COURSE: MSc Part -II

PAPER – IX

TOPIC- (Plant Physiology and Biochemistry)

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TOPIC-1

Stomatal opening and closing

There are different mechanisms which are responsible for the opening and closing of the stomata. The opening and closing depends upon the turgor pressure in the guard cells. The swelling of guard cells due to absorption of water causes opening of stomatal pores while shrinking of guard cells closes the pores. Opening and closing of stomata occurs due to turgor changes in guard cells. When guard cells are turgid, stomatal pore is open while in flaccid conditions, the stomatal aperture closes. There are other theories which explains the opening and the closing of the stomatal pore.

The stomata are very minute apertures, usually found on the epidermis of the leaves. Each stoma is surrounded by two kidney-shaped special epidermal cells, known as guard cells.

The stomata may be found in all the aerial parts of the plant. They are never found on its roots. The epidermal cells surrounding the guard cells of the stoma are known as accessory or subsidiary cells. Usually the term stoma stands for the stomatal opening and the guard cells.

The guard cells are always living and contain chloroplasts. These cells, however, contain much amount of protoplasm than the other ordinary cells. Usually the stomata are found scattered on the dicotyledonous leaves whereas they are arranged in parallel rows in the case of monocotyledonous leaves. The number of stomata may range from thousands to lacs per square centimeter on the surface of the leaf.

The stomata may be found on both the surfaces of the leaf, but their number is always greater on the lower surface. However, the upper surface of the leaves of banyan and rubber trees lack stomata. The upper surface of the leaves of several xerophytes also lacks the stomata.

The free floating leaves of the water plants bear stomata only on their upper surface. In normal condition the stomata remain closed in the absence of light. They are always open in the day time or in the presence of light.

The important theories of stomatal movement are as follows:

1. Theory of photosynthesis in guard cell- Von Mohl (1856) observe that stomata open in light and close in the night. He then proposed that chloroplasts present in the guard cells photosynthesize in the presence of light resulting in the production of carbohydrate due to which osmotic pressure of guard cells increases.

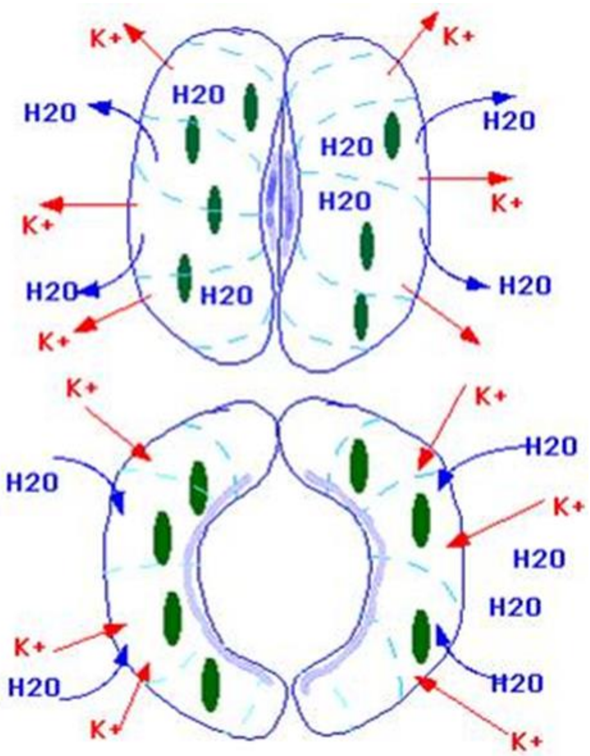
2. Starch Sugar inter-conversion theory- According to Lloyd (1908) turgidity of guard cell depends on inter-conversion of starch and sugar. It was supported by Loft-field (1921). He found out that guard cells contain sugar during day time when they are open and starch during night when they are closed.

