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Plants Response to Abiotic Stress: A Review

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Abstract: Stress is the unfavorable and external condition that affects a plant's metabolism, growth, development, productivity and others physiological condition. Various kind of abiotic stresses like cold, heat, drought, salinity, metal stress, etc affected the normal development, growth, productivity and other function of the plant. To respond with its changed environmental factors, plants rearrange its morphological, metabolic, and genetic mechanism. Under abiotic stress plants at first changes its structural and functional aspects of cellular components. Various stress responsible genes are activated in this time so that plants can rapidly synthesize important proteins and other metabolites during abiotic stress. Plants employ multiple and alternative morphological, metabolic, and genetic approaches, so that they could survive from those adverse environmental conditions.

Keywords: *Abiotic stress, drought, salinity, ROS, environmental factors, transcription factors*.

INTRODUCTION

Stress is the unfavorable and external condition that affects plants metabolism, growth, development, productivity and others physiological condition. Stress also affected the cellular metabolism, gene expression; signaling pathways etc (Cramer, *et al*., 2011, He, *et al*., 2018). Stress is mainly of two types, biotic stress and abiotic stress. Biotic stress is caused by biological agents such as bacteria, fungi, virus, insects, insects, nematode, weed etc (Stout, *et al*., 1999, Heil & Bostock, 2002). The agents of the biotic stress are directly depending on the host, as they absorb nutrients from the host and they may cause major harm to the plants (Li, *et al*., 2023). Abiotic stress on the other hand is caused by different physiological, chemical, environmental agents. The agents of abiotic stress include water (drought and submergence), temperature (cold, frost and heat), salts, minerals, metal etc (Andjelkovic, 2018, Dey & Rai Chaudhuri, 2022). Abiotic stress not only hampers plants growth and development but also it affects plants metabolism, their gene expression, yield and even survival ability (Ruelland, *et al*., 2009, Isayenkov, 2012, and Dagnino, *et al*., 2020).

Different types of stress interacted with each other and affected on the plant depending on the time, duration, nature. Some biotic and abiotic stress is interacting between the plant and plant stressors interface. In fact the interaction is caused the major damage to the plant and the crop (Des Marais, *et al*., 2013). Example in the high temperature and heat wave form, this is caused the major damage the plant and crop field. So, it is the negative impact on the growth and development of plant. On the other hand, some time the abiotic and biotic stress interaction is caused positive impact on the growth and plant. The high temperature is prevented the growth and development of some bacteria and fungi. So it is the positive impact the growth and development of the plant.

Different abiotic stresses adversely affect the plants due to ever changing different environmental and bio geographical factors (Sulmon, *et al*., 2015, Gull, *et al*., 2019). Pollution factors directly affect the plant pigments concentrations (Banik, S. *et al*., 2018, Ghosh, P. *et al*., 2018, Ghosh, P. *et al*., 2021, Ghosh, P. *et al*., 2023, Mukherjee, S. *et al*., 2018, Saha, M. *et al*., 2022). Abiotic stress directly affect on the morphological, biochemical, and physiological processes. Drought directly affected the all stages of plants growth and development, from molecular to morphological level (Roychowdhury, *et al*. 2013). Salinity affected the plant root by the osmotic pressure (Barnabas, *et al*., 2008, Avni Oktem, *et al*., 2008). Salinity caused ionic toxicity, which is related to nutritional limitations and oxidative damage. Water logging is primarily affected the plant growth and reduced photosynthesis and respiration. Cold stress also affected many important cellular activities and caused decreased protoplasmic streaming, electrolyte leakage, and plasmolysis to the plant cell. High temperature increased the range of evaporation and excessive evaporation is caused damaged to the plant and it may cause also the death of the plant (Hasanuzzaman, *et al*., 2013). Metal stresses also have negative impact on gene structure and cell signaling. Metal stress caused toxicity to the plant due to deposition of different toxic metal inside the cell (Roychowdhury and Tah 2011; Roychowdhury, *et al*., 2019). Therefore, in this present review we focus to highlight plants response when they are exposed to various abiotic stresses.

