

Salt Stress:

Salt stress can be defined as the accumulation of excess content of salt in the soil which cause inhibition of plant growth and sometime also leads to plant death. It is one of the major abiotic factors which decrease the crop yield in the arid region. Salinity leads to a number of inhibitory effects on the plant like limiting the crop productivity, seed germination, and crop yield. Salinity, in the higher concentration, also cause damage to the plant by ion toxicity, membrane disorganization, oxidative stress, water potential and decrease in cell expansion and its division. All these effects cause an adverse effect on the plant development and crop yield.

Salt stress caused numerous damage to plants which includes symptoms like accelerated growth, growth inhibition and senescence. It may also lead to death due to longer exposure to the salinity. Under the salt stresses, different plant characteristics like physiology, morphology, anatomy, chemical composition and water content of plant tissues are affected.

Affects plant adversely in two ways:

- High solute content in rooting medium creates water stress by decreasing osmotic potential and
- Direct toxic effect of higher concentration of ions.

Different plants response differently to the salt stress based on their salt tolerance ability. So, based on the tolerance ability, plants generally classified into two categories:

1. Halophytes
2. Glycophytes

Halophytes:

- These are not usually affected at higher salinity.
- Known for their ability to grow comfortably in saline soil with high salt concentration.
- Have a specific mechanism of salinity tolerance.
- Some of the halophytes excrete extra salt content with the help of salt glands present in their leaf cells while some plants excrete via salt hairs present on their stem.

Glycophytes:

The plant which cannot grow in the presence of high concentration of salts. But manage to grow in saline soil by adopting some mechanisms as

- Accumulation of sugars in leaves
- Compartmentalization (checked from reaching to photosynthetic parts)

Mechanism of Tolerance:

- Presence of salt excreting glands that reduce the concentration of salt in the plant e.g. *Frankenia*, *Spartina*.
- Development of small leaves, water storage hairs, and aerenchyma.
- Succulence that may lead to dilution of intracellular salt such as occurs in *Salicornia sp.*
- Sometimes there is a synthesis of organic solutes that aids in the maintenance of turgor.

There are two ways by which plant adapt themselves from the severe consequence of salt stress:

I. Avoidance:

A state of avoiding excessive salt from the parts of the plant where they are detrimental through:

- **Salt exclusion:** Some plants exclude salts from their parts are known as salt excluders. In this, movement of salt ions are restricted from the root part whereas permitting the water to pass. For example; mangrove plants.
- **Salt excretion:** Those plants which eliminate the salt through cuticle or bladders or glands present on each leaf called salt excreters. For example; Salt bladders – e.g. *Atriplex*, *Mesembryanthemum crystallinum* L.

Salt glands – These are the trash sites for the absorption of excess salt from the soil water; support the plants by adapting in saline soil. For example; Excretion by cuticle – e.g. *Tamarix*.

- **Salt Dilution:** Plants having dilution capacity in their parts and they dilute the ions in them by balancing succulence. Plants attain this ability by maintaining their storage volume high and thick like a succulent shape. And it is acquire through vacuoles of mesophyll cells filling with water as well as large in proportions. This adaptation is inadequate in the plant tissues.

II. Tolerance:

- **Osmotic adjustment-** Some plants can tolerate salt stress by dropping the cellular osmotic potential by increasing the solute accumulation (sucrose, amino acid, proline, betaine).
- **Hormone synthesis** - ABA stress hormone stabilizes plants against excess salt stress.

Temperature Stress:

Temperature stress is one of the severe environment factor which affect plant development, by showing low germination rate, growth retardation, reduced photosynthesis, and often die.

It is divided into three main parts:

1. Chilling Injury
2. Freezing Injury
3. Heat Stress or High-Temperature Stress

Chilling Injury:

The injury which causes due to low but above zero-degree centigrade temperature is called chilling injury.

- Temperature 0°C to 15°C causes chilling stress.
- Less than 0°C will cause freezing stress.
- This condition is shown by many tropical area plants.
- This chilling temperature is very low for optimal growth but not sufficient for ice formation.

Effect of Cold Temperature on Plants:

- Discoloration of leaves
- Delayed transition of flowering and plant growth.
- Shrinkage of protoplast due to extracellular ice formation.
- Destruction of chlorophyll.
- Photosynthesis inhibition, degradation of proteins, lower transpiration rates, reduced carbohydrate consumption.
- Water potential inside the cell is affected due to low temperature. Because the water inside the cell starts to convert in ice at low temperatures and will result in high solute potential and low water potential.
- This will affect the enzyme and ion channel of the plant and as a result, plants will die due to ice crystal formation.
- This is shown by plants- tomato, bean, rice, etc.

