REVIEW ARTICLE

# Effect of Abiotic Stress on Plant Growth and Development, Physiological and Breeding Strategies to Overcome Stress Condition

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## Abstract

Abiotic stress is a significant factor in "climate change," a complex phenomena with several unpredictable negative repercussions on the environment. Abiotic stress alters the continuity between soil and plant atmosphere, reducing the yield of several essential crops. Abiotic stress now poses a considerable obstacle to plant development, and it will certainly worsen as desertification spreads across a larger section of the planet's land area. The agriculture sector is significantly impacted by the weather and environment. Traditional farming methods and the food production required to sustain the nation's growing population might be threatened by climate change. Improved cultivars created via breeding for a greater harvest index and disease tolerance were readily embraced during this period of relatively consistent weather. Extreme climatic variability is projected due to climate change in this century. In many nations that produce crops, the agricultural climate will likely be warmer with more unpredictable rainfall, and stress spikes will be more severe. To maintain a growing population, agricultural productivity must be increased under more unfavourable environmental conditions. Using GPS locators and climatic data from across the world, it is now feasible to comprehensively examine the genetic diversity in ancient local landraces to characterise the natural selection for local adaptation and to identify potential germplasm for tolerances to high stresses . With the use of candidate gene techniques and next generation sequencing, the physiological and biochemical components of these manifestations may be genomically examined. Wild relatives of crops possess practically untapped genetic diversity for abiotic and biotic stress tolerances and may greatly improve the domesticated gene pools presently available as a survival omics strategy to assist crops endure the expected extremes of climate change. It is an issue to increase agricultural productivity in the face of climate change. In order to achieve this, it is necessary to combine a number of disciplines, including eco-geographical assessments of genetic resources, modern advances in genomics, agronomy, and farm management, all of which are backed by knowledge of how genotype-environment interaction affects crop climate adaptability.

**Keywords:** Abiotic stress, Crop development, Physiological strategies, Stress breeding.

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## Introduction

Any environmental condition that could be detrimental to living things is referred to as stress. There are two basic categories of plant stress are recognised, named abiotic and biotic stress. Abiotic stress is brought on by physical, chemical, and anthropogenic factors, including pesticides, air pollutants, ozone and photochemical smog, formation of highly reactive species, acid rain, heavy metal load, global climate change, and others. Physical and chemical factors that contribute to abiotic stress include high irradiance, high and low temperatures, water scarcity, nutrient deficiency, and others. Herbivores' defoliation, the spread of diseases (viruses, bacteria), and fungi like mycorrhizas are all examples of biotic stress. Since plants are fixed organisms and cannot escape stressors, their problem with stress is more difficult than that of animals and people. They have therefore developed unique strategies to deal with the stress cause or factors. To prevent water stress, plants can create a variety of protective anatomical structures, such as thick cuticles on their leaves. When a stressor acts on the plasma membrane or the symplast, the active plant response (stress tolerance) mechanism begins to work. Then, several plant stress reactions start.

Today, climate change is a widely accepted fact. Food security for the 21st century will be the main challenge for humankind in the years to come, given the declining production efficiency of agro-ecosystems due to depleting natural resource bases, serious effects of climate change on diversity and abundance of insect-pests, and the extent of crop losses. India has more challenges from the effects of impending climate change because it is a tropical nation. Pest damage varies in India's many agro-climatic areas due mostly to the diverse effects of abiotic elements including temperature, humidity, and rainfall. This involves a worsening of yield losses as a result of anticipated

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changes in crop diversity and an increase in insect pests as a result of climatic change. For rural farmers whose livelihoods are directly dependent on agriculture and other climate-sensitive industries, it will have major environmental and socioeconomic effects. Due to its complexity, uncertainty, unpredictability, and varied effects throughout time and place, dealing with climate change is a very arduous task. A crucial and difficult topic in agricultural study is how crop plants, insect pests, and their natural enemies respond to abiotic stress. Planning and developing adaptation and mitigation plans for upcoming pest management programmes must carefully consider how the impacts of climate change on crop production, as mediated by changes in populations of major insect pests, would affect crop productivity.

Screening agricultural germplasm for susceptibility to a variety of biotic and abiotic stressors requires coordinated efforts. Despite the use of improved crop types and agrichemicals for pest and pathogen control, U.S. farmers already suffer large output losses due to pests. The relationships between crops, pests, and pathogens will probably get much more complex as the climate changes and become more changeable, necessitating further research. Continued research in this area will give plant breeders fresh germplasm to use in developing adaptable cultivars that are beneficial to farmers.

