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Climate Change and Biotic/Abiotic Stress Management

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Abstract

Climate change refers to a significant and long-lasting change that occurs in the statistical distribution of weather patterns over a long period of time ranging from decades to millions of years. The rate at which the energy is received from the sun and the rate at which it is lost in space determine the equilibrium temperature and climate of the earth. This energy is distributed around the globe by winds, ocean currents, and other mechanisms to affect the climate of different regions. This gradually changing climate is leading to a change in the composition of flora and fauna of the earth at different times of the year which is indirectly affecting the normal metabolism of plants. These adverse effects on plants are referred to as stress which can be either biotic or abiotic in nature. This article will discuss the various mitigation strategies that can be followed to mitigate environmental stresses and adapt plants according to changing climate.

Key words: Biotic stress, Abiotic stress, Precision farming, Sustainable agriculture, Climate change.

Introduction

Minor climatic changes can have a significant impact on agricultural output even during a single growing season, so long-term agricultural productivity and food security will undoubtedly be impacted by ongoing climate change. This is a matter of growing concern because, over the next 30 years, the world will need to produce twice as much food to feed its expanding population.

The Intergovernmental Panel on Climate Change outlined several scenarios and examined the consequences for global areas in its Third Assessment Report. For Africa, it was determined that many nations would see a decline in cereal yields and would be more susceptible to droughts, floods, and other extreme events that would place more strain on water supplies, food security, and human health. It was determined that many nations in Asia's desert, tropical, and temperate zones could have their food security threatened by thermal and water stress, sea level rise, floods, droughts, and tropical storms. Additionally, it projected declining yields of significant food products for Latin America, particularly posing a danger to subsistence farming. Longer growth seasons and greater temperatures are anticipated to help agriculture at higher altitudes, but tools would also be required to take advantage of these possibilities.

Plants can manage climatic fluctuations to some degree on their own. Certain rice cultivars, for example, have a built-in ability to adjust, allowing them to flower early in the day and escape the damaging impacts of higher temps later in the day. However, research has been sparse and ambiguous regarding the overall possibility of plant resilience to high-temperature stress.

Adaptive technologies

The majority of food production's evolution is probably dependent on human activity. Thankfully, agricultural communities have a lot of practice dealing with unfavorable climatic occurrences like droughts, storms, and salinity. For instance, they have added new irrigation methods, expanded to higher producing types, or increased their endurance for salty or dry conditions. The use of "grass waterways," or regions where vegetation is allowed to grow continuously to clear run-off water, has also altered the topography of the land. Figure 1 lists a few of the choices that are offered.

Table 1. Examples of adaptation options for agriculture

Response strategy	Some adaptation options
Use different crops	○ Carry out research on new varieties
Change land topography to improve water uptake and reduce wind erosion	○ Subdivide large fields ○ Maintain grass waterways ○ Roughen the land surface ○ Build windbreaks
Improve water use and availability and control erosion	○ Line canals with plastic films ○ Where possible, use brackish water ○ Concentrate irrigation in periods of peak growth ○ Use drip irrigation
Change farming practices to conserve soil moisture and nutrients, reduce run-off and control soil erosion	○ Mulch stubble and straw ○ Rotate crops ○ Avoid monocropping ○ Use lower planting densities
Change the timing of farm operations	○ Advance sowing dates to offset moisture stress during warm periods

Transfer of technology

Agricultural systems are often fairly adaptable, so if farmers have access to the correct knowledge and resources, they should be able to make the majority of the required changes on their own. However, other people may find it more challenging because of poor soil quality, insufficient water supply, or a lack of investment. They could also encounter institutional or cultural obstacles. Governments may wish to assist in these situations by making more intentional and planned actions, by providing new information or tools, or by looking for new technology.

Fortunately, there are already established international networks that can help with research, development, and knowledge transfer in the agriculture industry. One of the most significant is the Consultative Group on International Agricultural Research (CGIAR), a strategic partnership of international organizations and private foundations that collaborates with both the public and commercial sectors as well as national agricultural research institutions. Any nation can connect its own research initiatives to this international framework.

The quest for a new generation of crop types will be one of the primary areas of concentration for worldwide research on climate change adaptation. The rise in yields over the last few decades was mostly the consequence of better management techniques, irrigation, and higher use of fertilizers or other inputs, but only about half was attributable to genetic crop variety improvement.

