Eco. Env. & Cons. 29 (May Suppl. Issue) : 2023; pp. (S453-S457)

ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i03s.079

In vitro Mutations for Biotic and Abiotic Stresses: A Review

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(Received 8 December, 2022; Accepted 23 February, 2023)

ABSTRACT

Plants are subjected to a wide range of environmental stresses which reduces and limits the productivity of agricultural crops. Two types of environmental stresses are encountered to plants which can be categorized as (1) Abiotic stress and (2) Biotic stress. The abiotic stress causes the loss of major crop plants worldwide and includes radiation, salinity, floods, drought, extremes in temperature, heavy metals, etc. On the other hand, attacks by various pathogens such as fungi, bacteria, oomycetes, nematodes and herbivores are included in biotic stresses. Establishment of a reliable, reproducible and efficient in vitro plant regeneration system with cell and tissue culture is a vital prerequisite for biotechnological application of crop improvement programme. An in vitro plant regeneration technique refers to culturing, cell division, cell multiplication, de-differentiation and differentiation of cells, protoplasts, tissues and organs on defined liquid/solid medium under aseptic and controlled environment. Recent progress in the field of plant tissue culture has made this area one of the most dynamic and promising in experimental biology. There are many published reports on in vitro plant regeneration studies including direct organogenesis, indirect organogenesis and somatic embryogenesis. This review summarizes those plant regeneration studies that could be helpful in drawing the attention of the researchers and scientists to work on it to produce healthy, biotic and abiotic stress resistant plant material and to carry out genetic transformation studies for the production of transgenic plants.

Key words: *In vitro mutations, Biotic, Abiotic, Plant regeneration.*

Introduction

Stress in plants refers to external conditions that adversely affect growth, development or productivity of plants (Verma *et al.,* 2013). Stresses trigger a wide range of plant responses like altered gene expression, cellular metabolism, changes in growth rates, crop yields, etc. A plant stress usually reflects some sudden changes in environmental condition. However, in stress tolerant plant species, exposure to a particular stress led to acclimation to that specific stress in a time time-dependent manner (Nizam *et al.*, 2013). Plant stress can be divided into two primary categories namely abiotic stress and biotic stress. Abiotic stress imposed on plants by environment may be either physical or chemical, while as biotic stress exposed to the crop plants is a biological unit like diseases, insects, etc. (Verma *et al.,* 2013). Some stresses to the plants injured them as such that plants exhibit several metabolic dysfunctions (Verma *et al.,* 2013). The plants can be recovered from injuries if the stress is mild or of short term as the effect is temporary while as severe stresses lead to death of crop plants by preventing flowering,

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seed formation and induce senescence. Such plants will be considered to be stress susceptible. However, several plants like desert plants (Ephemerals) can escape the stress altogether (Zhu *et al.,* 2002).

Biotic stress in plants is caused by living organisms, especially viruses, bacteria, fungi, nematodes, insects, arachnids and weeds. The agents causing biotic stress directly deprive their host of its nutrients can lead to death of the plants. Biotic stress can become major because of pre- and postharvest losses. Despite lacking the adaptive immune system plants can counteract biotic stresses by evolving themselves to certain sophisticated strategies. The defines mechanisms which act against these stresses are controlled genetically by plant's genetic code stored in them. The resistant genes against these biotic stresses present in plant genome are encoded in hundreds. The biotic stress is totally different from abiotic stress, which is imposed on plants by nonliving factors such as salinity, sunlight, temperature, cold, floods and drought having negative impact on crop plants. It is the climate in which the crop lives that decides what type of biotic stress may be imposed on crop plants and also the ability of the crop species to resist that particular type of stress. Many biotic stresses affect photosynthesis, as chewing insects reduce leaf area and virus infections reduce the rate of photosynthesis per leaf area.

Globally, abiotic stress is the key sources of crop loss, reducing more than 50% average yields for most major crop plants (Mahajan *et al.,* 2005). Particularly, drought and salinity are becoming devastating in many regions of the world, and may cause serious salinization of more than 50% of all arable lands by the year 2050" (Kumar *et al.,* 2013).

Crop plants and abiotic stresses Plants are encountered by number of abiotic stresses which impact on the crop productivity worldwide. These abiotic stresses are interconnected with each other and may occur in form of osmotic stress, malfunction of ion distribution and plant cell homeostasis. The growth rate and productivity are affected by a response caused by group of genes by changing their expression patterns. So, the identification of responsive genes against abiotic stresses is necessary in order to understand the abiotic stress response mechanisms in crop plants. The abiotic stresses occurring in plants include.

