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Sustainable crop production in stress condition: strategies and management

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Abstract

Stress in plants refers to external conditions that adversely affect growth and development and result in poor crop productivity. A wide range of environmental stresses reduce or limit the productivity of crops. These are two types of environmental stresses that are encountered by plants: abiotic stress and biotic stress. Abiotic stress causes the loss of major crops and includes salinity, flooding, drought, extreme temperature, heavy metals, etc. On the other hand, biotic stress is caused by attacks by various pathogens such as fungi, bacteria, nematodes, herbivores, etc., and plants are in nature; they cannot move from these environmental cues. Though the plants have developed different mechanisms in order to overcome these threats of abiotic and biotic stresses, they sense the external stress environment, get stimulated, and then generate appropriate cellular responses. On the basis of different scientists' perceptions, it is expected that the stresses may show their severity under climatic change. Now, there is a strong need to develop tolerant crop varieties to overcome stress like salinity, drought, and waterlogging conditions. Therefore, to reduce stress problems, plant breeders, pathologists, and agronomists should come forward to mitigate these stresses, so according to the past publication, it is clear that in the future, research should be done on integrated methodologies to mitigate stresses so that sustainable production can be achieved.

Keywords: Abiotic and biotic stresses, climate change, genetic and management options

Introduction

Crops stress an assortment of environmental stresses which include, abiotic stresses such as drought, water logging, salinity, extreme temperature, high variability radiation, subtle perceptible changes in atmospheric gases, and biotic stresses. such as insects, birds, other pests, weeds, and pathogens (viruses and other microbes). The productivity of land and water is declining day by day because of depleting underground water tables and non-scientific conventional practices used to establish various crops. Climate change further complicated the situations where uncertain rain both in terms of amount and frequency, high temperature regimes, frequent floods, and drought adversely affected the yield in total. Evapo-transpiration combines both evaporation and transpiration, and their management is important in improving land and water productivity (Bhatt et al., 2019). During salinity stress, plants tend to activate different physiological and biochemical mechanisms to cope with stress through altering their morphology, anatomy, water relations, protein synthesis, primary and secondary metabolism, and biological adaptations (Ayman et al., 2020). Crop water requirements during the vegetative phase varied due to different crops having difficult crop canopy cover and microclimatic conditions (Akram et al., 2018). To improve land productivity through resource conservation technologies (RCTs), as it is closely linked with livelihood stands under decreased water availability depending upon the geological conditions (Abdelaal et al., 2017). The cumulative effects of all abnormalities in climate parameters create problems for plants as well. Perhaps the best way to test recent memory as transformative biologists is to foresee how plant populations will react to future climate Conditions forced by environmental changes Hypothetical and trial-proven results show that, in light of natural change, populations may move to more favorable territories. The negative impact of climate change is prominent on plants and human civilization. Looking at the present scenario of stress divas, interventions can be given to mitigate this problem (Bhadra et al., 2021).

Stress factors which reduce crop productivity

Water deficit stress, salt stress, imbalances in nutrients (including mineral toxicity and deficiencies), and temperature extremes are significant environmental limitations on the productivity of crops all over the world (Lesk et al., 2016). Plant growth and coop yield are primarily affected by cold, drought, salt, and heavy metals. Climate change is a major threat to field crop production, and ultimately, it affects food security. Due to changes in weather patterns and extreme conditions of flood, drought, and heat waves, they negatively affect flood, water, and energy security, all of which reduce crop productivity (Amanullah, 2020; Shanker et al., 2016).

Types of stress affect crop production.

Stress that affects crops significantly is of two types: (1) abiotic stress and (2) biotic stress.

(1) Abiotic Stress

Abiotic stress causes the loss of major crop plants worldwide, which includes radiation, salinity, floods, drought, extreme temperatures, heavy metals, etc. Abiotic stress is imposed on plants by environmental stress, either physical or chemical. Some stresses to the plants injured them so much that plants exhibit several metabolic dysfunctions. The place can be recovered from injuries if the stress is mild or short-term, as the effect is temporary, while severe stresses lead to the death of crop plants by preventing flowering, seed formation, and induced senescence. Such plants will be considered to be stress-sensitive (Verma et al., 2013). However, some desert plants (ephemerals) can escape the stress altogether (Zhu, 2002). As plants are sessile in nature, they have no choice but to escape from these environmental cues. Plants have developed various mechanisms in order to overcome these threats of abiotic and biotic stresses. They sense the external stress, get stimulated, and then create suitable cellular responses (Gull et al., 2019).