The development of new crops will probably be crucial to sustaining and boosting agricultural output. Our oldest crops, such maize, wheat, potatoes, and sorghum, were only domesticated between 5,000 and 12,000 years ago, whilst blueberries and wild rice were domesticated more recently. Crop development and domestication have allowed us to alter their nutritional value and productivity. In order to create perpetual grain crops, some scientists are currently breeding their annual, domesticated equivalents with the perennial relatives of crops like maize, millet, rice, sorghum, sunflower, and wheat. The domestication and breeding of $C_4$ grasses, such switch-grass and miscanthus, has also been promoted by a growing interest in bioenergy. A long-term option that takes many years of work before formal testing can be done is domestication and breeding of new crops.

Large-scale field-level research in conjunction with access to global genetic resources and technologies provided by the current crop breeders toolkit will help identify previously unidentified genetic origins and areas on DNA related to abiotic stress tolerance. Researchers in both the applied and basic sciences will be able to create long-term plans that maximise the supply of new, improved cultivars after the information gap relating to abiotic stress tolerance has been closed. The complete range of crop development scientists, including breeders, physiologists, and geneticists, must therefore be involved in field-based research programmes and related breeding activities. These programmes and efforts must also be supported, integrated, and expanded. To boost agricultural tolerance to climate shocks and preserve productivity and output, new management strategies are being developed. Site-specific cropping systems and management approaches are required to match yield potential with inputs, soil fertility, and the range of climate variability in each area because agriculture will not be equally vulnerable to climate change in all regions. Naturally, growers have had to alter cropping patterns in the past because of either slow climatic change or the expansion of crops into new geographic areas. This process of adaptation necessitated a great deal of trial and error, which occasionally disrupted food supplies as well as agricultural economies. However, information from research and development in the public and private sectors enables producers to adjust more quickly. Simulation modelling and remote sensing are research and management techniques that help hasten cropping system adaptability. The negative economic effects that could otherwise be associated with ad hoc, untested modifications in cropping systems will likely be reduced by these technologies, in combination with faster and better communication of location-specific suggestions. The impact of insect pest scenarios related to climate change and how to create an appropriate integrated management programme will also be covered at this conference.

The discovery and introduction of novel stress genes from crop wild relatives, as well as the understanding of the underlying mechanisms governing stress tolerances in domestic germplasm, will be made possible by new molecular tools like NGS. For the majority of crops, domestic germplasm has not been eco-geographically assessed to identify landrace collection sites likely to have undergone natural selection for abiotic stress tolerances. The same is true for the wild gene pools, which have not been extensively explored for novel genes for stress tolerances. The domesticated gene pools of crops and the largely unexplored germplasm resources of associated wild gene pools could both offer significant potential for selection for adaptability to high abiotic stresses for use in survival omics to support crop adaptation to climate change.

The best definition of abiotic stress is any environmental influence on an organism's capacity to perform at its best. Protein dysfunction is typically brought on by abiotic stimuli such as heat, cold, freezing, drought, salt, flooding, or oxidising chemicals. Plants must deal with a wide range of intricate interactions involving many different environmental elements. External factors such as stress have a negative impact on productivity, growth, and/or development. Crop plants experience biotic and abiotic environmental stressors. The biggest factor affecting crop productivity globally is abiotic stress, which lowers average yields for the main crop plants. These abiotic pressures interact to form osmotic stress, which disturbs ion distribution and cell homeostasis. It mostly results from changes in the gene expression patterns of a particular group, which causes reactions that influence growth rates and productivity. They have developed particular systems that let them adapt to and endure difficult situations during the course of evolution. When plants are exposed to biotic and abiotic stress, their metabolism is disrupted, indicating physiological costs and eventually lowering fitness and productivity. One of the most crucial aspects is abiotic stress, which has a significant impact on development and, as a result, causes significant losses in the field. In most plant species, the ensuing growth decreases can reach >50%. Additionally, biotic stress is a problem that puts additional pressure on plants and exacerbates damage from pathogen or herbivore attacks.

## Effects of Different Stresses on Plants

### *Drought*

The single greatest threat to the world's food security in the face of scarce water resources is drought. It caused the past big famines. Numerous factors, including rainfall distribution and frequency, evaporative demands, and soil moisture storage capacity, could influence how severe a drought is. Excessive rainfall over a long period of time causes drought. In contrast to severe drought conditions, which cause a constant drop in the amount of soil water accessible to plants and lead to early plant death, intermittent drought conditions have a negative impact on plant growth and development but are often not lethal to plants. Due to the ability to survive longer and maintain normal function in intermittent drought circumstances, the yields are much lower than those observed under hydrated conditions. Drought tolerance enables plants to produce and maintain high yields despite drought conditions as a result of the plant's efforts to survive stress. If the plant's tolerance to drought is confined to that one generation, it is said to have become adapted to it. If a plant genotype persists over generations, it is said to be suited to drought conditions. As a first reaction to drought stress, plants halt growing. The plant's metabolic needs are lowered during a drought, and metabolites are mobilised to produce the protective compounds required for osmotic adjustment.