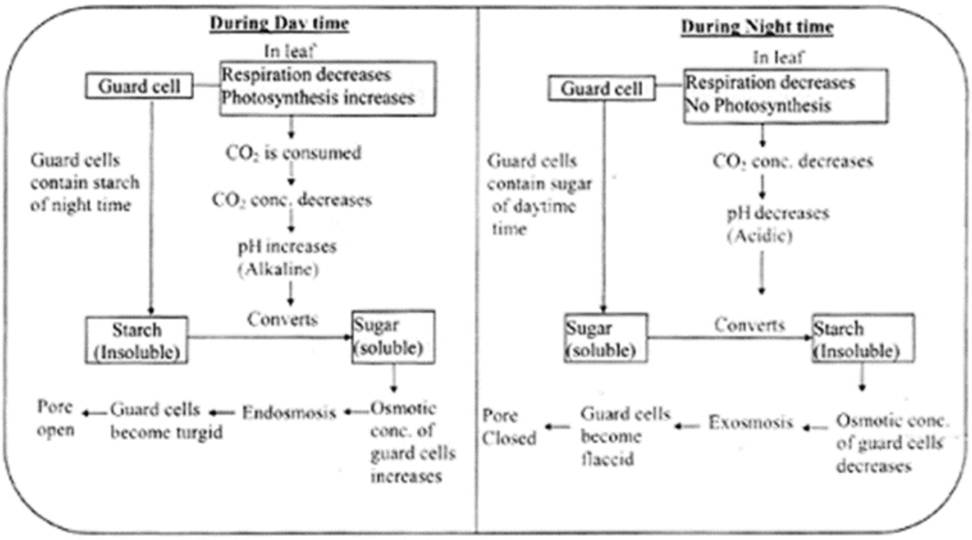
(ii) Sayre (1926) observed that stomata open in neutral or alkaline pH, which prevails during day time due to constant removal of carbon-dioxide by photosynthesis. Stomata remain closed during night when there is no photosynthesis and due to accumulation of carbon-dioxide, carbonic acid is formed that causes the pH to be acidic. Thus, stomatal movement is regulated by pH due to inter-conversion of starch and sugar. Sayre concept was supported by Scarth (1932) and Small et. al. (1942).

(iii) Yin and Tung (1948) isolated for the first time phosphorylase enzyme from the guard cells. According to them starch is converted into glucose-1, phosphate in the presence of this enzyme. During the process, inorganic phosphate is also used and light and dark phases (changing CO2 concentration) control the changes in pH. The reaction maybe represented as follows:

(iv) Steward's scheme:

Steward (1964) proposed another modified scheme of inter-conversion of starch and sugar for stomatal movement. He believes that conversion of starch to Glucose -1 phosphate is not sufficient. It should be converted to glucose in order to increase sufficient osmotic pressure. For this, ATP is also required which means that the process should be through respiration in presence of oxygen. Guard cell carries enzymes like Phosphorylase, Phosphoglucomutase, Phosphatase and Phosphorylase. These enzymes help in opening and closing of the stomata.





3. Theory of glycolate metabolism-- Zelitch (1963) proposed that production of glycolic acid in the guard cells is an important factor in stomatal opening. Glycolate is produced under low concentration of CO2. He suggested that glycolate gives rise to carbohydrate, thus raising the osmotic pressure and also that it could participate in the production of ATP. Which might provide energy required for the opening of stomata.

4. Active potassium transport ion concept-Role of potassium K+ in stomatal opening is now universally accepted. This was observed for the first time by Fujino (1967) that opening of stomata occurs due to the influx of K+ ions into the guard cells.The sources of K+ ions are nearby subsidiary and epidermal cells, thereby increasing the concentration from 50 mM to 300 mM in guard cells. The increase in K+ ions concentration increases the osmotic concentration of guard cells thus leading to stomatal opening. The uptake of potassium K+ controls the gradient in the water potential.

This in turn triggers osmotic flow of water into the guard cells raising the turgor pressure. ATP helps in entry of K+ ions into the guard cells. Levitt (1974) observed that proton (H+) uptake by guard cell’s chloroplasts takes place with the help of ATP. This leads to increase in value of pH in guard cells. Rise in pH converts starch into organic acid, such as malic acid.

