical and osmotic activities of K^+ are presented, emphasizing their intimate connection to transport networks, membrane energetics, and cellular K^+ homeostasis. The application of stress-sensitive determinants and the creation of plants with greater stress tolerance will benefit from the new information.

Hasanuzzaman et al.[22] discussed the physicochemical foundation of ROS generation, processes unique to each cellular compartment where they are created, and possible unsettling consequences. The authors further stress the importance of the antioxidant defense system for ROS homeostasis and detoxification in light of the most recent discoveries. Furthermore, identifying stress signals is a crucial first step toward a proper response and plant survival. Essential signaling modules in eukaryotes, plant mitogen-activated protein kinase (MAPK) cascades control how the body reacts to environmental stresses such as excessive salt, drought, high temperatures, and pest and pathogen infestations.

Sekmen et al.[23] claim that the APX activities were influenced by the species and salt content of the plants. The APX activity in sea plantain and hoary plantain leaves increased and was constant under 100 and 200 mM NaCl. H_2O_2 is converted to oxygen and water by the oxidoreductase enzyme catalase. Because this enzyme has a low affinity for H_2O_2 and doesn't need a reducing power, it can only remove large volumes of H_2O_2. It also has a rapid rate of reactivity.

5. Discussion

Abiotic stress can adversely affect a plant's relationships with other species in several secondary ways. This is why an abiotic stress that was previously present in a community environment is often transformed into a biotic component that induces plant stress, leading to a disrupted or altered relationship between the stressed plant and other interacting species. This phenomenon is shown figure 2:

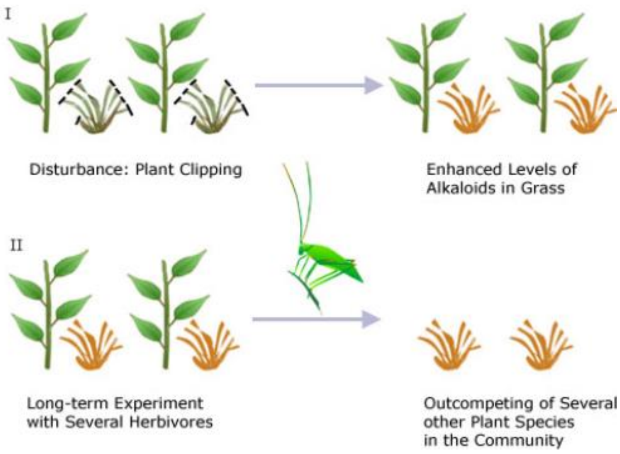

Figure 2. Impact of Biotic Interactions: (I) Grass resistance to herbivores is increased by clipping (resistant grass is highlighted in red). (II) Communities shift when a species has the chance to outcompete rival species.

Physically removing endophytic symbiont-containing grasses can increase the levels of alkaloids in the plant tissue, enhancing the plant's resistance to herbivores (Figure 2). Long-term studies have shown that plants that are better able to fend off herbivores are at a competitive advantage and are thus indirectly outcompeting other plant species. As a result, the community's organization is changed[24].

Extreme temperatures can cause damage to membranes and enzymes. Any abiotic substance that adds proteins and sterols and alters the lipid bilayer that makes up plant membranes has the potential to disrupt cellular processes. The physical properties of the lipids have a major impact on the roles of the integral membrane proteins, which include carriers, H+-pumping ATPases, and channel-forming proteins that regulate the flow of ions and other solutes. High temperatures cause the fluidity of membrane lipids to rise while the strength of hydrogen bonds and electrostatic interactions between polar protein groups in the membrane's aqueous phase decreases. As a result, high temperatures change the structure and makeup of membranes and can cause ion leakage. The three-dimensional structure required for structural cellular components or enzymes to function correctly can also be lost by extreme heat, which can lead to an incorrect structure and activity of the enzymes. Misfolded proteins often precipitate and cluster together, which can lead to serious problems for the cell[25].

Examples of Reactive Oxygen Species (ROS) that can result from salt stress include superoxide, hydrogen peroxide, and hydroxyl radicals. These ROS damage membrane lipids, proteins, and nucleic acids. Plants have developed enzyme systems for scavenging reactive oxygen species to protect themselves from oxidative harm. Catalase (CAT), peroxidase (POX), and ascorbate peroxidase (APX) are some of the enzymes that are involved in the metabolism of ROS. Antioxidant enzymes have been shown to help the body resist the harm caused by salt stress. It has been shown that the breakdown of membrane polyunsaturated fatty acids results in the buildup of malondialdehyde during serum stress. Changes in APX, POX, and CAT activity under salt stress have been examined in studies on several plant species. Increased POX and APX activities in cowpea (*Vigna unguiculata* (L.) Walp), CAT activity in tobacco (*Nicotiana tabacum* L.), and decreased CAT activity in cowpea have all been reported under salt stress. Malondialdehyde (MDA) is produced when the polyunsaturated fatty acids in plant membranes degrade under salt stress[26–30].

6. Conclusion

The effects of biotic and abiotic stress on plant physiological systems. The objective is to enhance plant performance under difficult growth conditions, when plants must deal with elemental stress, biotic stress, water stress, and sub-optimal or supra-optimal temperature. It is feasible for producers and breeders to boost nutritional element efficiency if they completely know the impacts of various stressors on plant cells, their mobility within the cells, and their influence on physiological processes. This will boost crop yield and help producers become more resilient to global stresses.

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Conflict of Interest

Not Applicable

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