### *Temperature*

Scientists studying plants are increasingly concerned about temperature stress as a result of global climate change. Given how difficult it is to foresee precisely how climate change will affect agriculture (Shah *et al.,* 2011). Because every plant species has a specific range of ideal temperatures for these processes, temperature stress has a significant negative impact on plant development and metabolism. As a result of global climate change, high temperature (HT) is currently recognised as one of the major abiotic pressures for restricting agricultural output, making high temperature an essential factor for plant growth and productivity. A temperature increase that lasts long enough to permanently impair a plant's capacity for growth and development is referred to as high temperature stress. The growth and development of plants involves numerous biochemical processes, each of which is somewhat temperature sensitive. As a result, how plants respond to high temperatures depends on the level of temperature increase, the duration of the increase, and the type of plant. Around the world, large-scale agricultural losses are attributed to heat, sometimes in conjunction with other environmental factors like drought (R. Mittler, 2006). Low temperature (LT), commonly known as cold stress, is a key environmental factor that frequently affects plant development and agricultural productivity and results in severe crop losses. Chilling stress happens when temperatures are cold enough to inflict damage without creating ice crystals, as opposed to freezing stress, which results in the creation of ice crystals inside plant tissues. Plants have varying degrees of resistance to freezing (0°C) and chilling (0–15°C) temperatures. Both chilling and freezing stressors are referred to as low temperature or cold stress. From suffocation and heaving to freezing and chilling injuries, cold stress can be harmful. In general, it is believed that plants from zones with temperate climates can withstand cold temperatures to varied degrees. Cold acclimation is the process of exposing animals to cold temperatures that are below freezing in order to increase their tolerance to freezing. Plants with tropical and subtropical ancestry, however, typically lack this process of cold adaptation and are more susceptible to chilling stress. Numerous aspects of agricultural growth, like as yield, cell division, photosynthesis, survival, and water transport, may be impacted by low temperatures.

### *Heat*

A temperature increase that lasts long enough to irreversibly impair plant growth and development is usually referred to as heat stress. Generally speaking, a temperature increase of only a few degrees over ambient is referred to as heat shock or heat stress. The specific threshold temperature for specific stage of growth for crops like Wheat, Corn, Pearl millet, Tomato, Brassica, Cool season pulses, Groundnut, Cowpea, Rice, suggested by Stone *et al*. (1994), Thompson *et al*. (1986) Rehman *et al.* (2004), Ashraf *et al.* (2004) Camejo *et al.* (2005) Morrison *et al.* (2002) Siddique *et al.* (1999) Vara Prasad *et al.* (2000) Patel *et al.* (1990) Morita *et al.* (2004) respectively described in table 1. However, the relationship between temperature intensity (expressed in degrees), duration, and rate of rise is complex. How frequently it occurs in specific climate zones depends on how often and how long high temperatures persist through the day and/or night. The broad meaning of heat tolerance is the ability of a plant to survive and produce an adequate yield under high temperatures. Others disagree, arguing that plants are not affected by day

**Table 1:** Threshold high temperatures for some crop plants

| *Crop plants* | *Threshold temperature (°C)* | *Growth stage* |
|---|---|---|
| Wheat | 26 | Post-anthesis |
| Corn | 38 | Grain filling |
| Cotton | 45 | Reproductive |
| Pearl millet | 35 | Seedling |
| Tomato | 30 | Emergence |
| Brassica | 29 | Flowering |
| Cool season pulses | 25 | Flowering |
| Groundnut | 34 | Pollen production |
| Cowpea | 41 | Flowering |
| Rice | 34 | Grain yield |

and night temperatures in isolation and that the diurnal mean temperature, rather than the day temperature, is a better indicator of how plants would react to high temperatures. Others have claimed that night time temperatures are not a significant limiting factor, contrary to the belief of certain studies. Crop productivity and plant development have suffered significantly as a result of widespread concern about extreme temperatures. Agricultural plants will be more susceptible in the near future due to greater extremes in temperature. Thus, much attention must be paid to the creation of heat-tolerant breeds and the process by which plants, especially crops, respond to heat stress. When plants are stressed by heat, their photosynthetic capacity, yield, and percentage of seed germination all decline. When there is heat stress during the reproductive development stage, the functions of the tapetal cells are lost, and the anther develops dysplastically. The inability of pollen grains to expand during flowering is hampered by higher temperatures, which results in inadequate pollen release and another indehiscence. Plants have evolved a range of chemical and physiological responses to deal with heat stress.

