School of Basic and Applied Sciences

Course Code : MSBS6002

Course Name: Plant Physiology

Plant stress

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Program Name: M.Sc. Biological Science Sem III

STOMATA RESPOND TO WATER DEFICIT

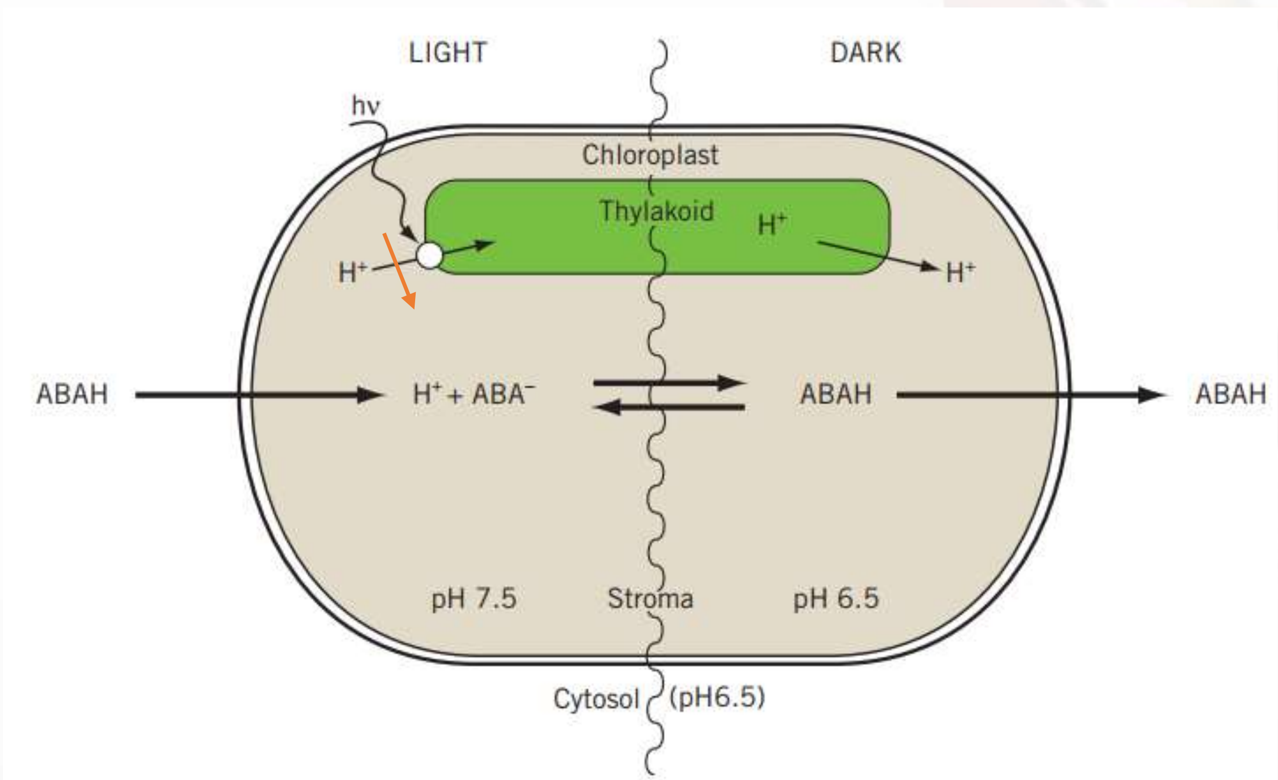
- ✓ Plants are often subjected to acute water deficits due to a rapid drop in humidity or increase in temperature → dramatic increase in the vapor pressure gradient between the leaf and the surrounding air → rate of transpiration increases.
- ✓ An increase in the vapor pressure gradient will also enhance drying of the soil → consequences for the uptake of water by shallow-rooted plants → respond to water stress by closing their stomata in order to match transpirational water loss through the leaf surfaces with the rate at which water can be resupplied by the roots.
- ✓ Established fact stomatal opening and closure is responsive to ambient humidity.
- ✓ Unlike the surrounding epidermal cells, the surfaces of the guard cells are not protected with a heavy cuticle guard cells lose water directly to the atmosphere → If the rate of evaporative water loss from the guard cells exceeds the rate of water regain from underlying mesophyll cells, the guard cells will become flaccid and the stomatal aperture will close.
- ✓ Closure of the stomata by direct evaporation of water from the guard cells is sometimes referred to as **hydropassive closure**.

