

## Plant response to Abiotic and Biotic stress

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### Abstract

A broad variety of environmental stressors are experienced by plants, which lowers and restricts the yield of agricultural products. Plants experience two different kinds of environmental stress, which are classified as (1) Abiotic stress and (2) Biotic stress. Major agricultural plants are lost due to abiotic stress, which includes radiation, salt, floods, droughts, temperature extremes, heavy metals, etc. On the other side, biotic stressors include assaults by different diseases such as fungi, bacteria, oomycetes, nematodes, and herbivores. Plants cannot avoid these environmental signals since they are sessile. To combat these biotic and abiotic challenges, plants have created a variety of strategies. They detect the environmental stressor, get activated, and then produce the necessary biological reactions. They achieve this by using several signal transduction pathways to transmit impulses from sensors on the cell surface or in the cytoplasm to the transcriptional machinery housed in the nucleus. The plant becomes more resilient to stress as a result of differential transcriptional modifications. Signalling pathways serve as a crucial connection between detecting the presence of stress and producing the proper biochemical and physiological response. This review research demonstrates how plants react to various pressures through their activities, new technology (such as genetic engineering), and the usage of nutrients in plant production that might lessen stress on the plants.

### Introduction

Stress is a modified physiological state brought on by a change in balance. When a pre-existing situation compels a system to depart from its thermodynamically ideal state, stress causes physical and chemical changes that are referred to as a strain. Numerous stressors in nature have an impact on plant development and other activities (productivity) through changes in their morphological, physiological, biochemical, and molecular processes. Plant stress is therefore separated into two categories. Biological and abiotic stress.

Abiotic stressors that negatively affect crop and other plant growth, development, yield, and seed quality include drought (water stress), excessive watering (waterlogging), high temperatures (cold, frost, and heat), salt, and mineral toxicity. Future experts believe that when fresh water becomes more scarce, abiotic stressors will become more intense.

### 2. Crop plants and abiotic stresses

Numerous abiotic stressors that plant face influence agricultural output globally. These abiotic challenges are interrelated and may manifest as osmotic stress, an issue with ion distribution, or an imbalance in plant cell homeostasis. A collection of genes reacts by altering their expression patterns, which affects growth and production. Therefore, to comprehend the abiotic stress response mechanisms in agricultural plants, the identification of sensitive genes against abiotic challenges is required. Several abiotic stressors affect plants.

Salinity, drought, floods, temperature extremes, heavy metals, radiation, etc. are examples of abiotic stressors.

It is a significant role in the loss of important agricultural plants around the globe. The world's terrestrial area is becoming more decertified, the soil and water are becoming more salinized, water resources are scarce, and environmental degradation will make the situation more difficult.

Abiotic stress refers to any environmental circumstance other than the behaviour of another creature that inhibits the growth, survival, and fruitfulness of plants. Abiotic stress can take many various forms, including drought, excessive soil salinity, floods, severe temperatures (either too high or too low), insufficient light or too much UV radiation, acidic or alkaline soils, nutrient-deficient soils, etc. The majority of plants and crops are vulnerable to abiotic stress.

Yield losses due to abiotic stress were estimated to be 65.8% for maize, 82.1 % for wheat, 69.3 % for soybeans, and 54.1 % for potatoes by Wang et al. (2013).

## 2.1 Water Stress

The plant experiences water stress when the water supply is restricted to the roots or the rate of transpiration increases. Due to high soil salinity, flooding, or low soil temperature, plants cannot absorb the water that is present in the soil solution, which is known as physiological drought. Water deficit (drought and high soil salinity) is one of the main causes of water stress.

At the biochemical and molecular levels, the effects of a water deficit are not well understood, despite the importance of this knowledge. All plants can withstand water stress; however, the degree of stress differs across species. Dehydration causes many plants to perish during droughts. Water stress causes an increase in the solute's concentration in the cytosol and extracellular matrix, which lowers the water potential of plant cells and turgor in plants. The drop in water content, turgor, and total water due to drought has an impact on a plant's water relationships. Drought has many negative effects on plants, including stomatal closure, limited gaseous exchange, decreased transpiration, and a stop in the rate of carbon absorption (photosynthesis).

## 2.2 Cold

Cold or low temperature, is another highly frequent environmental stressor that adversely impacts plant development and agricultural productivity. The majority of plants are not very resistant to freezing temperatures, but by being subjected to chilling, non-freezing conditions, they can develop a resistance to freezing temperatures. Cold acclimatisation is the term for this procedure. By altering the lipid composition and producing other non-enzymatic proteins, it restructures the cell membranes physically and biochemically. Significant transcriptome research has recently been done to better understand how plants detect cold and regulate their response to it so they may build a cold acclimation response. Genes involved in the manufacturing or signaling of plant hormones including ABA, gibberellic acid, and auxin are differentially regulated.