### *Cold*

Cold stress is one of the main abiotic variables that lowers the post-harvest quality and longevity of agricultural crops. Since they are fixed, plants must adapt their metabolism to withstand such stress. Most temperate plants undergo a process known as cold acclimation whereby they acquire chilling and freezing resistance following exposure to sub-lethal cold stress. Many important crops for agriculture, however, are unable to adapt to the cold. Cold stress has an effect on almost all aspects of plant cellular function. The cold stress signal is transmitted using a number of signal transduction pathway components. Important components include $Ca^{2+}$, ROS, protein kinase, protein phosphatase, and lipid signaling cascades. ABA also controls how the body responds to cold stress. Depending on how their genes are expressed, different plant species react to cold stress in different ways, which changes their physiology, metabolism, and growth. A few examples of modifications that migh+t be related to the cold response mechanism include the expression of kinases involved in signal transduction, the accumulation of osmolytes, and changes in the lipid content of membranes.

### *Salt*

Global agriculture is seriously threatened by the problem of soil salinity since it reduces crop production in affected regions. Salinity stress has varying effects on the growth and yield of crops. Osmotic stress and ionic toxicity are the two main effects of salt on plants. Plant cells frequently have higher osmotic pressure than soil solution does. This higher osmotic pressure is used by plant root cells to extract water and vital minerals from the soil solution. Under salt stress, the soil solution contains more salt, which results in a higher osmotic pressure there than in plant cells, which restricts the ability of plants to absorb water and minerals like K+ and $Ca^{2+}$. Na+ and Cl- ions, meanwhile, can penetrate cells and directly harm cell membranes as well as cytosolic metabolic processes. These primary impacts of salt stress have a number of secondary effects, including diminished assimilate synthesis, cell development, membrane function, cytosolic metabolism, and ROS production. During salt stress, two crucial defensive mechanisms against ionic stress are decreased uptake of toxic ions like Na+ and Cl- into the cytosol and sequestration of these toxic ions into the vacuole or the apoplast.

### *Aluminum (Al) Toxicity*

Al is the most widespread metal on the surface of the Earth and the third most frequent element. Most commonly, it takes the form of stable Al silicate complexes, which are harmless to plants (Ma and Ryan 2010). Al, however, dissolves and changes into $Al^{3+}$, also known as Aluminum trichloride hexahydrate ($AlCl_3H_{12}O_6$), in acidic situations. Even in micromolar quantities, this kind of aluminium poisons plants (Kochian *et al.,* 2005). Since 30 percent of the earth's surface is made up of acidic soils and 50 percent of cultivable land is potentially acidic, al toxicity is one of the biggest obstacles to agricultural output (Pieros *et al.,* 2005). For instance, more than 500 million hectares of Brazil's land is comprised of acid soils, particularly those that are vegetated with savannah (Cerrado biome) species (Vitorello *et al.,* 2005). The soils of these areas have low $Ca^{2+}$, $Mg^{2+}$, and P concentrations, high Al and manganese concentrations, and an average pH of 4.6. A noticeable drop in agricultural productivity may occur if these problems are not fixed. Although adding limestone ($CaCO_3$ or $MgCO_3$) to the soil is an effective way to lower soil acidity, it is typically not a financially sound option for farmers with limited resources. Additionally, limestone only corrects the top layers and is unsuccessful at resolving underground acidity due to the low mobility of the limestone soluble components. Duetoits huge load/atomic radius, $Al^{3+}$ may create exceptionally stable electrostatic bonds with negatively charged compounds like phosphates and carboxylic groups (Berthon, 1996). $Al^{3+}$ toxicity consequently has an impact on a number of cellular structures, such as the cell wall, plasma membrane, cytoskeleton, and nucleus.

The main site of Al accumulation and toxicity is the root meristem, more specifically the distal part of the transition zone. Exposure immediately inhibits root growth, indicating that Al quickly stops cell elongation and expansion before inhibiting cell division (Kochian *et al.,* 2005). Al causes a number of symptoms that are manifested in the morphology and physiology of the roots when it is exposed to the root system for an extended period of time. Reductions in biomass, the number and length of roots—which are frequently accompanied by an increase in the mean radius and root volume—as well as the uptake of water and mineral nutrients—which result in significant losses in root elongation and eventually cause the plant to die—are some examples of these symptoms.