Malic acid further dissociates to form H+ and malate anion. The uptake of potassium K+ ions is balanced by one of the following:

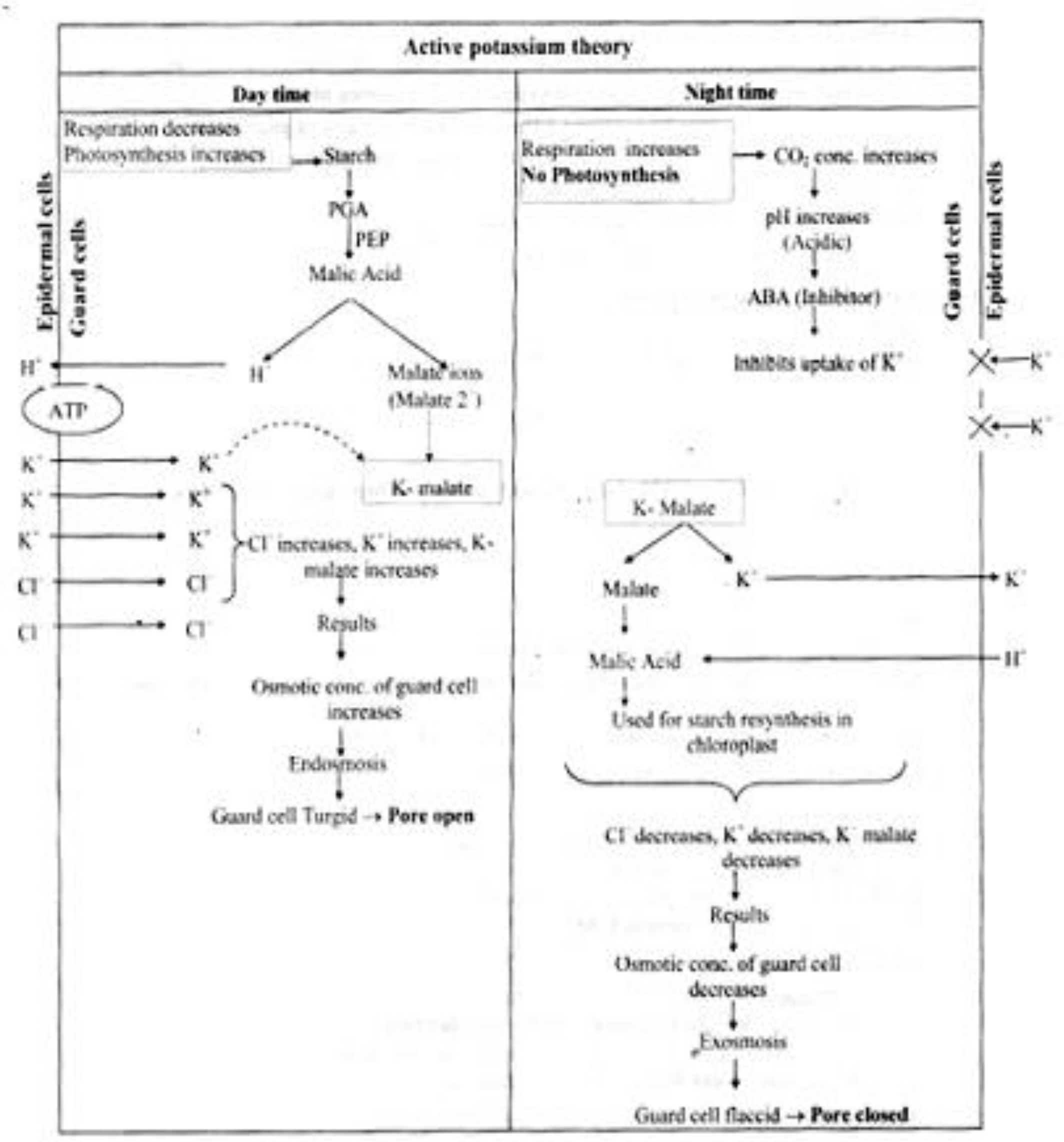
(i) Uptake of Cl–

(ii) Transport of H+ ions from organic acids, such as malic acid

(iii) By negative charges of organic acids when they lose H+ ions.

The accumulation of large amounts of K+ ions in guard cells is electrically balanced by the uptake of negatively charged ions, i.e., chloride and malate. The high amount of malate in guard cells of open stomata accumulates by hydrolysis of starch.

The stomatal closure is considered to be brought about by a passive or highly catalysed excretion of K+ and CI− from the guard cells to the epidermal tissue in general and subsidiary cells in particular. It is thought that subsidiary cells have an active reabsorption mechanism of K+.