I. Major abiotic stress limits crop yield.

Drought: Among the environmental stress factors, water is a very important factor that limits the crop yield if there is less drought and if there is more that creates flooding. It has been estimated that drought causes an average annual yield loss of 17% in the tropics (Edmeades et al., 1992), but losses can be much more severe, and total crop failures are not unknown (Flowers, 2004). An extended stretch of rainfall that is below the statistical mean for a region is referred to as a drought.

Agricultural droughts indicate an extended dry period that results in crop stress and reduced crop yields. Drought occurs due to a deficit of moisture in the soil when the moisture is not sufficient to meet the needs of growing crops. Moreover, the severity of stress imposed on crops also depends on their acceptability during different stages of crop growth and development (Tandzi et al., 2019; Shaheen et al., 2016).

Effect of drought stress on the crops are as hereunder:

- Poor Vegetative Growth
- Reduced seed germination and seedling development (Devasirvatham and Tan, 2018)
- Plant height and leaf area were reduced.
- Reproductive growth is severely affected.
- Reduced photosynthesis because of less leaf area.
- Reduced stomata conductance and
- Significant reduction in total dry matter

II. Mitigation of drought stress

- Folior spony 20% DAP +1% kcl during critical stages of flowering and grain formation.
- Spray 3% Kaoline at critical moisture stress.
- Spony of 500 ppm Cycocel (CCC) at 1 ml/liter of water.
- Mulching with 5 tomes to sugarcane or sorghum, which saves moisture.
- Spray of 40 lok NAA (4 ml of Plano Fix in 4.5 l of water).
- Use of drought-resistant varieties (Yadav et al., 2019)

Flood Stress

"Flooding may be defined as any situation of excess water." High intensity rainfall causes a severe flood, resulting in physiological stress on crops. Flooding environment to which plants must adapt if it is a regular cycle or seasonal charge. Vast areas of rainfed crops, particularly in the South and Southeast, are manually affected by flooding.

Types of floods: Flooding can be catastrophic, with flash floods causing major soil erosion and direct physical destruction of crops. These are two typical kinds of floods. One has a short duration over a few weeks and is not very deep, termed a "flash flood," and the other is deep flooding that lasts for a long time, called a *"deepwater flood."* False floods are unexpected and inconsolable, and their flooding water level can reach 50 cm in the rain-fed lowlands of the humid and semi-humid tropics of South and Southwest Asia. In these areas, flash floods at the seedling stage of paddy cause very low yields (Hottori *et al.,* 2011).

Effects of flooding stress on plants: Major flooding stresses on plants are as follows:

- Deacy and death
- Wilting
- Abscission
- Epinasty
- Lenticels foronation

Nutrient deficiency and toxicity: Under anaerobic conditions, iron toxicity is high. This leads to an increase in polyphenol oxidase activity. It also caused leaf bronzing and refused root oxidation power.

Important mitigations for flood stress are as follows:

- Providing adequate drainage for draining excessive water from fide
- Spray of growth stardant of 500 ppm Cycocel (CCC) for arresting apical dominance and thereby promoting growth of laterals.
- Foliar Spray of 2% DAP + 1% KCL (MOP)
- Spray of 0.5 ppm brassinolide for increasing photosynthesis activity.
- Apply sufficient K fertilizers.

III. Salinity stress: one of the most common forms of land degradation results from soil salinization. This problem is found throughout the country. However, salinity is predominately a problem in arid and semi-arid regions of the world when the potential for evapotranspiration exceeds rainfall and there is insufficient rain to leach away soluble salts from the root (Miller and Donahue, 1990). In India alone, 7 million ha of land are salt-affected. The impact of salinity on the economic exploitation of land for agriculture and forestry is very severe (Singh and Singh, 1995).