Physiological Changes of Plants under Abiotic Stress:

Drought stress is mainly occurred due to lack of cellular water in the plant. The lack of cellular water caused plasmolysis and due to this the cell may death. Lack of water is the also affected the photosynthesis process and hamper plant growth (Mahajan& Tuteja, 2005, Shinozaki and Yamaguchi-Shinozaki, 2007, Salehi-

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Lisar, *et al*., 2016).Water logging mainly occurred due to the excessive water deposition to the cell. The excessive water in the cell affected photosynthesis process and it affected the growth and productivity of the plant. Deposition of excessive water to the cell also caused death to the cell of the plant (Pradhan & Mohanty, 2013, Phukan, *et al*., 2016).Salinity is mainly occurred due to the presence of high range of salt ions in the soil. High concentrated salt ions in the soil is affected the roots of the plant and hamper the respiration process. Deposition of high salt ions in the cell alters the cellular metabolism and photosynthesis process (Mittler, *et al*., 2004, Sahi, *et al*., 2006, and Jiang, *et al*., 2007).

The cold temperature also lead to cellular damage, abnormal productivity, premature ripens of fruit, and even may caused death to the plant (Heidarvand & Maali Amiri, 2010, Thakur & Nayyar, 2013).High temperature also interferes with cellular structure and photosynthesis process. They caused excessive amount of evaporation which also eventually lead to the death of the plant. Increased temperature also boosts the sexual development, reduces the time to photosynthesis, alters seed germination, and often leads to the drought condition.

There are two types of metal, one are essential for plant growth (Fe, Mg, Zn) and other are non-essential (Pb, Hg, As). The essential metal helps plants growth; however, deposition of excessive amount of this metal affects development of the plant. Deposition of metal inside the cell affected the many cellular activity like photosynthesis, reparation, metabolism, and other cellular activity (Aydinalp, *et al*., 2009, Ghori, 2019). Deposition of excessive amount of unessential metal leads to the death of the plant. The low concentrate of metal is also affected the cellular activity and caused many dysfunction to the cellular activity. Abiotic stresses often cause oxidative damage lead to the production of reactive oxygen species (ROS) in plant cells.

Metabolic Changes of Plants on the Response of Abiotic Stress:

Different types of stress affected the plant metabolism like photosynthesis, seed germination, respiration, evaporation, plasmolysis etc (Koyro, *et al*., 2012, Zhang, *et al*., 2022). The plant cell regulates their metabolism to response the stress condition. The plant metabolism is the interconnected reaction which has a high degree of sub-cellular compartmentation and produce metabolites for development of the stages (Bolton, 2009).

Abiotic stresses also lead to changes in the storage function, defense mechanism, reproducibility, productivity of the plant (Rizhsky, *et al*., 2004, Quint, *et al*., 2016). The metabolic phenotype of the plant is also affected by the abiotic stress. Genes are involved in the early response and downstream assembly of the response. The metabolic response to the stress in plants diverse the metabolite like by product of stress metabolism and stress signaling transduction molecules. Metabolites are the small molecules which present in the plant and regulated the genotypes in response to environmental changes. Metabolites help to understand many physiological and biochemical changes in plant due to stress (Hasanuzzaman, *et al*., 2015).

Abiotic Stress Responsive Signaling Pathway in Plant:

Plants abiotic stress responses are being revealed to be possibly crosstalk with energy signaling pathways as any other growth-limiting factor of the plant (Chinnusamy, *et al*., 2004, Zandalinas, *et al*., 2020). As regarded to the mechanism the plant recycle the nutrients elements frequently according with stress response. Autophagy has played the important role in stress responsive signaling. The plants respond to the various adverse environmental factors by multiple gene products and maintain their homeostasis against the stress (Loredana, *et al*., 2011, Zhu, 2016, Nadarajah, 2020).

Stress-inducible genes are generally classified into two major groups; one is functional genes and another is regulatory genes. Functional genes synthesize proteins like stress tolerance proteins, enzymes etc which directly provide tolerance against different abiotic stresses. Regulatory gene products are mainly different transcription factors (DREBs, AREBs and NACs) which are involved in regulation of stresses (Lata & Prasad, 2011). Under abiotic stress, plants first sense the stress via various signaling molecules, which in turn activate other signaling molecules and ultimately lead to a cascade of downstream signaling pathway to counter the stresses (Anumalla, *et al*., 2016; Figure 1).