Topic-2

Vernalization

Vernalization defines as a process of growing flowers and fruits through a phase of cold treatment. It reduces the time period of the juvenile vegetative growth phase in the plants. The active meristematic cells of the shoot apex, root apex, embryo tips etc. participate in the production of stimulus refers as “Vernalin”. The term vernalization has been originated from the Latin word “Vernalis” which means “of the spring”. Before reproduction, it allows vegetative maturity.

Definition of Vernalization

Vernalization can define as the process where the seedling is subjected to low temperature (5-10 degrees Celsius) during winter followed by exposure to a high temperature (about 40 degrees Celsius). The process of subjecting seedling from the cold temperature to the high temperature is called devernalization. The temperature and the time period of the chilling process depend upon the plant species.

It was found by Lysenko (1928), a Russian worker that the cold requiring annual and biennial plants can be made to flower in one growing season by providing low temperature treatment to young plants or moistened seeds.He called the effect of this chilling treatment as vernalization. Vernalization is, therefore, a process of shortening of the juvenile or vegetative phase and hastening flowering by a previous cold treatment

Mechanism of Vernalization:

The stimulus received by the actively dividing cells of shoot or embryo tip travels to all parts of the plant and prepare it to flower. The stimulus has been named as vernalin. It can be passed from one plant to another through grafting in case of Henbane but not in others. However, the chemical has not been separated. In some plants cold treatment can be replaced by gibberellins.

Vernalization prepares the plant to flower. The induction of flowering depends upon the presence of other favourable conditions. Photoperiodism, however, not only prepares the plant to flower but also brings about flowering. Thus, Henbane is a long-day plant which also requires cold treatment. Unless and until both are provided the plant will not come to flower .

Effect of vernalization

Vernalization can occur in two ways, namely facultative and obligate. Facultative vernalization results in early flowering once exposed to the low temperature, while obligate vernalization requires exposure of the seedling to the desired time period to induce flowering.

The factors affecting vernalization includes:

1. Low temperature

2. Time period: The time period of vernalization depends upon the plant type, and can vary from a few days to weeks or even several months.

3. Actively dividing cells: The process of vernalization occurs in the germinating seed, which comprises an active embryo.

4. Water and Oxygen: Proper protoplasmic hydration is a prerequisite need for the seedling to recognize a stimulus. Vernalization needs the presence of adequate oxygen as it is an aerobic process which regulates metabolic energy inside a plant cell.

The hypothesis of phasic development

According to Lysenko, vernalization method completes in two stages:

Lysenko hypothesis of phasic development

Thermostage: It can defined as the primary stage, where the slightly germinated seeds are exposed to a low temperature of 0-5 degrees Celsius in the presence of oxygen and moisture. During this stage, structures like root, stem and leaves develop and also refers as a vegetative phase. Here the seed loses its dormancy and starts to germinate.

Photostage: It is the secondary stage, where the seedling after vernalization is subjected to the phase of correct photoperiod or high temperature upto 40 degrees Celsius. It can define as the reproductive stage, where the seedlings grow the reproductive structures like flowers and fruits.

The hypothesis of hormonal involvement

According to Chailakhyan, vernalization method has two possibilities:

In long-day plants: A flowering hormone “Anthesins” is present that convert vernalin hormone into the growth-regulating hormone gibberellic acid, which finally induces flowering in a plant.

In short-day plants: These lacks a flowering hormone “Anthesins” that convert vernalin into gibberellic acid, and do not induce flowering.

