

Plant responses to environmental stresses:

Plants exposed to unusual conditions such as intense lighting, extreme cold (chilling), extreme heat, thirst, flooding, radiation, pollution with toxic gases or increased concentrations of a specific gas such as ozone, infection with pathogens, and other environmental stress factors—all of these factors activate and mutually stimulate each other to increase the production of active oxygen species (AOS).

It is known that certain types of enzymes intervene to protect tissues against oxidation processes resulting from the action of active oxygen species and originally resulting under stress conditions.

Studies have also been conducted on the effect of low temperatures on physiological processes, showing a severe deficiency in photosynthesis. Studies have also been conducted on the effect of ozone gas (O₃), and it has been found to have a severe effect on photosynthesis deficiency - a clear decrease in the length of roots and stems of plants, as well as a clear decrease in the amount of plant crops. The reason for the severe phytotoxicity caused by O₃ is due to its superior and strong ability to oxidize, producing toxic molecules (generate toxic molecular specie) such as: super oxide anions, hydroxyl radicals, and hydrogen peroxide. Scientists agree that the harmful or fatal effects of stress are due to the direct or indirect effects of stress factors on the formation of activated oxygen radicals (AOR) and their impact on the electron transport chain. An experiment to demonstrate the production and accumulation of AOR under water stress conditions also observed an increase in membrane breakdown and an increase in lipid peroxides.

To counteract and eliminate the effects of stress, plants develop common mechanisms to tolerate stress, in addition to mechanisms specific to the stress in question, as follows:

- 1- Activation of cellular signaling factors.
- 2- Alteration of gene expression.
- 3- Accumulation of compatible solutes.
- 4- Synthesis of stress proteins.
- 5- Improving metabolic processes to produce antioxidants.
- 6- Stability and ionic balance.
- 7- Facilitating transport across cell membranes.
- 8- Accumulation of polyamines.
- 9- Adjustment of hormonal balance.

Free radicals and the role of antioxidants:

Plants exposed to many harsh weather conditions, such as extremely low or high temperatures, severe soil nutrient deficiency, drought conditions (water shortages), or flooding. In addition to abnormal biological conditions, infection with pathogens, ozone pollution, intense lighting, or intense radiation. All these conditions negatively affect plant growth and the quality and quantity of the crop. Many scientists have studied the response of plants to the aforementioned stress conditions and the subsequent release of free radicals, which cause the destruction and demolition of plant cells and tissues, as well as the antioxidants that protect these plant cells and tissues under stress conditions.

It is known that Reactive Oxygen Species (ROS) or free radicals are overcome by what are called antioxidants, which neutralize free radicals in plant cells and tissues. However, the content of these antioxidants gradually decreases with increasing stress conditions or aging. These conditions cause a noticeable increase in the activity of oxidative enzymes, which produce ROS. All of this causes and leads to increased deterioration of plant cells or tissues and the plants entering the senescent plant phase.

Oxygen free radicals are known to be one of the most important factors that contribute to plant senescence by activating harmful oxidation processes in biological molecules, leading to cell destruction and plant death.

The most important factors that appear or are produced in plant cells and tissues under stress conditions are:

- 1- Lipoxygenase activity.
- 2- Activated oxygen species.
- 3- Stressed promoting compounds such as; A- Ethylene.B- Jasmonic acid.

Lipoxygenase activity is an enzyme that breaks down and decomposes polyunsaturated fatty acids by oxygen to produce hydroperoxide products. This enzyme also plays an important role in the breakdown of membrane lipids induced by stress.

Types of free radicals:

Activated oxygen species include:

Active oxygen species are known to be the main oxidizing agent and destroyer of plant cells and tissues under stress conditions. These oxygen species are:

- 1- Super oxide radicals O_2^-
- 2- Hydroxy radicals OH.
- 3 -Singlet oxygen radicals O_2^1
- 4- Peroxyl radicals H_2O_2
- 5- Alkoxy radicals RO
- 6- Peroxyl radicals ROO.
- 7- Poly unsaturated fatty acids.
- 8- Semi quinone free radicals.
- 9- Atomic oxygen radicals (O^-).
- 10- Photolytic ozonation radicals (O_3).
- 11- Sulfur monoxide radicals (SO^-).

