Biotic and Abiotic Stresses

Plants relentlessly encounter a wide range of environmental stresses which limits the agricultural productivity.

The environmental stresses conferred to plants can be categorized as

1) Abiotic stress 2) Biotic stress

Abiotic stresses include salinity, drought, flood, extremes in temperature, heavy metals, radiation etc. It is a foremost factor that causes the loss of major crop plants worldwide. This situation is going to be more rigorous due to increasing desertification of world's terrestrial area, increasing salinization of soil and water, shortage of water resources and environmental pollution.

Biotic stress includes attack by various pathogens such as fungi, bacteria, oomycetes, nematodes and herbivores. Diseases caused by these pathogens accounts for major yield loss worldwide. Being sessile plants have no choice to escape from these environmental cues. Expertise in tolerating these stresses is crucial for completing the lifecycle successfully. Therefore, to combat these threats plants have developed various mechanisms for getting adapted to such conditions for survival. They sense the external stress environment, get stimulated and then generate appropriate cellular responses. These cellular responses work by relaying the stimuli from sensors, located on the cell surface or cytoplasm to the transcriptional machinery which is situated in the nucleus, with the help of various signal transduction pathways. This leads to differential transcriptional changes making the plant tolerant against the stress. The signaling pathways play an indispensable role and acts as a connecting link between sensing the stress environment and generating an appropriate physiological and biochemi cal response (Zhu 2002). Recent studies using genomics and proteomics approach .

Stresses Plants are constantly exposed to a variety of potential microbial pathogens such as fungi, bacteria, oomycetes, nematodes and herbivores. In order to defend themselves plants have developed a variety of defense responses many of which are induced by pathogen attack. Penetration of the cell wall exposes the microbes to the plant plasma membrane, where they encounter extracellular surface receptors that recognize pathogen-associated molecular patterns (PAMPs). Recognition a microbe at the cell surface initiates PAMP-triggered immunity (PTI), which usually halts infection before the pathogen gains a hold in the plant. However, pathogenic microbes have evolved the means to suppress PTI by secreting specialized proteins, called as effectors, into the plant cell cytosol that alter resistance signaling or manifestation of resistance responses.

Bacteria Metabolomic and transcriptomic analysis of rice in response to bacterial blight pathogen Xanthomonas oryzae pv. oryzae revealed global metabolic and transcriptomic changes in leaf tissues (Sana et al. 2010). Ethylene response element binding protein (EREBP) transcription factor gets significantly expressed together with ROS scavenging system and lower expression of alcohol dehydrogenase gene. These factors lead to hypersensitive cell death in the resistant cultivar upon bacterial infection. Stimulation of glutathione-mediated detoxification and flavonoid biosynthetic pathways in combination with up-regulation of defense genes during infection inhibits pathogen from further spreading in the host tissues (Kottapalli et al. 2007). Transcripts encoding disease resistance proteins via JA/ET signaling as well as osmotic regulation via proline synthesis genes were found differentially expressed when microarray analysis was performed in cotton associated with Bacillus subtilis induced tolerance (Medeiros et al. 2011). The major protein of bacterial flagella is flagellin which is a well characterized PAMP.

Fungi On the basis of their lifestyles, plant pathogenic fungi have been divided into two classes: the biotrophs and the necrotrophs. Biotrophs feed on living host tissue, whereas necrotrophs first kill the host tissue and then feed on the dead tissues. However, there are many plant pathogenic fungi which behave both as biotrophs and necrotrophs, depending on the conditions in which they find themselves or the stages of their life cycles. Such pathogens are called hemi-biotrophs. Earlier, many fungi were commonly considered as necrotrophs whereas they had a biotrophic stage early in the infection process and hence were basically hemi-biotrophs. In general, SA signaling is involved for resistance against biotrophic and hemibiotrophic pathogens whereas the JA and ET signaling is important for immnity towards necrotrophs (Pieterse et al. 2009).

Biotrophic Fungi For resistance against biotrophs, gene-for-gene mechanism is important. According to gene-for-gene hypothesis, given by Flor, for every gene in the plant that confers resistance, there is a corresponding gene in the pathogen that confers avirulence. It leads to activation of SA-dependent signaling and SAR. In Arabidopsis, overexpression of ADR1 (NBS-LRR resistance gene) provides resistance against Erysiphe cichoracearum (Grant et al. 2003). Another example is of barley and Blumeria graminis (Schulze-Lefert and Vogel 2000) where gene-for-gene resis- tance response is evident. Various studies show that SA signaling has important role in resistance whereas JA- and ET-signaling may not be involved. Therefore, during biotrophic pathogen attack, SA-dependent defense responses are effective together with gene-for-gene resistance. There is no induction in JA-dependent responses, but if they are artificially induced, then they are quite effective (Glazebrook. 2005). Transcriptome data from microarray experiments suggest that during defense responses the photosynthesis-related genes are highly down-regulated which is required to support the induction of a defence response (Bilgin et al. 2010). The nitrogen invested in photosynthetic proteins, primarily Rubisco, is lowered or even withdrawn to provide nitrogen for the induction of defensive compounds.