Cold

Cold stress as abiotic stress has proved to be the main abiotic stresses that decreases productivity of agricultural crops by affecting the quality of crops and their post-harvest life. Plants being immobile in nature are always busy to modify their mechanisms in order to prevent themselves from such stresses. In temperate conditions plants are encountered by chilling and freezing conditions that are very harmful to plants as stress. In order to adopt themselves, plants acquire chilling and freezing tolerance against such lethal cold stresses by a process called as acclimation. However, many important crops are still incompetent to the process of cold acclimation. The abiotic stress caused by cold affect the cellular functions of plants in every aspect. Several signal transduction pathways are there by which these cold stresses are transduced like components of ROS, protein kinase, protein phosphate, ABA and Ca2+, etc. and among these ABA proves to be best.

Salt

Soil salinity poses a global threat to world agriculture by reducing the yield of crops and ultimately the crop productivity in the salt affected areas. Salt stress reduces growth of crops and yield in many ways. Two primary effects are imposed on crop plants by salt stress; osmotic stress and ion toxicity. The osmotic pressure under salinity stress in the soil solution exceeds the osmotic pressure in plant cells due to the presence of more salt, and thus, limits the ability of plants to take up water and minerals like K+ and Ca2+. These primary effects of salinity stress cause some secondary effects like assimilate production, reduced cell expansion and membrane function as well as decreased cytosolic metabolism.

Drought

Nowadays climate has changed all around the globe by continuously increase in temperature and atmospheric CO2 levels. The distribution of rainfall is uneven due to the change in climate which acts as an important stress as drought. The soil water available to plants is steadily increased due severe drought conditions and cause death of plants prematurely. After drought is imposed on crop plants growth arrest is the first response subjected on the plants. Plants reduce their growth of shoots under drought conditions and reduce their metabolic demands. After that protective compounds are synthesized by plants under drought by mobilizing metabolites required for their osmotic adjustment.

Heat

Increase in temperature throughout the globe has become a great concern, which not only affect the growth of plants but their productivity as well especially in agricultural crops plants. When plants encounter heat stress the percentage of seed germination, photosynthetic efficiency and yield declines. Under heat stress, during the reproductive growth period, the function of tapetal cells is lost, and the anther is dysplastic.

Role of Genes to Overcome

The biotic stresses plants have two levels of immune system that protects them against different types of pathogens. At the first, a pattern recognition receptor (PRR) recognizes pathogens attacks on the surface of the plant cell. The PRR produces signalling and pass to nucleus that activate defines related genes. Thereby, the cells are tried to stop further invasions of the pathogens through producing huge amount of callose, tyloses and ROS. Plant cells are deposited callose and tyloses just inside cell wall, resulting in cell walls thicker which protect the microorganisms (Fig. 1). Secondly, the plant cells are started secretion of high amount of ROS and activation of pathogenesis related (PRs) damaging threatening pathogens (Oppel *et al.*, 2009). At the same time, pathogens also are injecting sets of affecter molecule inside the cell that try to damage or defeat the plant immunity system. The affecter molecules damaging transduction signalling and response that disrupt plant defines system and ultimately plants are infected by pathogens in susceptible plants (Kumar *et al.,* 2013).

Crop plants and biotic stresses

Plants struggle with many kinds of biotic stresses caused by different living organisms like fungi, virus, bacteria, nematodes, insects etc. These biotic stress agents cause various types of diseases, infections and damage to crop plants and ultimately affect the crop productivity. However, different mechanisms have been developed through research approaches to overcome biotic stresses. The biotic stresses in plants can be overcome by studying the genetic mechanism of the agents Abiotic and Biotic Stress in Plants 4 causing these stresses. Genetically modified plants have proven to be the great effort against biotic stresses in plants by developing resistant varieties of crop plants.

Polyamine: plant response to stresses

Plants being immobile in nature have to go through continuous fluctuations in the environment with appropriate physiological, developmental and biochemical changes (Alcazar *et al.,* 2006). More than 50% reduction in crop plants occur due to abiotic