"Salinity is defined as the presence of an excessive amount of soluble salt that hinders or affects the normal functions of plant growth. It is measured in terms of electrical conductivity (EC), exchangeable sodium percentage (ESP), sodium adsorption ratio (NAR), and pH". Therefore, saline soils are those that have saturated soil paste extract with an event of more than 4dSm-1, ESP less than 15, and pH below 8.5 (Avril, 1986; Szaboles, 1994). There are two sources of salinity:

Primary or Natural Sources: This is developed from the weathering of minerals and the soils derived from saline parent rocks.

Secondary salinization: Secondary salinization caused by human factors such as irrigation, deforestation, overgrazing, or intensive cropping (Ashraf, 1994).

Salinization effects are as follows:

- If it affects the chemical properties of the same by changing CEC,
- After the physical properties of the soil, the soil structure is damaged by the defloculation of clay particles, and hydraulic conductivity is decreased, resulting in a slow movement of irrigation water.
- Soil salinity also affects the soil microflora, which plays important roles in the improvement of soil structure, the decomposition of organic matter, and the nitrogen and sulfur cycle (Lal and Khanna, 1994).

Mitigation and Salt Stress are as hereunder:

- Seed hardening with Nacl.
- Application and Gypsum at 50% Gypsum Requirement (GR).
- Incorporation of Sasbaniya (6:25 t/ha) in the soil before planting.
- Folior spray of 0.5 ppm brassinolode for increasing photosynthesis activity.
- Spray of 40 ppm of NAA for arresting the pre-mature fall of flowers, buds, and fruits.
- Folior application of ascorbic acid alone increased the number of leaves and leat area, while in combination with zinc sulfate, it increased the plant height and total plant biomass.
- Extra dose of nitrogen (25%) in excess of the recommended.

IV. Temperature stress: "Greaves (1996) defined subtropical temperature stress as any reduction in growth or induced metabolic cellular or tissue injury that results in limitations to the potential yield, caused by a direct exposure to temperature above or below the thermal thresholds for optimum biochemical and physiological activity or morphological development.”.

High Temperature Stress: Levitt (1920) classified plants into psychophiles, mesophiles and thermophiles according to whether or not they tolerate low, medium, at high temperature. Psychrophiles are those plants whose high temp threshold is 15-20 °C; mesophiles are those plants whose high temperature threshold is 35–45 °C; and thermophiles have thresholds and high temperature ranges from 45–1000 °C Levitt (1980) proposed that the high-temperature injury process progresses from a direct reversible strain, *i.e.,* excess respiration over photosynthesis due to elevated temperature. High temperatures may be experienced by plants on a daily and seasonal basis. Plants may be as affected by prolonged periods of moderately high temperature as they are by short periods of extreme temperature, though the mechanisms for coping with these stresses may differ. Heat stress affects grain quality and yield.

Low Temperature Stress: Plants can also be damaged by a chilling effect leading to physiological and developmental abnormalities and by freezing, causing cellular damage directly or via cellular dehydration. There are many symptoms of low-temperature injuries. Some physiological processes, such as flowering in rice, are extremely sensitive to low temperatures, and damage may occur at temperatures as high as 20 °C. In common, a symptom of low temperature injury to the leaves includes wilting and bleaching due to photo-oxidation of pigments, water logging of intercellular spaces, browning, and eventually leaf necrosis and plant death (Witt and Garfield, 1982). According to Dudal (1976), it is estimated that 15% of arable land is affected by freezing stress. Crop yields may be reduced in several ways by low temperatures. Crop growth may be directly affected by chilling and freezing injuries by causing physical damage to normal biochemical and physiological functions, thus reducing yield. Low temperatures also reduce potential agricultural productivity by limiting crops or varieties that are grown in particular areas.