Freezing Injury:

Freezing injury occurs at a temperature below the freezing point of water (below 0°C) and primarily the liquid phase in the cell wall freezes.

- At 0°C there is a phase transition in water from liquid to solid. Development of ice crystals in the cell walls and intercellular places.
- Bulky polysaccharides enable ice crystal development, which is known as ice nucleators.
- Damage occurs when ice crystals grow and puncture into the cytoplasm.

Adaptation of Plants for Prevention:

1. Needle-like leaf structure which prevents freezing and transpiration of water due to low surface area. They also have terpenes and alcohol which are antifreezing factors.
2. Termination of growth activity during winter.
3. Cold area plant has anti-freezing proteins. It is also found in the winter Rye plant.
4. Production of dehydrins (stress proteins) which prevent dehydration in plants in response to drought and cold fluidity of membrane lipids stress.
5. Some trees become leafless so to avoid the accumulation of ice on their surface.

Cold Stress Signalling:

- Calcium level increases inside the plant cell on cold stress conditions and this will lead to the further expression of genes that will help in tolerance from cold.
- Low temperature will increase the level of ABA and Jasmonic acid. Their signaling pathway will also increase.
- Low temperature will decrease the level of Gibberellic acid, ethylene, and Cytokinin. So, all the signaling will get inhibited.

High Temperature Stress or Heat Stress:

High temperature (HT) or Heat stress is also a main abiotic stress that affects the development of plant, their different processes, and their overall production. Almost every physiological and biochemical processes are sensitive to high temperature. Different plants have different ability to respond to the high temperature.

- Normal temperature ranges from 0oC to 40°C.
- Stress temperature is above 40oC.

Effect on Plant Growth:

- Change the plant growth pattern, reduction in seed germination, changes in leaf pattern, and decrease in plant production.
- ROS generation that will lead to apoptosis of plant cell.
- High temperature may cause injury to the chloroplast by-
 1. Disturbing thylakoids structure
 2. Swelling of grana
 3. Affect the grana stacking ability
- Inhibition of photosynthesis and respiration. Chloroplast enzymes become unstable and performs abnormal function.
- Fluidity of membrane lipids, destabilize the bond between polar proteins within membrane.
- Change membrane composition and structure and can cause leakage of ions.
- Denaturation of proteins occur by losing its three-dimensional structure which is required for the activity and function of proteins. Formation of unfolding proteins, destabilize the cell functions.

Some plants avoid high-temperature stress by:

- Angle and arrangement of the leaves.
- Thick cuticle and leaf hairs (improves conductive cooling) reduce the absorption of solar radiation.
- Closure of stomata to reduce water loss at high temperatures.
- Large xylem vessels.
- Rolling of leaf blades.

Tolerance to High Temperature:

- High expression of antioxidant enzymes like Catalase, Peroxidase, SOD, Glutathione reductase.
- Plant produce antioxidant metabolites like ascorbate, carotene etc.
- Expression of Heat Shock Proteins (HSPs).

Light Stress:

Light stress is also a stress factor that damages plants and its development very badly. Light is one of the most important components for photosynthesis as an energy source and a main environmental factor for plant growth and development. But the changed light quality and quantity can also be harmful to plant processes and lead to photo-destruction and photo-inhibition. Due to changed light intensity either low or high, plants unable to protect them by being stabilized and loss their normal metabolic functions.

- When light intensity is low below the compensation point, carbohydrate level in plants declines by using it as a substrate first for respiration and then for the other purpose.
- In high-intensity, light photosynthesis performance of plants, is depends upon the relationship between photo-inhibition of photosynthesis and the damaged chlorophyll ratio.

Ultraviolet radiation:

At sea level, electromagnetic radiation contains around 7% ultraviolet rays coming from the sun. Due to these harmful ultraviolet rays, membrane permeability of plant cells changes by changing in lipid and protein ratio. These are in the result of reduced photosynthesis and respiration.

Avoidance of Light Stress by Plants:

- To avoid the absorption of excess of light, various plants moves their chloroplasts in a way that they receive minimum light. On the other hand,

during low light, chloroplasts may be moved to high-intensity light to make the best use of it.

- To protect themselves from the excess of light, plant leaves make an angle to diminish light interception.
- Plants of shady region grow horizontally to take full advantage of light interception.