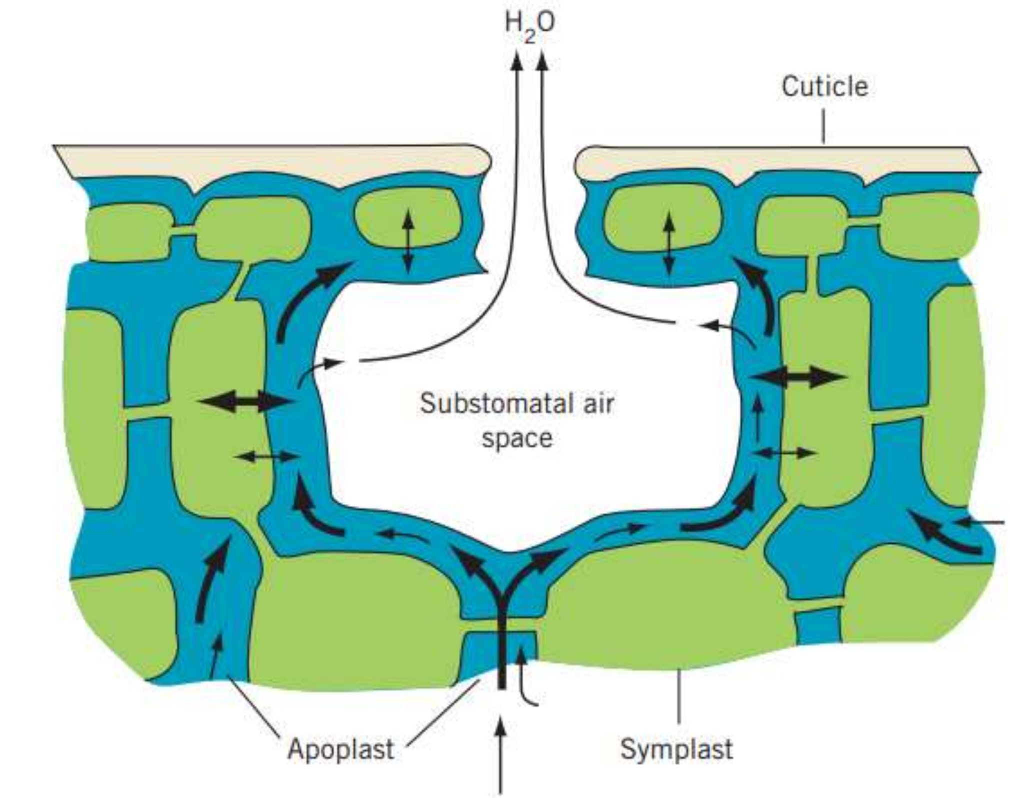
STOMATA RESPOND TO WATER DEFICIT

- Stomatal closure is also regulated by *hydroactive* processes. **Hydroactive closure** is metabolically dependent and involves essentially a reversal of the ion fluxes that cause opening.
- Hydroactive closure is triggered by decreasing water potential in the leaf mesophyll cells and appears to involve abscisic acid (ABA) and other hormones.
- ABA has been known to have a prominent role in stomatal closure due to water stress.
- ABA accumulates in water-stressed (that is, wilted) leaves and external application of ABA is a powerful inhibitor of stomatal opening.
- The precise role of ABA in stomatal closure in water-stressed whole plants has, however, been difficult to decipher with certainty because ABA is ubiquitous, often occurring in high concentrations in nonstressed tissue.
- In most well-watered plants, ABA appears to be synthesized in the cytoplasm of leaf mesophyll cells but, because of intracellular pH gradients, ABA accumulates in the chloroplasts.
- At low pH, ABA exists in the protonated form ABAH, which freely permeates most cell membranes. The dissociated form ABA- is impermeant; because it is a charged molecule it does not readily cross membranes.

STOMATA RESPOND TO WATER DEFICIT

- Thus, ABAH tends to diffuse from cellular compartments with a low pH into compartments with a higher pH.
- It is well established that in actively photosynthesizing mesophyll cells the cytosol will be moderately acidic (pH 6.0 to 6.5) while the chloroplast stroma is alkaline (pH 7.5 to 8.0).
- It has been calculated that if the stroma pH is 7.5 and cytosolic pH is 6.5, the concentration of ABA in the chloroplasts will be about tenfold higher than in the cytosol.





STOMATA RESPOND TO WATER DEFICIT

- ✓ Inhibition of electron transport and photophosphorylation in the chloroplasts would disrupt proton accumulation in the thylakoid lumen and lower the stroma pH.
- ✓ At the same time, there is an increase in the pH of the apoplast surrounding the mesophyll cells.
- ✓ The resulting pH gradient stimulates a release of ABA from the mesophyll cells into the apoplast, where it can be carried in the transpiration stream to the guard cells.
- ✓ How ABA controls turgor in the guard cells remains to be determined.
- ✓ Evidence indicates that ABA does not need to enter the guard cell, but acts instead bind on the outer surface of the plasma membrane (binding sites) interferes with proton pumps and, consequently, the uptake of K+, or that it stimulates K+ efflux from the guard cells lose turgor, leading to closure of the stomata.