A lot of these developments are the consequence of the technological transfer. Much of this has consequently been across places with comparable agroclimatic conditions since crop varieties are susceptible to local factors. As a result, transfers between temperate regions have occurred north to north, whereas transfers between tropical or subtropical regions have occurred south to south. When semi-dwarf wheat varieties originally developed in Mexico were transferred to India during the Green Revolution, the potential for South-South transfers was utilized. India also benefited from infusions of germplasm gathered by the International Rice Research Institute from other parts of Asia.

Problems in adapting new technologies

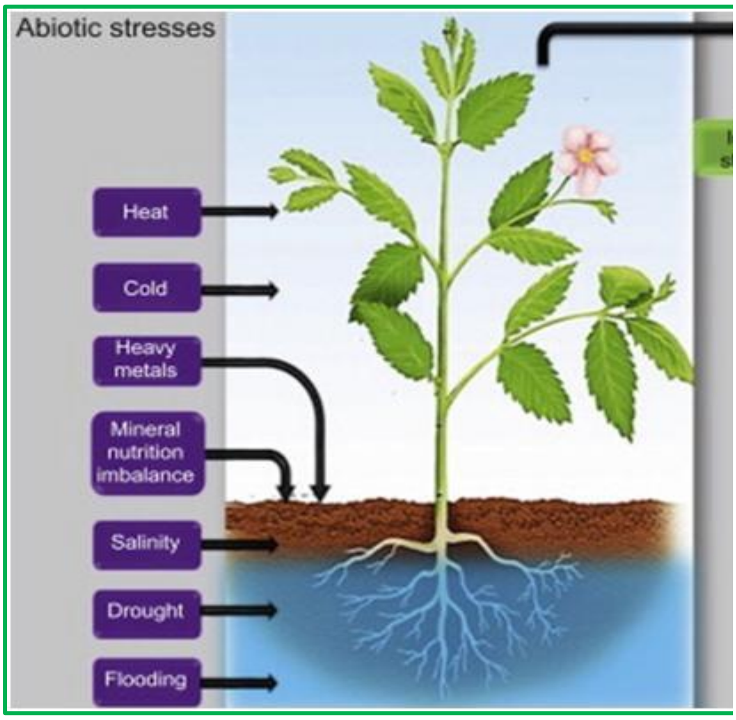
The advantages of research must be widely dispersed, though. For instance, CGIAR's genetic crop development initiative mixes traditional and modern techniques and takes into account the interests of all stakeholders, including farmers, local residents, breeders, and biotechnology firms. It might be challenging for the less wealthy farmers to accept new technology, even if they are developed and fit for local conditions. They can lack the capacity and motivation to invest in cutting-edge technologies due to their modest farm sizes and restricted access to funding. More food will need to be grown on a warmer planet with a growing population. Thus, adaptation will be crucial for both the livelihoods of agricultural households and the security of the world's food supply, which highlights the need for much more study and for global collaboration in the creation of essential technology.

Biotic and Abiotic stress in plants

External circumstances that negatively impact a plant's growth, development, or output are referred to as stress in plants. Plants respond to stress in a variety of ways, altering their gene expression, cellular metabolism, growth rates, crop yields, etc. Stress in plants typically results from certain abrupt alterations in the environment. Yet, exposure to a given stress results in adaptation to that specific stress in stress-tolerant plant species in a time-dependent way. Abiotic stress and biotic stress are the two main classifications of plant stress. Whereas biotic stress is a biological entity like illnesses, insects, etc. that agricultural plants are exposed to, abiotic stress is imposed on plants by the environment and can be either physical or chemical. The plants are harmed by several stressors, which caused many metabolic dysfunctions in the plants. If the stress is minor or short-lived, the effect is transient, and the plants can recover. But, excessive stress can kill agricultural plants by stopping blooming, and seed production, and inducing senescence. Those plants will be regarded as vulnerable to stress. Nonetheless, some plants, such as desert plants (Ephemerals), can completely avoid stress.

