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The Impact of UV Light on Plants to cope the Stress Environment

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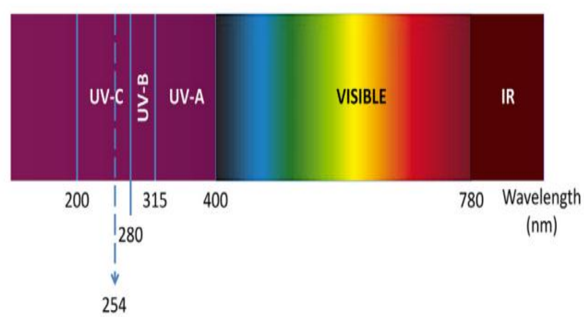
Introduction:

The sun is essential for sustaining life on the earth; however, sunlight also contains a small amount of short wavelength ultraviolet (UV) light irradiation, which is harmful to life on planet earth. Fortunately, most of this harmful UV irradiation is filtered out by the stratospheric ozone layer, which strongly absorbs UV light. Unfortunately, this protective shield is being continually damaged by human activities. The UV radiation intensity is mostly affected by the thickness of the stratospheric ozone layer and exactly this type of radiation is most harmful to plants. However, many of the acclimation changes elicited by UV induce a wide range of positive effects in plant physiology through the elicitation of secondary antioxidant metabolites and natural defences. Plants are often subjected to various environmental stressors i.e., biotic stress and abiotic stress. Abiotic stress, such as drought, high salinity, and extreme temperatures, which can adversely affect their growth and development. Biotic stress, caused by living organisms such as pathogens, pests, and herbivores, poses a significant threat to plant health and productivity. Plants responses to UV are an integration of its cross-talks with both environmental factors and phytohormones. Ultraviolet (UV) light, despite its potential to cause damage, can also have positive effects on plants under stress conditions.

Ultraviolet radiation-

Ultraviolet radiation (UVR) small part of electromagnetic spectrum lying between visible light and X ray region. Natural source of UVR is sun and UVR are invisible to the human eyes. farmers. However, the growth of agriculture sector has not kept pace with the growth of the



(Zhang *et al*. 2019)

Pic 1- UV light positioned in relation to the rest of the light spectrum

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- **Mechanisms evolved by plants for protection against the deleterious effects of UV radiation-:**

a. **Activation of Defense Mechanisms-** UV light exposure activates various defense mechanisms in plants, including the production of antioxidants and other protective compounds. These compounds help plants cope with oxidative stress caused by environmental factors, enhancing their resilience to stress conditions.

b. **Regulation of Gene Expression-** UV light can induce changes in gene expression in plants, leading to the upregulation of genes involved in stress responses. This helps plants adapt to adverse environmental conditions by enhancing their ability to tolerate stressors.

c. **Enhancement of Photosynthetic Efficiency-** While excessive UV exposure can damage photosynthetic machinery, moderate levels of UV light can stimulate the production of protective pigments such as flavonoids and carotenoids. These pigments not only protect the plant from UV damage but also improve photosynthetic efficiency, ensuring sufficient energy production under stress conditions.

d. **Improved Water Use Efficiency-** Plants exposed to UV light have been found to exhibit improved water use efficiency, allowing them to better withstand drought stress. This is attributed to the enhanced closure of stomata, reducing water loss through transpiration. In some cases, UV can reduce drought stress in plants and increase plant production through several potential water conservation and stress tolerance mechanisms (Manetas *et al*., 1997; Schmidt *et al*., 2000).

e. **Regulation of Ion Transport-** UV light can influence the expression of genes involved in ion transport, particularly sodium (Na+) and potassium (K+) uptake and distribution. This regulation helps plants maintain ion balance, which is disrupted under salinity stress, thus mitigating the negative effects of salt accumulation.

f. **Induction of Hormonal Responses-** UV light exposure can trigger changes in plant hormone levels, including abscisic acid (ABA) and jasmonic acid, which play key roles in stress responses. These hormonal changes help plants modulate their physiological processes to cope with stress conditions.

g. **Induction of Stress-Responsive Pathways-** UV light exposure can trigger the activation of stress-responsive pathways in plants, including the expression of stress-related genes and the accumulation of stress-related proteins. These pathways help plants adapt to salinity stress by modulating their physiological processes.

h. **Induction of Oxidative Stress:** Both UV light and heat stress can induce oxidative stress in plants, leading to the accumulation of reactive oxygen species (ROS) and damage to cellular structures. When plants are exposed to both stressors simultaneously, the effects can be additive or synergistic, exacerbating oxidative damage.