Cold-induced abiotic stress has a profound impact on all cellular processes in plants. There are some signal transduction pathways by which these cold stressors are transduced, including protein kinase, protein phosphate, ABA, Ca<sup>2+</sup>, and others. However, ABA emerges as the most effective of them.

## 2.3 Drought and Oxidative Condition in Plants

When there is a lack of water in the land and atmosphere, it is called a drought. When under drought stress,

plants go through several physiological and biochemical changes. These reactions cause the stomata to close, the transpiration rate to drop, photosynthesis and cell development to be suppressed, the osmotic potential of plant tissues to decrease, and respiration to be activated. Adaptations also occur at the cellular and molecular levels. The phytohormone abscisic acid (ABA), various osmolytes (such as mannitol, proline, sorbitol, trehalose, and fructans), and novel stress-tolerating proteins are all accumulated by plants. Numerous genes in *Arabidopsis* and rice that respond to stress have been found by studies utilising microarray analysis.

Abiotic stress, which includes high temperature, salinity, and draught stress, also includes oxidative damage. On cells, it has a major side effect. Reactive oxygen species (ROSs) such as oxides, water, and hydroxides are produced as a result of oxidative stress, which damages plant macromolecules and membranes and impairs cell metabolism.

Due to the effects of drought, there is an imbalance between how much light is captured and how it is used. The photosynthesis of leaves is prevented by this imbalance. Reactive oxygen species (ROSs) are produced when photosynthetic machinery degrades due to too much light energy. ROS causes functional and structural macromolecules to get denaturation, DNA to become damaged, amino acids to become oxidised, proteins to become photosynthetic pigments, and lipids to become peroxidized. Then, in reaction to ROS, cells begin to respond in a variety of ways, including up-regulating antioxidant systems, including antioxidant enzymes, and accumulating suitable solutes, as well as increasing the expression of genes for antioxidant activities and producing stress proteins.

## 2.4 Salt Stress

Due to the current global population boom, producing 70 per cent more food crops is a significant task. In this instance, salinity is a significant stressor that prevents the demand for food crops from rising. More than 20% of all farmed land is affected by salt stress, and that percentage is growing daily.

By lowering crop yields and, eventually, crop production in salt-affected areas, soil salinity poses a danger to world agriculture. Crop development and yield are both impacted by salt stress in various ways. Osmotic stress and ion toxicity are the two main impacts that salt stress has on agricultural plants. Because there is more salt in the soil solution during salinity stress than there is in plant cells, the capacity of plants to absorb water and minerals like  $K^+$  and  $Ca^{2+}$  is constrained. These main consequences of salt stress lead to several downstream effects, such as decreased cytosolic metabolism, assimilate synthesis, and impaired cell growth and membrane function.

According to adaptive evolution, plants can be divided into two groups:

Halophytes: those plants that are resistant to the stress of salt

Glycophytes: These are the plants that succumbed to salt stress because they were unable to survive.

Salinity has an impact on photosynthesis as well because it reduces the availability of carbon dioxide, which limits plant diffusion and lowers the number of pigments used during photosynthesis. Salinity reduces a plant's overall capacity for photosynthetic activity by slowing the development of its leaves and restricting its ability to expand.

## 2.5 Heat

The rise in global temperatures has become a major worry since it affects plant development and production, particularly in agricultural produce plants. The proportion of seed germination, photosynthetic efficiency, and yield all decrease when plants are under heat stress. The function of tapetal cells is lost during the reproductive growth stage when there is heat stress, and another is dysplastic.

## 3. Crop plants and biotic stresses

In terms of their morphological, biochemical, and molecular processes, plants are subject to a wide range of biotic stressors and unfavourable environmental circumstances. Damage caused by living things including insects, nematodes, bacteria, fungi, nematodes, parasites, viruses, and other pests and parasite-related creatures is known as “biotic stressors” on plants. Plant diseases are brought on by these living things.

Pathogen attacks from fungi, bacteria, oomycetes, nematodes, and herbivores are examples of biotic stress. Globally, diseases brought on by these pathogens are a major source of crop loss. Sessile plants are unable to ignore these environmental stimuli since they are sessile. Successful completion of the lifetime requires expertise in handling these stressors. Hence, to counteract these challenges plants have created diverse methods for getting accustomed to such environments for survival. They detect the environmental stressor, get activated, and then produce the necessary biological reactions.