Advantages

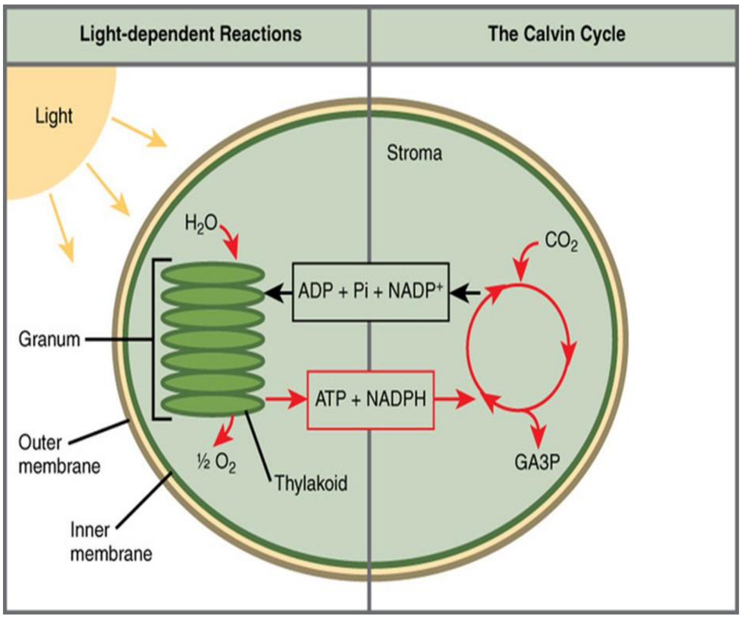
Vernalization gives adequate time to the plants to get mature and prevents pre maturing during their growing season. It reduces the vegetative phase and hastens the reproductive period. Vernalization increases the growth yield.It makes the plant more adaptable by allowing them to grow in such regions where they usually don’t grow.It also removes wrinkles on kernels of Triticale.This process is not only applicable to the temperate plants but also some tropical plants like wheat, rice, millets etc.

Topic-3

Mechanism of Photosynthesis

Photosynthesis, the process by which green plants and certain other organisms transform light energy into chemical energy. During photosynthesis in green plants, light energy is captured and used to convert water, carbon dioxide, and minerals into oxygen and energy-rich organic compounds.

It is convenient to divide the photosynthetic process in plants into four stages, each occurring in a defined area of the chloroplast: (1) absorption of light, (2) electron transport leading to the reduction of NADP+ to NADPH, (3) generation of ATP, and (4) conversion of CO2 into carbohydrates (carbon fixation).



The Process of Photosynthesis

During photosynthesis, molecules in leaves capture sunlight and energize electrons, which are then stored in the covalent bonds of carbohydrate molecules. That energy within those covalent bonds will be released when they are broken during cell respiration. How long lasting and stable are those covalent bonds? The energy extracted today by the burning of coal and petroleum products represents sunlight energy captured and stored by photosynthesis almost 200 million years ago.

Photosynthetic and Chemosynthetic Organisms: Photoautotrophs, including (a) plants, (b) algae, and (c) cyanobacteria, synthesize their organic compounds via photosynthesis using sunlight as an energy source. Cyanobacteria and planktonic algae can grow over enormous areas in water, at times completely covering the surface.

Photosynthesis and the Leaf

In plants, photosynthesis generally takes place in leaves, which consist of several layers of cells. The process of photosynthesis occurs in a middle layer called the mesophyll. The gas exchange of carbon dioxide and oxygen occurs through small, regulated openings called stomata (singular: stoma), which also play a role in the plant's regulation of water balance. The stomata are typically located on the underside of the leaf, which minimizes water loss. Each stoma is flanked by guard cells that regulate the opening and closing of the stomata by swelling or shrinking in response to osmotic changes.

Photosynthesis within the Chloroplast

In all autotrophic eukaryotes, photosynthesis takes place inside an organelle called a chloroplast. For plants, chloroplast-containing cells exist in the mesophyll. Chloroplasts have a double membrane envelope composed of an outer membrane and an inner membrane. Within the double membrane are stacked, disc-shaped structures called thylakoids.

Embedded in the thylakoid membrane is chlorophyll, a pigment that absorbs certain portions of the visible spectrum and captures energy from sunlight. Chlorophyll gives plants their green color and is responsible for the initial interaction between light and plant material, as well as numerous proteins that make up the electron transport chain. The thylakoid membrane encloses an internal space called the thylakoid lumen. A stack of thylakoids is called a granum, and the liquid-filled space surrounding the granum is the stroma or "bed."

Structure of the Chloroplast: Photosynthesis takes place in chloroplasts, which have an outer membrane and an inner membrane. Stacks of thylakoids called grana form a third membrane layer.

The Two Parts of Photosynthesis

Light-dependent and light-independent reactions are two successive reactions that occur during photosynthesis.

In light-dependent reactions, the energy from sunlight is absorbed by chlorophyll and converted into chemical energy in the form of electron carrier molecules like ATP and NADPH.

Light energy is harnessed in Photosystems I and II, both of which are present in the thylakoid membranes of chloroplasts.