➢ **UV Light as a Secondary Stressor (Interactive Effects) -:**

- **Exacerbating Water Stress:** UV light can exacerbate the effects of water stress on plants by inducing oxidative damage, disrupting photosynthesis, and affecting membrane integrity. Excessive UV exposure can increase plant water loss through transpiration, leading to accelerated dehydration and reduced plant survival under water-stress conditions.
- UV light and **water (drought) stress** can interact to modulate plant physiology and metabolism. The combined stressors can alter stomatal conductance, photosynthetic rates, and water use efficiency, leading to either improved drought tolerance (Manetas *et al*. 1997; Schmidt *et al*. 2000; Poulson *et al*. 2006) or increased susceptibility to water stress depending on the plant species and environmental conditions. Synergistic or additive effect of UV rays has been observed to inhibit growth in the presence of water deficit conditions (Ren *et al*. 2007).
- UV light and **heat stress** can both impair photosynthetic processes in plants. UV-B radiation can directly damage photosynthetic pigments, while heat stress can disrupt photosynthetic machinery and reduce carbon assimilation. Together, these stressors can lead to a significant reduction in photosynthetic efficiency and plant productivity (Findlay and Jenkins, 2016).
- Both UV light and **heavy metals** can induce the production of reactive oxygen species (ROS) in plant cells.

Under heavy metal stress, ROS levels are elevated due to metal-induced oxidative damage. UV light exposure exacerbates this oxidative stress, leading to further damage to cellular components such as proteins, lipids, and DNA.

- **Modulation of Stress Responses**

1. **Activation of Defense Mechanisms**: UV light exposure can induce the production of defense-related compounds in plants, such as antioxidants and heat shock proteins (HSPs). Antioxidants, such as superoxide dismutase (SOD), catalase (CAT), glutathione (GSH), and ascorbic acid (vitamin C). These antioxidants scavenge reactive oxygen species (ROS) generated under stress conditions, reducing oxidative damage (Costa *et al.*, 2002), maintaining cellular integrity and assist in the refolding of denatured proteins, maintaining cellular homeostasis under heat stress conditions. Plants have developed a complex antioxidant system that includes reduced glutathione (GSH), ascorbic acid (ASA), tocopherol, carotenoids and enzymes that protect plants against oxidative damage
2. **Regulation of Hormone Levels:** UV light exposure can modulate the levels and activity of plant hormones, such as abscisic acid (ABA) and ethylene, which play key roles in plant responses to heat stress. UV-B radiation can induce the synthesis of ABA, which regulates stomatal closure and water use efficiency, helping plants cope with heat-induced water stress.
3. **Regulation of Metal Transporters:** UV light exposure can influence the expression of genes encoding metal transporters in plants. This can affect the uptake, translocation, and sequestration of heavy metals in plant tissues, altering their distribution and accumulation patterns. UV-induced changes in metal transporter expression can influence plant tolerance to heavy metal stress.
4. **Alteration of Metal Chelation:** UV light exposure can affect the synthesis and accumulation of metal-chelating compounds, such as phytochelatins and metallothioneins, in plant cells. These compounds bind to heavy metals and sequester them in vacuoles, reducing their toxicity and protecting plant cells from heavy metal-induced damage.
5. **Regulation of Plant-Pathogen Interactions :**

a. **Modulation of Pathogen Growth:** UV light exposure can directly inhibit the growth and development of pathogens by inducing DNA damage and disrupting cellular functions. UV-B radiation can also alter the structure of pathogen cell walls, making them more susceptible to plant defense mechanisms.

b. **Enhanced Plant Immunity**: UV light exposure can enhance plant immunity by priming defense responses. Primed plants exhibit faster and stronger defense responses upon subsequent pathogen attack, leading to increased resistance to biotic stressors.