Although the majority of the aluminium in the root system is found in the apoplast (Xue *et al.,* 2008), a sizable portion of this cation may penetrate fast and interact with molecules and symplast subcellular structures, like the nuclei of cells in the meristematic regions of the root apex. Due to Al's affinity for phosphate groups, it binds to DNA and modifies its chromatin structure and template activity (Silva *et al.,* 2000; Barceló and Poschenriede, 2002; Kochian *et al.,* 2005). Al also modifies the cell-division process.

### *Toxin*

As a result of agriculture's increasing reliance on chemical fertilisers, sewage wastewater irrigation, and rapid urbanisation, toxic metals have been introduced to agricultural soils, having detrimental effects on the soil-plant environment system. Due to its prolonged solubility in soil, cadmium (Cd), the main metal pollutant, is recognised as a significant environmental risk for the agricultural system.

Cadmium (Cd)-polluted soils are becoming a growing concern around the world. Phytoextraction of Cd pollutants by high biomass plants, such as sweet sorghum, is regarded as an eco-friendly, economically viable, and long-term solution to this issue. A macronutrient called nitrogen (N) is necessary for plant growth, development, and stress resistance. However, it is still unclear how nitrate, a significant form of N, affects Cd uptake, translocation, and accumulation in sweet sorghum (Bai *et al*., 2020).

*Light Stress (High and Excess)*

Light is an essential factor in regulating a plant's growth, development, and reaction to stress, but it is also the source of the reactive oxygen species that lead to PCD. Numerous Arabidopsis thaliana and Zea mays lesion mimic mutants show a light-dependent cell death phenotype. Light sensing and signalling pathways are highly developed in plant cells, and both are essential for plant defence. Photoreceptors in plant cells can be divided into three categories: phytochromes (PHY), cryptochromes (CRY), and phototropin (PHOT). They locate themselves in the plasma membrane, cytoplasm, or nucleus. The light-quantity sensing mechanism is housed in chloroplasts, whereas photoreceptors primarily perform a regulatory role by alerting us to changes in light quality that take place throughout the day and over the seasons. The photosynthetic machinery can absorb photons thanks to the chlorophylls found in the light-harvesting complexes (LHCs) of photosystem II (PSII) and photosystem I (PSI) in the thylakoid membrane of chloroplasts. PSII has a maximum absorption at the orange/red light spectrum (650-680 nm), in contrast to PSI, which is concentrated in chlorophyll a molecules and absorbs in the far red (700nm). The reaction centres of PSII and PSI are linked by an electron carrier chain. A spectral imbalance of light may excite two photosystems differently, leading to either an increase or decrease in the production of ROS (Partelli *et al.,* 2009). The distribution of light-absorbing antenna complexes between PSII and PSI is therefore under control and can be altered through either long-term acclimatisation processes or short-term adaptation (such as state transition). During a state change, the main LHCII protein is reversibly phosphorylated and switches between PSII and PSI. This process requires thylakoid-associated kinase 1 (TAK1), which oversees phosphorylating thylakoid proteins. Long-term responses, on the other hand, alter the structure of the photosynthetic complexes by altering the PSI/PSII ratio or the sizes of the LHCII and PSII. Redox signals from the photosynthetic electron transport (PET) chain, especially from one of the electron carriers, plastoquinone, indicate the perception of imbalanced photosystem activation (PQ).

*UV Radiation Stress*

UV radiation is damaging to plants that are exposed to sunshine because it compromises the strength of their genomes and prevents development and output. In addition to nucleic acids, these effects are the result of damage to a number of cell components, including proteins, membrane lipids, and nucleic acids. After exposure to UV radiation, very mutagenic cross-linked forms of DNA can form. To lessen the effects of UV radiation, plants gather UV-absorbing secondary metabolites, perform UV-induced pyrimidine dimer monomerization (DNA repair), and neutralise generated ROS. UV radiation comes in three different wavelengths: UV-C (below 280 nm), UV-B (280–320 nm), and UV-A. (320-390). The cell damage induced by UV-C is equivalent to that caused by UV-B radiation, which reaches the Earth's surface, despite the fact that UV-C is well filtered by the stratosphere and hence is not physiologically relevant to plants (Sharma *et al.,* 2012). UV-C radiation has been widely used to study DNA damage and repair mechanisms in response to UV stress. Understanding how plants respond to abiotic stress has come a long way.