Light-Dependent Reactions

Just as the name implies, light-dependent reactions require sunlight. In the light-dependent reactions, energy from sunlight is absorbed by chlorophyll and converted into stored chemical energy, in the form of the electron carrier molecule NADPH (nicotinamide adenine dinucleotide phosphate) and the energy currency molecule ATP (adenosine triphosphate). The light-dependent reactions take place in the thylakoid membranes in the granum (stack of thylakoids), within the chloroplast.

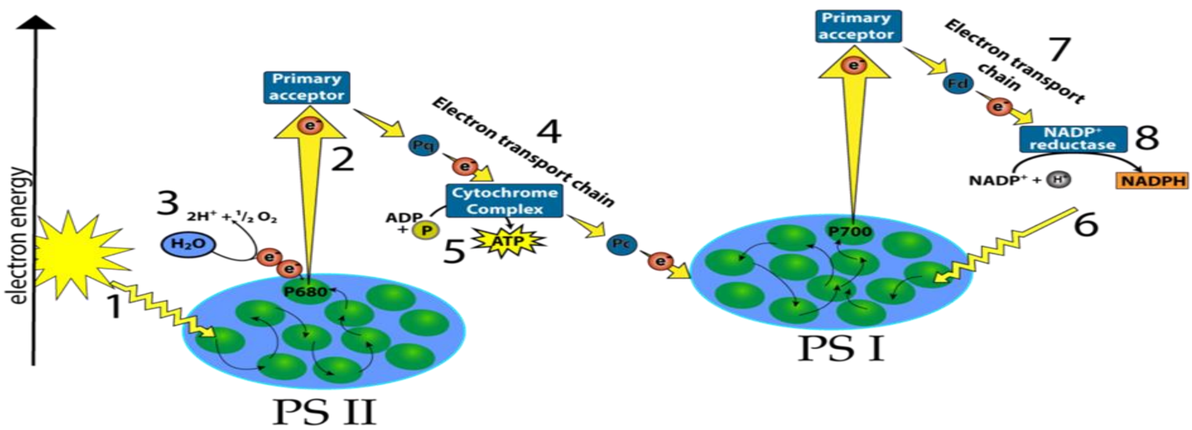
Photosystems

Photosystems I & II: As explained above, the photosystems manipulate electrons with energy harvested from light.

The process that converts light energy into chemical energy takes place in a multi-protein complex called a photosystem. Two types of photosystems are embedded in the thylakoid membrane: photosystem II (PSII) and photosystem I (PSI). Each photosystem plays a key role in capturing the energy from sunlight by exciting electrons. These energized electrons are transported by “energy carrier” molecules, which power the light-independent reactions.

Photosystems consist of a light-harvesting complex and a reaction centre. Pigments in the light-harvesting complex pass light energy to two special chlorophyll a molecule in the reaction centre. The light excites an electron from the chlorophyll a pair, which passes to the primary electron acceptor. The excited electron must then be replaced. In photosystem II, the electron comes from the splitting of water, which releases oxygen as a waste product. In photosystem I, the electron comes from the chloroplast electron transport chain.

Sunlight trapped by Chloroplast enters PS1 and PSII to transduce solar energy into Chemical energy, this chemical energy is required during Carbon fixation or Calvin cycle. This has been shown below in the z scheme. This Scheme is operative in thylakoid. This process is also called as Light reaction which involves Photolysis of water to release e- which is instrumental in operation of PSII. The left-over e- enters PSI to carry out operation. The resultant energy product during these two cycles is ATP and NADPH.The energy produced during light as ATP and NADPH is consumed during dark reaction as shown Calvin cycle below.



Light-Independent Reactions

In the light-independent reactions or Calvin cycle, the energized electrons from the light-dependent reactions provide the energy to form carbohydrates from carbon dioxide molecules. The light-independent reactions are sometimes called the Calvin cycle because of the cyclical nature of the process.

Although the light-independent reactions do not use light as a reactant (and as a result can take place at day or night), they require the products of the light-dependent reactions to function. The light-independent molecules depend on the energy carrier molecules, ATP and NADPH, to drive the construction of new carbohydrate molecules. After the energy is transferred, the energy carrier molecules return to the light-dependent reactions to obtain more energized electrons. In addition, several enzymes of the light-independent reactions are activated by light.