These AOS, especially O_2^- and OH, are very strong oxidizing agents and quickly attack biological molecules such as DNA molecules, leading to severe metabolic disturbances and irreparable dysfunction, which leads to the death of plant tissue cells.

The most important effects of free radicals on plant cells are

- 1- Attacking biological molecules such as RNA and DNA, leading to a clear disruption in plant metabolism.
- 2- Oxidation and destruction of lipid membranes by the enzyme Lipoxygenase activity.
- 3- Accelerating the plant's entry into the senescence stage.
- 4- A clear decrease in meristematic activity and decreased cell elongation.
- 5- Increase the rate of cell respiration and consume a large portion of energy.
- 6- A deficiency in the supply of plant cells and tissues to their basic needs of nutritional transformation products.
- 7- Loss of hormonal balance within cells.
- 8- A deficiency in protein and nucleic acid synthesis.
- 9- Toxicity occurs inside cells as a result of the accumulation of toxic ions inside them, such as chlorine and sodium.
- 10- Ozone causes harmful biochemical processes, as it destroys protein molecules, lipids, and plasma membranes.

Antioxidants:

Antioxidants are enzymatic and non-enzymatic. Examples of enzymatic antioxidants include:

- 1- Superoxid dismutase
- 2- Catalase
- 3- Peroxidaese
- 4- Ascorbat-glutathion cycle enzymes

5- Ascorbate peroxidase

6- Mono-dehydro ascorbate reductase

7- Dehydro ascorbate reductase

8- Glutathion reductase

Examples of non-enzymatic antioxidants include:

1- Ascorbate (C.Vit).

2- Glutathion.

3- Tocopherol (Vit.E).

4- Carotene.

5- Flavonoids.

These substances are found in abundance in chloroplasts, mitochondria, and peroxisomes. Under normal conditions, the antioxidant defense system protects the cellular system against active oxygen. However, when active oxygen increases to a very high degree, and its activity is greater than the capacity of the antioxidant defense system, as is the case in stress conditions or aging, then oxidative stress is clearly produced.

The physiological role of activated oxygen radicals in plant tissues:

- Free oxygen radicals generated in plant cells can play an important role in physiological processes such as:

1- Cellular damage.

2- Promoters of senescence.

3- Metabolic oxidation.

- In chloroplasts, superoxide radicals (O_2^-) are produced through the PSI reaction. This active oxygen is controlled by converting it to H_2O_2 . If the O_2^- in the form of H_2O_2 produced by PSI is not scavenged in the chloroplast, CO_2 fixation to carbohydrates (CO_2 fixation) will cease within seconds, leading to significant wilting.

- The continuous production of H_2O_2 from O_2^- through PSI inhibits some Calvin cycle enzymes, as well as the oxidation and degradation of photosynthetic products.

- Microbial or viral infection results in increased production of oxygen free radicals and nitrogen oxide (NO). A reaction occurs between oxygen radicals and nitrogen oxide, producing peroxynitrite. This compound causes oxidation of plant tissue cells and mutations through the oxidation and nitration of biomolecules. (Oxidation and nitration of various biomolecules).

Examples of some free radical scavengers and inhibitors:

1- Azide (inhibit myeloperoxidase).

2- 1,4 diazo – bicyclic – (2,2,2) octan (DABCO).

3- Diphenylisobenzofuran (as O_2^- trap).

4- Deuterium oxide.

5- Superoxide anion dismutase (SOD) convert (O_2^- to H_2O_2).

6- Sulfite (scavenge O_2^- produced by xanthin oxidase).

7- Benzoate (Trap for OH).

8- Mannitol (scavenge OH).

9- Ascorbic acid (it is oxidized by both H_2O_2 to dehydromonoascorbate).

10- Triton (iron chelator) (inhibit peroxidase).

11- Catalase.

12- Salicyl hydroxamic acid (SHAM) (inhibit lipoxygenase).

13- Cyanide (metabolic inhibitor).

14- Detergents (chloro mercuri benzoate) (inhibit NADPH₂ oxidase).

The above-mentioned substances are considered activated oxygen radical scavengers or inhibitors. It is known that the plant cell contains its own cleaning or scavenging materials, such as enzymes, carbohydrates, nucleic acids, and amino acids.