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ENVIRONMENTAL STRESSES AND ITS IMPACT ON PHOTOSYNTHESIS AND PLANT PRODUCTIVITY.

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INTRODUCTION:

I need not emphasize the importance of plants. We live as guest of green plants on earth. The two essential requirements of human for survival on earth are food and fuel and both are products of photosynthesis. The photosynthesis is a process by which plants convert solar energy into chemical energy (ATP & $NADPH_2$) which is able to reduce abundant and simple molecules of CO_2 to more more complex organic compounds such as sucrose.

The process of photosynthesis has evoked great interest among physiologist, biochemist, geneticist and breeders because of its importance to the food and fuel (biomass) productivity. A lot of research work is being carried out all over the world to improve the productivity by understanding the mechanism of damage to the process under various environmental stresses such as drought, salt stress, light and temperature. To this we can also add industrial pollutents such as SO_2, O_3 etc.

It is not possible for plants to avoid light & temperature and to some extant drought. They have to experience at one stage or other during their life cycle. All these stresses have different mechanism of damage but generally it is the photosynthetic process which is affected in one way or other. Since photosynthesis is directly related to plant productivity hence the growth is reduced under stress conditions and if extent of stress is high or continue for longer time then it may result in death of the plant.

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PHOTOSYNTHESIS:

Photosynthesis is a process by which the green plants convert energy into food and fuel. This is a two step process, (1) light reaction and (2) dark reaction, carried out in the two different parts of the chlorophyll containing organelle, chloroplasts. The light reaction which convert the solar radiation into reducing power such as ATP and $NADPH_2$ and also produces O_2 as a by product of the reaction, is carried out in the grana part of the chloroplasts while the dark reaction which utilize this energy to fix the CO_2 to complex compounds is carried out in the stroma part of the chloroplasts. The damage to any of these two reaction would result in the decreased plant productivity. Here I would discuss how various environmental stresses affect the process of photosynthesis.

DROUGHT:

Drought is an inevitable and recurring feature of world agriculture and despite our improved ability to predict their onset and modify their impact, drought remains the single most important factor affecting world food security and condition and stability of the land resource from which that food is derived.

EFFECT OF DROUGHT ON GROWTH AND YIELD:

Drought has profound effects on growth, yield and plant quality. The first effect of the stress may well be a loss of turgor that affects the rate of cell expansion and ultimately the cell size. Loss of turgor is probably the process most sensitive to water (drought) stress. The result is a decrease of growth rate of stem elongation, of leaf expansion, and of stomatal aperture.

The mechanism underlying the responses of plants to water stress may be divided into five categories.

1. Reduction of water potential or activity of cellular water.
2. Decrease of cell turgor pressure.
3. Concentration of small molecules and macromole-

cules as cell volume decreases with reduced turgor.

4. Alteration of spatial relations in the plasmalemma, tonoplast and organelle membranes by volume changes.
5. Changes in structure and configuration of macromolecules by removal of water of hydration or through modification of structure of adjacent water.

EFFECT OF DROUGHT ON PHOTOSYNTHESIS:

The effect of water stress on photosynthesis are not well understood, but there has been sustained interest in trying to understand how drought stress affect photosynthesis. Experiments have suggested that water stress affect photosynthesis in atleast three ways.

1. By closure of stomata.
2. By inhibition of light reaction.
3. By inhibition of dark reaction.

While much of the reduction in photosynthesis can be attributed to stomatal closure, part of the reduction has been attributed to direct effects of dehydration on the biochemical reactions of photosynthesis. Under water-stress conditions that causes closure of stomates, radient energy continues to be intercepted and observed by leaves . The reducing power produced that ordinarily would be used in reducing the carbon of CO_2 but with stomates closed, CO_2 entrance into leaf is limited. This causes damage to both electron transport system as well as to CO_2 fixation. This excess reducing energy is damaging and has to be dissipated (utilized) inorder to protect the photosynthetic process. Photorespiration in C3 plants is one such process by which the reducing power are utilized by fixing the CO_2 released in the breakdown of Ribulose-1,5-bisphosphate during glycolate pathway. The biological cost of this process is high thus productivity is reduced at the cost of plant survival. Severe osmotic stress of chloroplasts and cell can

also inhibit activity of an enzyme (fructose-1,6-bisphosphatase) which also participate in CO_2 fixation process.

SALT STRESS:

Salinity like drought remains as one of the world's oldest and most serious environmental problem. Excessive irrigation and inadequate drainage are the principal cause of this build-up of salinity. It is claimed that mismanaged irrigation system and the resulting salinity is undermining to varying degrees the productivity of at least one-third of 230×10^6 hactare of the world's irrigated land.

Plants are stressed in two ways in high salt environment. In addition to the water stress imposed by the increase in osmotic potential of the rooting medium as a result of high solute content, there is the toxic effect of high concentrations of ions. Some plants have evolved mechanisms for dealing with these stresses and other can become adapted to them. But the majority of crop plants are susceptible and will not survive under conditions of high salinity or may survive but with substaintially decreased yield since most of the energy is being spent on the maintaining of the plants by generating organic solute (organic osmoticum) to over come the changes in the osmotic potential.

Recent studies point out that salt stress could also affect the photosynthesis. There is a theory that salt stress would affect the photosynthesis in the similar manner as does the drought since both causes closure of stomatas. However, it has been reported that salt stress generally does not causes damage to the primary photochemistry of the photosynthesis and it rather increases the rate of electron transport, but it may cause in the phosphorylation rate thus producing less ATP. However, actual mechanism is not yet fully understood.

LIGHT:

Light is the primary source of energy to the plants. As long as the absorbed light is utilized for photochemical reactions it is harmless to the photosynthetic system. However, in nature plants frequently experience excess light energy which lead to the formation of toxic singlet oxygen in chloroplasts and degradation of D1 (32 kDa) protein in the photosystem II, thus resulting in the decreased activity of photosynthesis. Additional environmental stresses, such as temperature, drought, salinity, can enhance the damage by light. Under these conditions a given light level which was previously not excessive become inhibitory because the utilization of energy through photosynthesis is decreased by predisposing the photosynthetic system under additional stresses.

The light reaction is further divided into two systems, photosystem I (PS I) and photosystem II (Ps II) on the basis of the wave length of light absorbed by these systems. Generally PS I system is not affected much by excess light but the PS II is damaged significantly. High light condition generate free oxygen radicals which causes damage (degradation) of 32 kDa protein. This protein is important because it houses the mechinary which is involved in the interception of light photon, generating oxidising power to carry out photolysis (break down of H_2O into H^+ and $\frac{1}{2} O_2$) and further transportation of electrons (generated due to photolysis). The machinary include Z (a tyrosine 161 residue which act as electron donor tp P680), pheophytin, quinones, a special pair of chlorophyll (known as PS II reaction centre) and probably O_2 evolving system. As a result of the degradation of 32 kDa protein the efficiency of electron capture as well as electron transport is reduced, thus limiting the photosynthesis process. Besides certain enzymes involved in the CO_2 metabolic pathway (light regulated ones) might also be affected.

A substantial amount of information is now available regarding the mechanism of damage to the plant system under various environmental stresses. However, the challange before the plant scientist is to modify the plant system so that plants are not susceptible to the damage caused by environmental stresses. Research is in progress in this direction but lot of work (read money) is to be done to overcome the problem.

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