Necrotrophic Fungi Transcript profiling of various plant-pathogen systems suggest differential regulation of a large number of transcripts in response to pathogen attack. These transcripts included those which are associated with JA biosynthesis and signaling, ROS metab- olism, and cell wall structure and function. Isolation of early responsive genes of chickpea infected with blight fungus Ascochyta rabiei was carried out using PCR based suppression subtractive hybridization (SSH) strategy and ~250 unique genes were identified. These genes belonged to eleven different categories viz. stress, signaling, gene regulation, cellular metabolism and genes of unknown functions (Jaiswal et al. 2012). Chitin, which is a major component of fungal cell wall, serves AU2 as a PAMP. Therefore, chitosan (the deacetylated form of chitin) plays important role in inducing defense responses against pathogens in many plant species. GeneChip microarrays and quantitative RT-PCR of Botrytis cinerea infected Arabidopsis leaves revealed that chitosan has inductive role on several genes involved in defense responses and camalexin biosynthesis (Povero et al. 2011).

The basic concepts of plant stress

Stress: stress in physical term is defined as mechanical force pe unit area applied to an object.

- In response to the applied stress ,an object_a change in the dimension, which is also khown as strain.
- A biological condition which may be stress for one plant may be optimum for another plant.
- As plants are sessile, it is though to measure the exact force exerted by stress and therefore in biological term it is difficult to define stress.

Environmental modulation of homeostasis defined as biological stress

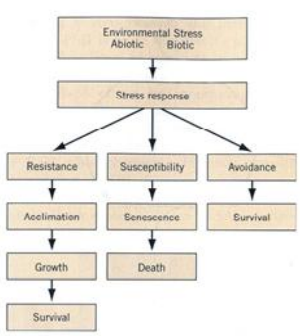
Any change in the surrounding environment may disrupt homeostasis. Environmental modulation of homeostasis may be defined as **biological stress**. Thus, it follows that **plant stress** implies some adverse effect on the physiology of a plant induced upon a sudden transition from some optimal environmental condition where homeostasis is maintained to some suboptimal condition which disrupts this initial homeostatic state. Thus, plant stress is a relative term since the experimental design to assess the impact of a stress always involves the measurement of a physiological phenomenon in a plant species under a suboptimal, stress condition compared to the measurement of the same physiological phenomenon in the same plant specie under optimal conditions.

Plant respond to stress in several different ways

Plant stress can be divided into two primary categories. **Abiotic stress** is a physical (e.g., light, temperature) or chemical insult that the environment may impose on a plant.

Biotic stress: is stress that occurs as a result of damage done to plant by other living organism. Such as bacteria, virus, fungi, beneficial and harmful insects and cultivated plant.

Abiotic stress: is defined as the negative impact of non-living factor on the living organism in a specific environment.



The effect of environmental stress on plant survival

Ephemeral plants germinate, grow, and flower very quickly following seasonal rains. They thus complete their life cycle during a period of adequate moisture and form dormant seeds before the onset of the dry season. In a similar manner, many arctic annuals rapidly complete their life cycle during the short arctic summer and survive over winter in the form of seeds. Because ephemeral plants never really experience the stress of drought or low temperature, these plants survive the environmental stress by **stress avoidance** . Avoidance mechanisms reduce the impact of a stress, even though the stress is present in the environment. Many plants have the capacity to tolerate a particular stress and hence are considered to be **stress resistant**. Stress resistance requires that the organism exhibit the capacity to adjust or to acclimate to the stress.

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A plant stress usually reflects some sudden change in environmental condition. However, in stress-tolerant plant species, exposure to a particular stress leads to **acclimation** to that specific stress in a time-dependent manner . Thus, plant stress and plant acclimation are intimately linked with each other. The stress-induced modulation of homeostasis can be considered as the signal for the plant to initiate processes required for the establishment of a new homeostasis associated with the acclimated state. Plants exhibit stress resistance or stress tolerance because of their genetic capacity to adjust or to acclimate to the stress and establish a new homeostatic state over time. Furthermore, the acclimation process in stress-resistant species is usually reversible upon removal of the external stress.