In accordance with Wang et al. (2013), biotic stress can result in yield losses of 28.2% for wheat, 37.4% for rice, 31.24% for maize, 40.34% for potatoes, 26.34% for soybeans, and 28.84% for cotton. The fungi factor is a biotic stress factor that more frequently than other variables causes illnesses in plants and crops. In addition to the fungal component, other microorganisms can harm seeds, induce root rot, and produce leaf spots and plant wilt. Stresses Plants are continually in contact with a wide range of possible microbial pathogens, including bacteria, nematodes, oomycetes, fungi, and herbivores. Plants have developed a range of defensive mechanisms, many of which are triggered by pathogen invasion. The microorganisms are exposed to the plant's plasma membrane after breaking through the cell wall, where they come into contact with extracellular surface receptors that identify pathogen-related molecular patterns (PAMPs). PAMP-triggered immunity (PTI), which normally stops infection before the pathogen takes root in the plant, is activated by the recognition of a microbe at the cell surface. Yet, by secreting specific proteins known as effectors into the cytoplasm of plant cells that affect resistance signalling or the appearance of resistance responses, pathogenic microorganisms have discovered a way to inhibit PTI.

Plants experience a variety of biotic stressors brought on by diverse living things such as nematodes, insects, fungi, viruses, and bacteria. These biotic stress factors impair agricultural yield by inflicting numerous illnesses, infections, and damage on crop plants. To combat biotic stressors, however, many mechanisms have been created through research methodologies. By researching the genetic mechanisms of the agents producing these stressors, biotic stresses in plants can be mitigated. By creating resilient agricultural plant kinds, genetically modified plants have been demonstrated to be a tremendous effort against biotic stressors in plants.

## 3.1 Bacteria

Global metabolic and transcriptomic alterations in leaf tissues were found in rice in response to the bacterial

blight pathogen *Xanthomonas oryzae* pv. *oryzae* (Sana et al.2010). The ROS scavenging mechanism dramatically increases the production of the transcription factor Ethylene Response Element Binding Protein (EREBP), whereas alcohol dehydrogenase gene expression is decreased. When the resistant cultivar becomes infected with bacteria, these substances cause the death of hypersensitive cells. Infection-induced upregulation of defence genes, glutathione-mediated detoxification, and flavonoid biosynthesis pathways stop the spread of the pathogen in the host tissues (Kottapalli et al. 2007).

Transcripts that use JA/ET to code for proteins that fight illness In cotton linked to *Bacillus subtilis*-induced tolerance, microarray analysis revealed differential expression of genes involved in signalling and osmotic control via proline synthesis (Medeiros et al. 2011). Flagellin, a well-characterized PAMP, is the main protein of bacterial flagella.

### 3.2 Fungi

Based on their lifestyles, plant pathogenic fungi have been classified into two classes: biotrophs and necrotrophs. Necrotrophs first destroy the host tissue before feeding on the dead tissues, whereas biotrophs consume the living host tissue. Yet, depending on their environment or the phases of their life cycles, many plant pathogenic fungi exhibit both necrotrophic and biotrophic behaviour. Hemi-biotrophs are the term for these pathogens.

Several fungi were formerly thought to be necrotrophs, but they have a biotrophic stage early in the infection process, making them essentially hemi-biotrophs. Generally speaking, JA and ET signalling are crucial for immunisation against necrotrophs, whereas SA signalling is implicated in resistance against biotrophic and hemibiotrophic infections (Pieterse et al. 2009).

#### 3.2.1 Biological fungi

Gene-for-gene mechanisms are crucial for resistance to biotrophs. According to Flor's gene-for-gene theory, there is a matching gene in the pathogen that imparts virulence for every gene in the plant that confers resistance. It causes SAR and SA-dependent signalling to become active. Overexpression of the NBS-LRR resistance gene *ADR1* confers resistance to the *Erysiphe cichoracearum* in *Arabidopsis* (Grant et al. 2003). Another illustration is the gene-for-gene resistance response in barley and *Blumeria graminis* (Schulze-Lefert and Vogel 2000). Many studies indicate that, in contrast to JA- and ET signalling, SA signalling plays a significant role in resistance.

As a result, during a biotrophic pathogen attack, both gene-for-gene resistance and SA-dependent defensive responses are successful. JA-dependent reactions cannot be produced, although they can be successfully created artificially if they are (Glazebrook. 2005). The development of a defensive response requires the significant down-regulation of genes associated with photosynthesis, according to transcriptome data from microarray research (Bilgin et al. 2010). To supply nitrogen for the generation of protective chemicals, nitrogen that was previously invested in photosynthetic proteins most notably Rubisco is reduced or even eliminated.

#### 3.2.2 Necrotrophic Fungi

The differential regulation of a large number of transcripts in response to pathogen infection is suggested by transcript profiling of distinct plant-pathogen systems. These transcripts included those related to cell wall

construction and function, ROS metabolism, and JA biosynthesis and signalling. Using a PCR-based suppression subtractive hybridization (SSH) method, early responsive genes of chickpeas infected with the blight fungus *Ascochyta rabiei* were isolated, and around 250 distinct genes were discovered.