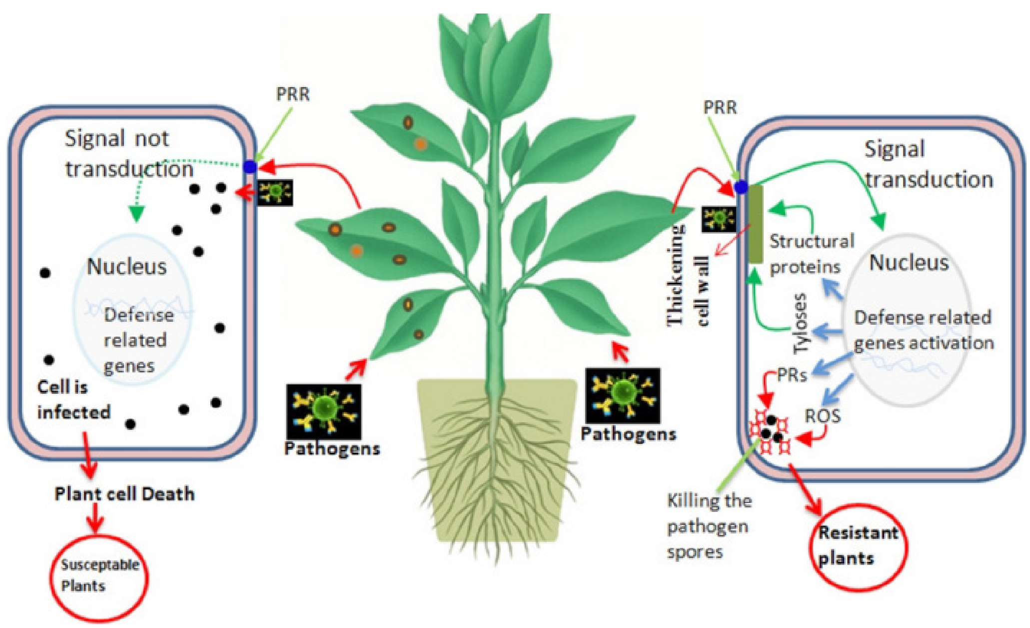

Fig. 1. Schematic model of plant-pathogen interaction and molecular mechanisms involved in resistance and susceptible reactions to pathogens attacks.

stresses worldwide which is the main cause of crop loss (Bartels *et al.,* 2005). To counteract the stresses, plants are equipped with a large set of defines mechanisms. Among the different classes of compatible solutes, polyamines stand as one of the most effective against extreme environmental stress. Polyamines are low molecular weight aliphatic nitrogen compounds positively charged at physiological pH (Sunkar *et al.,* 2005). Investigations into plant polyamines at a molecular level have led to isolation of a number of genes encoding polyamine biosynthetic enzymes from a variety of plant species (Groppa *et al.,* 2008). In recent years, molecular and genomic studies with mutants and transgenic plants having no or altered activity of enzymes involved in the biosynthesis of polyamines have contributed to a better understanding of biological functions of polyamines in plants.

Polyamine and plant response to abiotic stresses

Stress derived changes in cellular polyamines provide clues on their possible implication in stress but do not provide evidence of their role in counteracting stress. The levels of endogenous polyamines can be increased by application of exogenous polyamines, which has been attempted before or during stress (Groppa *et al.,* 2001). Exogenous application of polyamines could preserve plant cell membrane integrity, minimize growth inhibition caused by stress, moderate expression of osmotically responsive genes and increase activities of antioxidant enzymes (Navakouidis *et al.,* 2003). In another approach treatment with biosynthesis inhibitors can reduce endogenous polyamine resulted in stress sensitive phenotypes. However, this effect is reversed by the concomitant application of exogenous polyamine (Wang *et al.,* 2007). Another genetic approach employed for analysing biological functions of polyamine metabolism in stress response is the use mutant deficient in polyamine biosynthesis (He *et al.,* 2002) 4.2 Polyamine and plant response to biotic stresses Polyamine metabolism has long been known to distort in plant cells responding to insightful changes in plants interacting with fungal (Kaur-Sawhney *et al.,* 2003), viral pathogens (Asthir *et al.,* 2004) and mycorrhizae (Torrigiani *et al.,* 1997). It is hard to identify the contribution of polyamine accumulation in infected organs as it is present both in plants and pathogenic fungi (Galston *et al.,* 1998). The possibility of control of fungal plant diseases through specific inhibition of polyamine biosynthesis is most excited and for reaching development (Walters *et al.,* 2000).

Conclusion

It is expected that earth's temperature will increase by 3–5 °C in the coming 50–100 years. As there is continuous increase in temperature and uneven rainfall the changes of flood and drought is always in consideration. The anthropogenic activities such as excessive fertilizers, inappropriate irrigation and exploitation of metal resources can lead to salt stress to a large extent. Under these circumstances, plants will probably encounter more frequently, concurrently both biotic and abiotic stresses. It is the duty of plant breeders to develop stress tolerant cultivars in order to secure food security and to ensure safety to the farmers. Molecular work is to be done at the genetic level to develop mechanisms in plants in order to prevent them from different types of stress conditions. Unless responsive mechanisms are not developed against biotic and abiotic stresses, the plants will continuously be subjected to such stresses and ultimately will prove a great threat to world agriculture.

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