The ability of the plant to respond to stress is constrained by inherent physical, morphological, and molecular limitations. Thanks to systems biology methods, we now have a more complete understanding of the chemical reactions. Plants have evolved a range of strategies to adapt to various environmental conditions. The most basic strategy is the production of highly plastic plant tissues. It has been demonstrated that programmed cell death significantly contributes to this adaptability to challenging situations. Plants respond in a diverse and dynamic way to abiotic stress. To fully understand how plants respond to abiotic stress, further in-depth mapping of these responses at the organ, tissue, and cellular level is necessary. Proteomics and enzyme activity levels must be considered in these network analyses. Models must be created and connected to phenotypic traits. The process of genetically engineering crop plants will be expedited by the relationship between crucial regulatory hubs and phenotypic traits. Current developments include the identification and validation of multiple significant genes that improved the stress tolerance of crops in the field. Systems biology and plant sciences are expected to advance at an accelerated rate in the near future.

## Abiotic Stress Management Solutions using the Approaches Listed below

*Breeding*

Due to the quick and unexpected effects of climate change, it is particularly difficult for agricultural scientists and farmers to adjust to pressures from biotic and abiotic factors. Drought and soil salinity are the primary abiotic factors that significantly affect crop productivity and food safety. They show detrimental consequences on the socioeconomic frameworks of many developing countries. Salinity of the soil, a lack of water, and poor irrigation water quality are issues that are getting worse. An estimated 20% of all cultivated land and up to 50% of irrigated land are affected by salt, significantly reducing crop yields below their genetic potential. In order to breed commercial cultivars that combine drought and temperature resistance, yield potential, and yield stability, which is a requirement for stable productivity, it will be necessary to introgress resistance genes from landraces and wild relatives to commercial cultivars and evaluate them in a matrix of stress environments. It has never been easy for plant breeders to genetically increase production when faced with abiotic stresses.

Biotechnology has a wide range of possible uses in the fight against diseases and pests, which can provide plant breeders with information and tools they can use. However, the exceedingly intricate relationships between pests, diseases, vectors, host plants, and the environment need the use of integrated management strategies. Unquestionably, an integrated management plan incorporates biotechnology along with resistant species, biocontrol, appropriate cultural practises, and responsible pesticide use. Host plant resistance is an essential strategy for managing diseases that impact the major food crops, such as wheat, rice, potato, cassava, chickpea, peanuts, and cowpea, in less developed countries. Farmers with limited resources are glad to utilise resistant cultivars since they are less expensive and more environmentally friendly.

*Genomics*

Gene by gene analysis has historically been used to understand its function. In functional genomics, large-scale gene function research utilising high throughput technologies is combined with interactions of gene products at the cellular and organismal level. Gene tagging offers greater potential for functional analysis on a larger scale than gene identification, which has become viable for large-scale research due to the availability of markers (Lukowitz *et al.,* 2000). To fully understand the complex processes involved in stress signalling and plant adaptation, a functional investigation of the numerous genes implicated in stress response would also be necessary.

*Proteomics*

By suffering significant changes in gene expression, which change the transcriptome, proteome, and metabolome makeup of the plant, plants can adapt to biotic or abiotic stress conditions. Since proteins are directly engaged in the plant stress response, proteomics studies can significantly aid in the clarification of any potential relationships between protein abundance and plant stress tolerance. Numerous studies have already shown that changes in gene expression at the transcript level frequently do not match with changes at the protein level (Bogeat *et al.,* 2007). Because proteins, not transcripts, directly affect how plants react to stress, it is essential to analyse how the plant proteome has changed. Proteomics research can therefore aid in the discovery of potential protein markers whose fluctuations in abundance are quantitatively correlated with changes in certain physiological parameters associated with stress tolerance (Jewell *et al.,* 2010).

*Metabolomics*

If it were possible to monitor the complete spectrum of metabolites, many physiological plant processes might be better understood. The goal of metabolicomics is to provide a comprehensive picture of an organism's functioning state through systematic research. In addition to its use as a breeding or selection tool, metabolomics techniques have been utilised to evaluate stress responses in barley (Widodo *et al.,* 2009), citrus (Djoukeng *et al.,* 2008), and Arabido psisthaliana (Fukushima *et al.,* 2011). There are a number of metabolites that are related to plant stress responses.

### Crop Genetic Improvement

The basis for using modern molecular biology techniques to elucidate the regulatory mechanisms of stress tolerance and develop stress-tolerant plants is the expression of certain genes associated to stress. Environmental stress resistance has so far been genetically improved by altering a single or a limited number of genes that are involved in signaling/regulatory pathways (Jewell *et al.,* 2010,) or that encode enzymes implicated in these pathways. The plant hormone abscisic acid (ABA) affects how plants adapt to environmental difficulties including drought, salt, and cold through a range of physiological and developmental pathways (Arbona *et al.,* 2010). As a result of significant research on the ABA biosynthetic pathway, many important enzymes involved in ABA production have been used in transgenic plants to boost their ability to survive abiotic stress (Dong *et al.,* 2011). Transgenic plants that overexpressed the genes responsible for producing ABA showed increased resilience to drought and salinity stress (Mahajan *et al.,* 2005).