(2) Biotic factors affecting crop fields

I. Diseases and insect pests:

Numerous microorganisms, including bacteria, fungus, and viruses, are the cause of diseases. Furthermore, a variety of insect pests that are above-ground and soil-borne have an impact on crop productivity. It frequently encourages the growth of diseases under various climatic circumstances while adversely influencing soil fertility and plant yield. They result in a decrease in the resources that are accessible to plants, which prevents them from producing enough biomass, seeds, and yields. Pathogens and pests can migrate from one area to another due to climate change. The crop genotypes that have been accepted locally are thus exposed to novel biotic stressors. Resistance to pathogen-induced secondary infections is one aspect of the interactions between microorganisms and plants, or microbe-associated molecular patterns. A complex of low-molecular-weight plant metabolites, which are well-characterized for dicotyledonous plants but little understood for monocotyledonous plants like cereal crops, are involved in its production and systemic signal (Dressel Halls and Heckel hoven, 2017). According to Osman et al. (2020), the changing climate is bringing with it new diseases and pests for which there is currently no remedy.Nematodes are mostly responsible for soil-borne illnesses that result in nutrient deficiencies, stunted development, and wilting. Nematodes feed on plant components (Bernard et al., 2017). Parallel to this, viruses can cause harm both locally and systemically, which can lead to growth retardation and chlorosis (Pallas and Garcia, 2011). Conversely, insects and mites damage plants by either laying eggs on them or feeding on them (piercing and sucking). Additionally, insects may serve as carriers of several germs and viruses (Saijo and Loo, 2020).

II. Biotic stress and plant defense responses:

A number of pests, pathogens, and parasites are responsible for infecting plants and inciting biotic stress. The fungal parasites are of two types: necrotrophic (kills host cell toxin secretion) and biographic (feeds on living host cells). They induce vascular wilts, leaf spots, and cankers in plants. Plants have developed an elavorate immune system to combat such stresses (Saijo and Loo, 2020). Plants have a passive first line of defense, which includes physical barriers such as cuticles, wax, and trachoma to avert pathogens and insects. Plants also produce chemical compounds to defend themselves from infecting pathogens (Tariz and Zeiger, 2006). Phytophagous pests respond by identifying herbivore-associated elicitors (HAES), herbivore-associated molecular patterns (HAMPs), or PRR herbivore effectors (Santanaria *et al*. 2013). The second level of pathogen recognition is encircle resistance proteins, which identify specific receptors from a phathogen (Avr. proteins) (Abdul Malik *et al.*, 2020). It is considered an effective mechanism of plant resistance to pests and involves effector-triggered immunity (ETI) (Gouveia *et al*., 2017; Spoel and Dong, 2012). The ETE stimulates hypersensitive responses and triggers programmed cell death (PeD) in infected and surrounding cells (Mur *et al*., 2008).

III. Polyamine and Plant Response to Biotic Stresses:

Polyamine metabolism has long been known to distort in plant cells in response to insightful changes in plants interacting with fungal (Asthir *et al., 2003*), viral pathogens, and mycorrhiza. It is hard to identify the contribution of polyamine accumulation in infected organs as it is present both in plants and pathogenic fungi. The possibility of controlling fungal plant diseases through specific inhibition of polyamine biosynthesis is most exciting and worth pursuing.

Conclusion and future perspectives

Plants are constantly exposed to a number of adverse conditions in the environment. Being immobile and deprived of a highly specialized immune system, they have developed intricate mechanisms to adapt and survive under various types of abiotic and biotic stresses. According to the perception of scientists, it is expected that the temperature of the earth will increase by 3–5 °C in the coming 50–100 years. As there is a is a continuous increase in temperature and scattered uneven rainfall, the changes of floods as well as droughts are always in consideration. Activities such as excessive use of fertilizers, inappropriate irrigation, and exploitation of natural resources may lead to salt stress to a large extent. Under these circumstances, crop plants will probably encounter more rapidly, concurrently, both biotic and abiotic stresses. Therefore, plant breeders should develop stress-tolerant varieties looking to food security and ensure safety for our farmers. Molecular work is to be done at the genetic level to develop mechanisms in plants in order to prevent different types of stress. Unless responsive mechanisms are developed against biotic and abiotic stresses, the crop will continuously be subjected to such stress problems and ultimately prove a great threat to agriculture. In the future, the role of this review will be to decipher combined stress tolerance in plants due to the required research on tolerant genomic mechanisms. It is now clear from this review that the agronomist and field pathologist are assessing the impact of the intersection between drought and plant pathogens on crop performance. Further, the review will be helpful for physiologists and molecular biologists to design or plan agronomically relevant strategies for the development of broad-spectrum stress-tolerant crops as well as to create management strategies to crack down on stress problems.

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