PLANTS ARE SENSITIVE TO FLUCTUATIONS IN TEMPERATURE

- ✓ Plants exhibit a wide range of sensitivities to extremes of temperature.
- ✓ Some are killed or injured by moderate chilling temperatures while others can survive.
- ✓ Each plant has its unique set of temperature requirements for growth and development.
- ✓ There is an optimum temperature at which each plant grows and develops most efficiently, and upper and lower limits.
- ✓ As the temperature approaches these limits, growth diminishes, and beyond those limits there is no growth at all.
- ✓ Except in the relatively stable climates of tropical forests, temperatures frequently exceed these limits on a daily or seasonal basis, depending on the environment.
- ✓ For example, desert and high altitudes plants.
- ✓ Plants native to the northern temperate and boreal forests must survive temperatures as low as -70◦C every winter.

PLANTS ARE SENSITIVE TO FLUCTUATIONS IN TEMPERATURE

- ✓ Plants native to warm habitats are injured when exposed to low, nonfreezing temperatures and are considered to be **chilling sensitive**.
- ✓ Eg. maize (*Zea mays*), tomato (*Lycopersicon esculentum*), cucumber (*Cucurbita* sp.), soybean (*Glycine max*), cotton (*Gossypium hirsutum*), and banana (*Musa* sp.) are particularly susceptible and will exhibit signs of injury when exposed to temperatures below 10 to 15◦C.
- ✓ Symptoms of chilling injury reflect a wide range of metabolic dysfunctions in chilling-sensitive tissues, including: impaired protoplasmic streaming, reduced respiration, reduced rates of protein synthesis as well as altered patterns of protein synthesis.
- ✓ One of the immediate plant responses to a chilling stress is the light-dependent inhibition of photosynthesis.
- ✓ Because low temperature inhibits the D1 repair cycle, this leads to chronic photoinhibition of PSII and PSI in cucumber.

PLANTS ARE SENSITIVE TO FLUCTUATIONS IN TEMPERATURE

- ✓ Low temperature causes reversible changes in the physical state of cellular membranes.
- ✓ Membrane lipids consist primarily of diacylglycerides containing two fatty acids of either 16- or 18-carbon atoms.
- ✓ Chilling-sensitive plants tend to have a higher proportion of saturated fatty acids and a correspondingly higher transition temperature.
- ✓ Chilling-resistant species, on the other hand, tend to have lower proportions of saturated fatty acids and, therefore, lower transition temperatures.
- ✓ During acclimation to low temperature, the proportion of unsaturated fatty acids increases and transition temperature decreases.
- ✓ The integrity of membrane channels is disrupted.

HIGH-TEMPERATURE STRESS CAUSES PROTEIN DENATURATION

- ✓ Reactions in the thylakoid membranes of higher plant chloroplasts are most sensitive to high-temperature damage, with consequent effects on the efficiency of photosynthesis.
- ✓ Photosystem II and its associated oxygen-evolving complex are particularly susceptible to injury.
- ✓ Other studies have indicated that the activities of Rubisco, Rubisc activase, and other carbon-fixation enzymes, may also be severely compromised at high temperatures.
- ✓ Exposure of most organisms to supraoptimal temperatures for brief periods also suppresses the synthesis of most proteins including the PSII reaction center polypeptide, D1.
- ✓ This leads to an inhibition of the D1 repair cycle that is critically important to overcome the effects of chronic photoinhibition.
- ✓ High-temperature stress also induces the synthesis of a new family of low molecular mass proteins known as **heat shock proteins (HSPs)**.

HIGH-TEMPERATURE STRESS CAUSES PROTEIN DENATURATION

- ✓ They either not present or present at very low levels in nonstressed tissues.
- ✓ HSPs are found throughout the cytoplasm as well as in nuclei, chloroplasts, and mitochondria.
- ✓ Eg. Ubiquitin (proteolytic degradation), HSP90, HSP70. molecular chaperone, or chaperonin (prevent the disassembly and denaturation of multimeric aggregates).
- ✓ The speed of their appearance suggests that HSPs might have a critical role in protecting the cell against deleterious effects of rapid temperature shifts.

HSP

HSP Family	Probable Function
HSP 110	Unknown.
HSP 90	Protecting receptor proteins.
HSP 70	ATP-dependent protein assembly or disassembly reactions; preventing protein from denaturation or aggregation (molecular chaperone). Found in cytoplasm, mitochondria, and chloroplasts.
HSP 60	Molecular chaperone, directing the proper assembly of multisubunit proteins. Found in cytoplasm, mitochondria, and chloroplasts.
LMW HSPs (17–28 kDa)	Function largely unknown. LMW (low-molecular-weight) HSPs reversibly form aggregates called "heat shock granules". Found in cytoplasm and chloroplasts.
Ubiquitin	An 8 kDa protein involved in targeting other proteins for proteolytic degradation.

References

- ✓ Hopkins, W.G. and Hüner, N.P.A. 2009. Introduction to plant physiology, 4th ed. John Wiley & Sons, Inc.
- ✓ Taiz, L. and Zeiger, E. 2002. Plant Physiology, 3rd ed. Sinauer Associates.