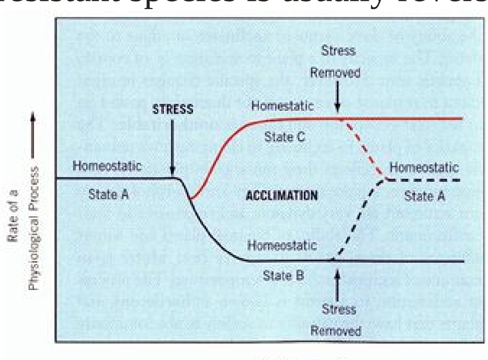

Figure A schematic relationship between stress and acclimation (*source: Hopkins W.G., Hüner N.P.A., 2009*)

Adaptation and phenotypic plasticity

Plants have various mechanisms that allow them to survive and often prosper in the complex environments in which they live. **Adaptation** to the environment is characterized by genetic changes in the entire population that have been fixed by natural selection over many generations. In contrast, individual plants can also respond to changes in the environment, by directly altering their physiology or morphology to allow them to better survive the new environment. These responses require no new genetic modifications, and if the response of an individual improves with repeated exposure to the new environmental condition then the response is one of acclimation. Such responses are often referred to as **phenotypic plasticity**, and represent nonpermanent changes in the physiology or morphology of the individual that can be reversed if the prevailing environmental conditions change.

Temperature stress

Mesophytic plants (terrestrial plants adapted to temperate environments that are neither excessively wet nor dry) have a relatively narrow temperature range of about 10°C for optimal growth and development. Outside of this range, varying amounts of damage occur, depending on the magnitude and duration of the temperature fluctuation.

Temperature stress can result in damaged membranes and enzymes

Temperature stress can inhibit photosynthesis

Freezing temperatures cause ice crystal formation and dehydration

Imbalances in soil minerals

Imbalances in the mineral content of soils can affect plant fitness either indirectly, by affecting plant nutritional status or water uptake, or directly, through toxic effects on plant cells.

Soil mineral content can result in plant stress in various waysSeveral anomalies associated with the elemental composition of soils can result in plant stress, including high concentrations of salts (e.g., Na^+ and Cl^-) and toxic ions (e.g., As and Cd), and low concentrations of essential mineral nutrients, such as Ca^{2+}, Mg^{2+}, N, and P. The term salinity is used to describe excessive accumulation of salt in the soil solution. **Salinity stress** has two components: nonspecific osmotic stress that causes water deficits, and specific ion effects resulting from the accumulation of toxic ions, which disturb nutrient acquisition and result in cytotoxicity. Salt-tolerant plants genetically adapted to salinity are termed *halophytes*, while less salt-tolerant plants that are not adapted to salinity are termed *glycophytes*.

Soil salinity occurs naturally and as the result of improper water management practices

Saline soils are often associated with high concentrations of NaCl, but in some areas Ca^{2+}, Mg^{2+}, and SO_4^- are also present in high concentrations in saline soils. High Na^+ concentrations that occur in sodic soils (soils in which Na^+ occupies 10% of the cation exchange capacity) not only injure plants but also degrade the soil structure, decreasing porosity and water permeability. Salt incursion into the soil solution causes water deficits in leaves and inhibits plant growth and metabolism.

Stress resistance mechanism

- Avoidance mechanism: prevent exposoure to stress.
- Tolerance mechanism: permit the plant to withstand stress
- Acclimation: alter their physiology and response stress.
- **Regulation of plant stress responses**
- Abscises acid (ABA)
- Jasmonic acid
- Ethylene
- Calcium

Conclusion

In the environment, plants are constantly being exposed to a number of adverse conditions. Being immobile and deprived of highly specialized immune system, they have developed intricate mechanisms to adapt and survive under various types of abiotic and biotic stresses. On the perception of certain stimuli various signaling cascades are stimulated generating appropriate responses. This result in massive transcriptional reprogramming that makes the plant tolerant against the stress. Recent advances in the field of genomics and proteomics approach have widened our view regarding plant signal transduction and gene regulation. The cDNA and GeneChip microarrays are tremendously helpful in identifying novel signaling determinants on genome wide scale. Therefore, the role of various genes can be elucidated in response to the stress conditions. Post-translational modifications of the proteins can be well understood by proteomics analyses. Several recent studies using these techniques have added to our understanding of stress signaling mechanisms in plants.