➢ **Influence on Plant Growth and Development**

1. **Stimulation of Growth Regulators:** UV light exposure can stimulate the production of growth-promoting hormones, such as gibberellins (GA) and cytokinins (CK), which counteract the inhibitory effects of heat stress on plant growth. These hormones promote cell elongation, root growth, and lateral root development, enhancing plant adaptation to heat stress.

2. **Impact on Flowering and Reproduction:** UV light exposure can influence flowering time and reproductive development in plants. Heat stress can disrupt flower development and reduce pollen viability, leading to reduced seed set and yield. UV light exposure may exacerbate these effects or trigger compensatory responses in plants.

3. **Reduce crop yield due to UV rays** Hakala *et al*. (2002) observed sensitivity of various agricultural plant species including barley, wheat, oat, clover, timothy, fescue and potato to UV-B radiation exposure (as if ozone layer would be decreased by 30%) and found no significant variation of biomass accumulation or yield.

Conclusion

Climate change is going to differently affect crop productivity in different areas of the world, although regional climatic variations and differences in availability of natural resources make difficult the assessment of crop response at a local level based on global models. The depletion of the stratospheric ozone layer by manmade pollution has substantially increased UV light impinging on the earth surface. Higher than normal levels of UV causes various damages to plants such as DNA and membrane injuries, photosynthetic or hormone systems disorders. Many species of plants have evolved mechanisms for protection against the deleterious effects of UV radiation. There are several protective mechanisms against UV-B damage in plants that is dependent on plant species. The main mechanisms are accumulation of UV-B absorbing pigments such as flavonoids and polyamines, ways by which plants alleviate the harmful effects of UV irradiation.

References

1. Costa H, Gallego SM, Tomaro ML (2002). Effects of UV-B radiation on antioxidant defense system in sunflower cotyledons. Plant Sci., 162(6): 939-945.
2. Dai Q, Coronel VP, Vergara BS, Barnes PW, Quintos AT (1992). Ultraviolet-B radiation effects growth and physiology of four rice cultivars. Crop Sci., 32: 1269-1274.
3. Findlay KM, Jenkins GI (2016) Regulation of UVR8 photoreceptor dimer/monomer photo-equilibrium in Arabidopsis plants grown under photoperiodic conditions. Plant Cell Environ 39: 1706–1714.
4. Hakala K, Jauhiainen L, Koskela T, Kayhko P, Vorne V (2002). Sensitivity of Crops to Increased Ultraviolet Radiation in Northern Growing Conditions. J. Agro. Crop Sci., 188: 8–18.
5. Manetas Y, Petropoulou Y, Stamatakis K, Nikolopoulos E, Levizou G, Psaras, and Karabourniotis G (1997). Beneficial effects of enhanced UV-B radiation under field conditions; improvement of needle water relations and survival capacity of Pinus pinea L. seedlings during the dry Mediterranean summer. Plant Ecol., 128: 100–108.
6. Poulson ME, Boeger MRT, Donahue RA (2006) Response of photosynthesis to high light and drought for Arabidopsis thaliana grown under a UV-B enhanced light regime. Photosynth Res 90: 79.
7. Ren J, Dai W, Xuan Z, Yao Y, Korpelainen H, Li C (2007) The effect of drought and enhanced UV-B radiation on the growth and physiological traits of two contrasting poplar species. For Ecol Manag 239: 112–119.
8. Schmidt A, Ormrod DP, Livingston NJ, Misra S (2000). The interaction of ultraviolet-B radiation and water deficit in two Arabidopsis thaliana genotypes. Ann. Bot., 85: 571–575.
9. Ziska LH, Teramura AH (1992). CO2 enhancement of growth and photosynthesis in rice: Modifications by increased ultraviolet-B radiation. Plant Physiol., 99: 473-481.