### Elicitors for Management of Abiotic and Biotic Stresses

Plant environmental stress, which includes drought conditions, high water or soil salinity, or excessively cold or hot temperatures, is the most serious financial problem for agricultural output globally. An increase in ROS levels, which results in oxidative damage in plants under abiotic stress, is common. Therefore, plant tolerance to abiotic stressors necessitates adaptive modifications in morphological, physiological, and biochemical processes in order to reduce stress-induced oxidative harm. Reactive oxygen species (ROS), which are both detrimental byproducts that accumulate in cells and essential signalling molecules, are produced by plants in response to stress.

### Bio-elicitors for Management of Abiotic and Biotic Stresses in Crop

Because they are being grown in recently restored sandy soils, field crops have recently attracted a lot of interest. Farmers must use high rates of chemical fertilisers to maintain a satisfactory yield because, generally speaking, the production of the majority of crops is not economically feasible under such unfavourable circumstances and in soil that is characterised by low fertility, low organic matter content, and high leaching rate. Its yield improvements have been attributed to a variety of factors. It is acknowledged that the interactions that surround soil microbial communities have an effect on plant health and soil quality. Beneficial free-living bacteria called plant growth promoting rhizobacteria (PGPR) are found in the rhizosphere of plants and aid in both direct and indirect plant growth.

## Physiological Mechanisms For Dealing With Some Abiotic Stress

### Physiological Techniques to Boost Productivity in Conditions of Water Scarcity

The following equation can be used to describe a crop's yield (Y) under water stress situations (Passioura 1977): E = transpired water, WUE = water usage efficiency, and HI = harvest index (i.e., correlation between the biomass of the commercially valuable organ and the overall plant biomass). Y = E + WUE + HI. Breeding programmes with considerable productivity advantages were accomplished by increasing the harvest index. For the majority of farmed annual species, HI is virtually at its maximum value, hence any future increases in crop yields must necessarily be obtained through larger biomass accumulation. Therefore, increasing the plant's capacity to produce more dry matter per unit of area is the main objective. In breeding programmes for drought conditions, this increased biomass output must be combined with less water use or improved water use efficiency (Tambussi *et al.,* 2007).

To quickly and easily estimate WUE, a small amount of dry biomass can be burned in a mass spectrometer to produce $12CO_2$ and $13CO_2$. The resulting data can be used to determine the carbon isotopic discrimination (D13C) once the WUE has been integrated across time (Farquhar *et al.,* 1989). The substantial inverse relationship between D13C and WUE has been empirically demonstrated in several species (Condon *et al.,* 2002; Monneveux *et al.,* 2007). Because of this, the measure D13C has been commonly used in breeding programmes to select genotypes with higher production in settings susceptible to drought (Ehleringer *et al.,* 1993).

Lowering stomatal conductance, increasing photosynthetic capacity, or even combining the two could lead to a higher WUE. A decrease in stomatal conductance is unfavourable in breeding programmes aimed at increasing productivity since it leads to reduced $CO_2$ intake, lower photosynthetic rates, and consequently less biomass accumulation. The primary challenge is to increase photosynthetic capacity because stomatal conductance is limited (Tambussi *et al.,* 2007). There are several ways to increase cultivars' capacity for photosynthetic growth. One of these techniques uses mechanisms like those seen in species that use C4 metabolism, or $CO_2$ concentrators. Making the enzyme ribulose- 1,5-bisphosphate carboxylase/oxygenase (Rubisco) more $CO_2$ selective would be another strategy that would reduce the losses caused by photorespiration in $C_3$ plants (Parry *et al.,* 2005). An increase in mesophyll conductance is directly related to an increase in photosynthetic rates without the need for higher stomatal conductance. Increasing the specific leaf mass is one method to do so because it results in more photosynthetic apparatus per unit area of leaf.

### Physiological Mechanisms to Increase Heat Tolerance

To increase crop heat tolerance, crop breeding has been done utilising biotechnological methods, such as altering membrane composition (Murakami *et al.,* 2000) or developing cultivars with constitutive expression or overexpression of HSPs (Wang and Luthe, 2003). According to studies, plant heat tolerance appears to be a multigenic characteristic. Despite the intricacy of the genetic makeup and difficulties encountered, some heat-tolerant strains and hybrid cultivars of crops like tomatoes have been developed (Scott *et al.,* 1995).