Living things, in particular viruses, bacteria, fungi, nematodes, insects, arachnids, and weeds, induce biotic stress in plants. Plant death can result from the agents producing biotic stress directly depriving their host of its nutrients. Pre- and post-harvest losses can generate significant biotic stress. Plants can withstand biotic stressors even if they lack an adaptive immune system by adapting to certain sophisticated techniques. The genetic code housed in plants regulates the defensive systems that respond to various challenges. The plant genome has hundreds of genes that are resistant to various biotic stressors. Abiotic stress, which is imposed on plants by non-living variables such as salt, sunshine, warmth, cold, floods, and drought having a detrimental influence on agricultural plants, is completely distinct from biotic stress. The sort of biotic stress that may be applied to agricultural plants depends on the environment in which they are grown, as does their capacity to withstand that specific form of stress. While chewing insects diminish leaf area and viral infections decrease the rate of photosynthesis per leaf area, many biotic stressors have an impact on photosynthesis.

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 scarcer, abiotic stressors will become more intense. To maintain food security and safety in the upcoming years, it is urgent to create crop types that are resistant to abiotic stressors. The roots of a plant act as its first line of defense against abiotic stress. If the soil in which the plant is growing is healthy and biologically varied, the plant will have a good chance of surviving adverse conditions. Disruption of the Na+/K+ ratio in the plant cell's cytoplasm is one of the main reactions to abiotic stress, such as excessive salinity. Abscisic acid (ABA), a phytohormone, is crucial for plant response to environmental stressors such as excessive salt, dehydration, cold temperatures, or mechanical injury.



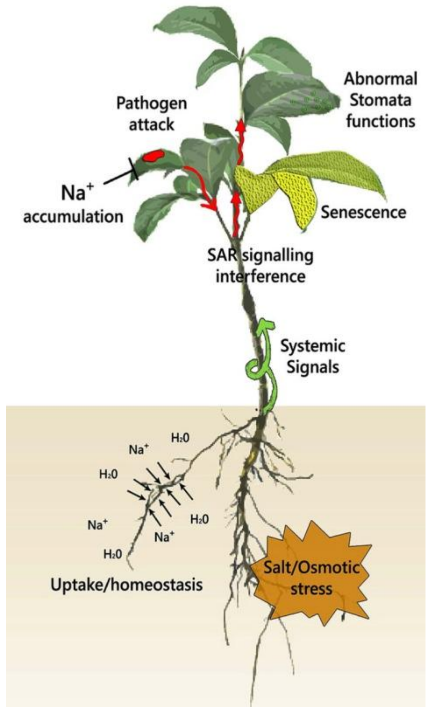


Figure 1: Various Abiotic and secondary environmental stresses that a plant faces.

Polyamines: Plants response to stresses

Due to their stationary nature, plants must constantly adapt to environmental changes by undergoing the necessary alterations in their physiology, development, and biochemistry. Abiotic stressors, the primary cause of crop loss, produce a global decline of more than 50% in agricultural plants. Plants are endowed with a vast array of defensive systems 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.

Polyamines and plants responses 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. Yet the simultaneous introduction of exogenous polyamine reverses this effect. Using mutants lacking in polyamine production is another genetic strategy used to examine the biological functions of polyamine metabolism in stress response.

Polyamines and plants responses to biotic stresses

Long known to cause distortions in polyamine metabolism in plant cells, these alterations occur when plants interact with fungi, viruses, and mycorrhizae. As polyamines are found in both plants and pathogenic fungi, it is difficult to determine how polyamine buildup in infected organs contributes to disease. The most exciting and important breakthrough is the potential for controlling fungal plant diseases by targeted suppression of polyamine production.

Conclusion

In the next 50 to 100 years, it is predicted that the earth's temperature would rise by 3 to 5°C. As temperatures continue to rise and rainfall patterns become more erratic, variations in flood and drought are constantly taken into account. Salt stress may be further exacerbated by anthropogenic activities such as the overuse of fertilizers, poor irrigation practices, and resource exploitation. Plants will likely experience both biotic and abiotic stressors more frequently under these conditions. To safeguard both the safety of the farmers and the security of the food supply, it is the responsibility of plant breeders to create cultivars that can withstand stress. It will take molecular effort at the genetic level to create systems in plants that will protect them from various stress scenarios. Plants will be continually exposed to such challenges unless response mechanisms are created against biotic and abiotic stresses, which will ultimately prove to be a major danger to global agriculture.

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