These genes fit into eleven main categories, including genes for cellular metabolism, stress, signalling, and gene control (Jaiswal et al. 2012). AU2 uses chitin, a significant component of fungal cell walls, as a PAMP. As a result, chitosan (the deacetylated form of chitin) is crucial for triggering pathogen defence mechanisms in a variety of plant species. Chitosan has an inductive effect on a number of genes involved in defensive responses and camalexin production, according to results from Gene Chip microarrays and quantitative RT-PCR of *Botrytis cinerea*-infected *Arabidopsis* leaves (Povero et al. 2011).

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#### 4. Combination of Different Stress

Climate change and its effects on plants result in various stress combinations. Based on the number of interrelated components, stresses are divided into three categories: singular, numerous, and combined stressors

**Single Stress:** There is just one stress factor that has an impact on plant growth and development.

**Multiple Individual Stress:** the occurrence of two or more stress factors at distinct times that do not cross over.

**Combined Stress:** the occurrence of many stresses at once that overlap with one another.

Combined abiotic stress, for instance, results from the co-occurrence of heat and drought in the summer. The mix of stress is most obvious.

While coupled biotic stress refers to the simultaneous onslaught of bacterial and fungal pathogens.

Environmental influences on plant illnesses cause disease triangles, which is why plant pathologists pay close attention to this issue. The kind, degree, and length of the stressors all have a role in how they affect plants and how they interact with one another. When there are abiotic-abiotic and abiotic-biotic stress interactions, the interaction does not just happen on the plant interface; it also happens there and elsewhere.

#### 5. Polyamine: plant response to stresses

Due to their stationary nature, plants must constantly adapt to changes in their environment through appropriate physiologic, developmental, and biochemical modifications. Abiotic stress is the primary cause of crop loss since it causes more than just a decline in crop plants. Plants are equipped with a vast array of defence mechanisms to combat stressors. Polyamines are one of the most successful types of suitable solutes for handling extremely stressful environmental conditions. Low molecular weight aliphatic nitrogen molecules that

are positively charged at physiological pH are known as polyamines.

Several genes encoding polyamine biosynthetic enzymes have been isolated from a range of plant species as a result of molecular studies on plant polyamines. The biological activities of polyamines in plants have been better understood recently because of molecular and genomic investigations using mutants and transgenic plants with no or altered activity of the enzymes involved in polyamine production.

### **5.1 Polyamine and plant response to abiotic stresses**

Cellular polyamine alterations brought on by stress offer hints about their potential involvement in stress, but they do not show that they play a function in reducing stress. Exogenous polyamines can be administered to raise endogenous polyamine levels. This has been done before or during stressful situations.

Exogenous administration of polyamines might maintain the integrity of plant cell membranes, reduce growth inhibition brought on by stress, modulate the expression of osmotically responsive genes, and boost antioxidant enzyme activities. Another strategy is to address the endogenous polyamine that causes stress sensitivity by using biosynthesis inhibitors to diminish it. However, the simultaneous introduction of exogenous polyamine reverses this effect. The use of mutants lacking in polyamine production is another genetic strategy for analyzing the biological activities of polyamine metabolism in stress response.

### **5.2 Polyamine and plant response to biotic stresses**

It has long been recognized that plant cells' polyamine metabolism can become distorted in response to subtle alterations brought on by interactions between mycorrhizal fungi, viral infections, and plants. Given those polyamines are found in both plants and pathogenic fungi, it is difficult to determine how they contribute to polyamine build-up in infected organs. The most exciting potential for development is the ability to prevent fungus-related plant diseases by specifically inhibiting polyamine production.

## **6. Role of Potassium and Silicon in the Reduction of Stress:**

More infections can occur in plants with a potassium deficit than with a good or adequate supply. For instance, the enormous borer infestation on rice is caused by a lack of potassium supply, but it goes away when the potassium content rises. Potassium can have a positive influence in some circumstances, but it can also have negative or no effects. Proteins, starches, and cellulose are examples of high molecular weight substances found in plants with adequate potassium levels.

### **Conclusion**

The most important elements that have an impact on a plant's growth and development are stresses, either biotic or abiotic. This review research demonstrates how salt and drought stressors alter plant activity because the drought condition's oxidative stress disrupts photosynthesis by absorbing more light. The salt stress prevents water from getting to all areas of plants, which prevents vital nutrients from getting to plant components. Some scientists who studied the physiology of plants claimed that the plants had a stress response mechanism as well. The two important nutrients that may be employed to lessen plant stress are potassium and silicon. Because pressures and the capacity to manage them differ from species to species of plants, it is important to understand the effects of biotic and abiotic stresses before dealing with them.

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