Dwarfism is gradually influenced by heat tolerance genes as the principal stalk internodes in beans slender (Ismail and Hall, 1998). Similar to this, cotton varieties that are heat-tolerant dramatically reduce in size. These changes reduce planting density and could lower leaf temperatures. High planting densities may change how the canopy is designed, with little affects on water use and potential benefits for lowering heat stressors.

### Physiological Mechanisms of Al Tolerance

Al tolerance or internal detoxification can be achieved by complexing Al with various organic molecules in the symplast and/or by compartmentalising Al or its complexes in vacuoles (Hartwig *et al.,* 2007). Al would, in this case, have minimal to no impact on plant metabolism, allowing for growth and development even after Al was injected into the symplast. This tolerance mechanism is primarily present in endemic species that are found in areas with acidic soils, where the capacity to deal with Al toxicity is necessary for survival (Ryan and Delhaize, 2010). The few plants that may collect significant levels of Al in their shoots without experiencing its toxicity (Jansen *et al.,* 2002). Al immobilisation in the cell wall, Al selective permeability in the plasma membrane, pH increases in the rhizosphere or the root apoplast, and exudation of organic acids (such as citrate, oxalate, and malate) and phenolic compounds by the roots are the main tolerance mechanisms that encourage Al exclusion or prevent its absorption by the roots. Perhaps the main mechanism of Al tolerance is the production and exudation of organic acids. According to Kochian *et al.* (2004), the following evidence is in favour of the statement:

- In many species, there is a direct link between Al tolerance and the exudation of organic acids.
- The toxicity of Al is decreased by the addition of organic acids to the nutritive media.
- The roots do not appreciably absorb di- and tri-carboxylic complexes of Al/organic acids because they cannot pass the membrane.
- The principal site of Al toxicity is at the root apex, where organic acids are exuded after being activated by Al.
- In general, $Al^{3+}$ particularly causes the exudation process to activate; additionally, Al activates anionic channels in the plasma membrane that help with the efflux of organic acids.

Numerous studies have demonstrated that too much Al causes the creation of ROS, leading to oxidative stress (Boscolo *et al.,* 2003). Genotypes with stronger antioxidant defences are typically more tolerant to excess Al, however it is yet unclear how Al worsens the generation of ROS (Darkó *et al.,* 2004). Although the specific mechanism by which $Al^{3+}$ induces ROS generation in the cell is unknown, it is unlikely that $Al^{3+}$ directly participates in redox reactions because it is not a transition metal. $Al_3$high +'s affinity for biomembranes may be able to modify the structure of membranes, which would therefore encourage the production of ROS (Cakmark and Horst, 1991). $Al_3$affinity +'s for biomembranes may also lead to stiffness and make it easier for chain reactions to be mediated by $Fe^{2+}$ ions, which heightens lipid peroxidation. Since Al preferentially accumulates in the roots, its most significant impacts are felt here, and indirect effects are thought to affect nutrient transport in the shoots (Lindon *et al.,* 1999). $Al^{3+}$, however, can also result in oxidative stress in shoots. This condition can be indirectly observed by evaluating fluorescence characteristics, especially those that track the maximal quantum yield of photosystem II.

## Conclusion

Plants are frequently subjected to a several harmful environmental factors that might cause stress and, as a result, have a detrimental impact on their development and production. To reduce the negative effects of stress and increase output, it is crucial to understand the physiological reactions of crops to stress situations. Therefore, there is a critical need for greater scientific investigation to deepen our understanding of the physiological responses of crops to numerous interrelated stressors, such as water and heat stresses, as well as to a single, particular stresses. The accurate evaluation of this data might lead to the development of crucial tools for tracking the most promising genetic material in plant breeding initiatives. Our knowledge of how plants adapt to abiotic stresses has greatly improved over the past few years. Our understanding of the physiological processes involved in successful crop development and yield in challenging conditions is still quite incomplete. For instance, it is still exceedingly difficult to understand drought-stress signalling, which is crucial for logical genetic engineering programmes targeted at long-lasting stress tolerance. Additionally, some important physiological studies dealing with plant stress tolerance have been carried out on potted plants without the proper calibration in the field, which can result in a waste of time and resources because, in most cases, the results cannot be extrapolated or simulated by crop modelling to describe what may happen under actual field conditions. Whatever the case, the development of new biotechnological methods for accurately identifying the genetic and physiological variables involved in plant stress adaptation would undoubtedly increase the effectiveness of selection for enhanced crop performance under stress.

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