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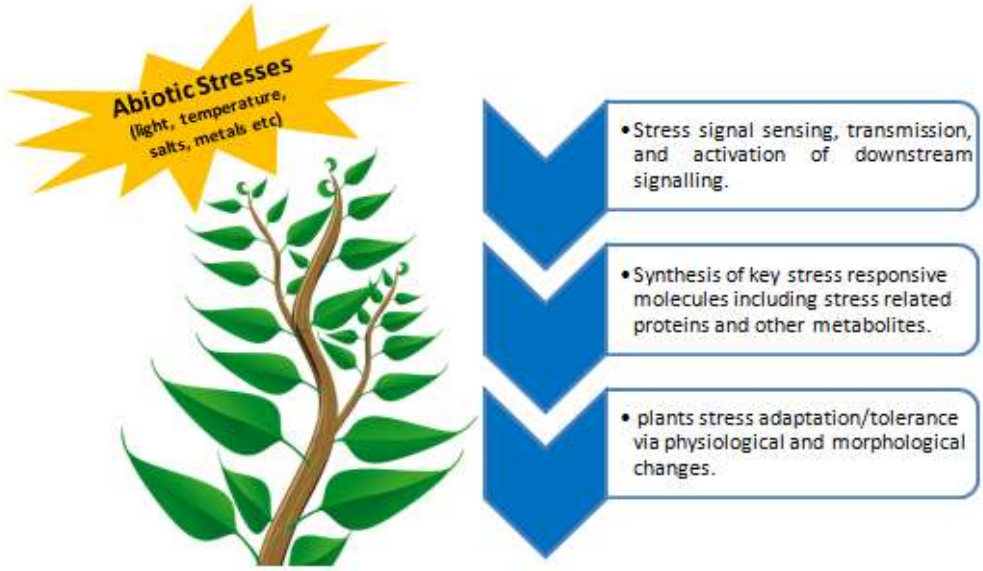

Figure 1: Schematic presentation of plants response under abiotic stress

Important Genes Related to Abiotic Stress Response in Plant:

Plants abiotic stress response involved hundreds of genes and these genes can be classified into three broad categories such as: A. Directly produce the proteins in the plant cell to protect the plant cell from the different types of stress factors (some proteins are heat stress protein, anti-frizzing protein, detoxification enzyme); B. Signaling cascade and transcriptional control protein (calcium depending protein kinase, phosphplipase, and other transcriptional factors etc); and C. Water and ion uptake and transporter (aquaporins and ion transporter etc).Transcription factors are regulatory proteins which up or down regulate plant stress responsive gene expression by binding with the genes promoter regions (Agarwa and Jha, 2010,Saibo, *et al*., 2009, Mao, *et al*., 2015). These types of transcriptional regulatory factors are also called as regulon.

There are two important transcriptional regulatory pathways which play important roles in plants under water deficit stress; one is ABA-independent pathway and another is ABA-dependent pathway (Yoshida, *et al*., 2014). The first pathway is controlled by the TFs which are called dehydration response element binding protein (DREB) (Savitch, *et al*., 2005, Sakuma, *et al*., 2006). In ABA-independent pathway, DREB are the important factors which are responsible for abiotic stress. DREB divided into two major groups: - A. DREB 1 which is responsible for the signal transduction in low temperature, B. DREB 2 which is responsible for the signal transduction in dehydration condition. Many genes like Aquaporin, ERD10, ERD13 and ERF described in plant response to water stress. A member of the A. thaliana family of R2R3-MYB TFs, AtMYB61, is also specifically expressed in guard cells in a consistent manner, being involved in the regulation of stomata aperture (Liang, *et al*., 2005). Many transcriptional genesplayan has important roles to regulate the activity of guard cell and stomata activity.

ABA- dependent pathway on the other hand control by the five different types of the TFs. Gene expression performed by the several transcriptional factors like heat shock factors, ethylene response binding proteins, etc. TFs also involved in ABA which helps the regulation of the drought stress. TFs over expression are involved in the enhancement of the sensitivity of ABA pathway. The plant stress responsive genes synthesize many proteins and enzymes such as DNA binding protein and nitric oxide syntheses etc which comprehensively play critical role to plants stress response and adaptation.

CONCLUSIONS

Abiotic stresses hamper the plants normal growth and development. They also cause damage to the cell and molecular activity. Various kind of abiotic stresses like cold, heat, drought, salinity, metal stress, etc affected the development, growth, productivity and other function of the plant. Multiple stress responsible genes are formulated in response to the abiotic stress, so that the plant could survive from those conditions. Various types of proteins and metabolites are produced during abiotic stress. Plants developed multiple mechanisms to respond with different types of abiotic stress.

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