Plant Growth and Development - Part 3

Objectives

After going through this lesson, the learners will be able to understand the following:

- Important phases of growth?
- Classification of plants based on photoperiodism
- Vernalisation effect on flowering

Content Outlines

- Photoperiodism
- Vernalisation
- Seed Dormancy
- Phytochrome
- Summary

Photoperiodism

The physiological mechanism responsible for flowering in plants is controlled by (i) light period- Photoperiodism and (ii) temperature (Vernalization).

W.W. Garner and H.A. Allard (1920) observed in a tobacco mutant Maryland Mammoth, and Soybean a unique response to day length for induction of flowering. They coined a term Photoperiodism to designate the response of organisms to the relative length of the day and night and photoperiod to designate the favourable length of day for each plant. They classified the plants into three groups according to their photoperiods. (Fig.15.15)

- **Short - day plants:** These plants flower when the day length is less than a critical length i.e., twelve hours e.g., *Chenopodium rubrum, Xanthium strumarium.* In short day plants, the length of the day is not as important as the length of night. Such plants require a relatively long period of uninterrupted darkness for flowering. Flowering is inhibited even if a very weak intensity of light is given to plant for some time or as a flash during the dark period
- **Long - day plants:** These plants flower when the day length is greater than a critical length of twelve hours e.g., *Brassica campestris, Sinapsis alba, Spinacia oleracea*. A

long day plant can be made to flower even under short day conditions, if a flash of light is given to the plant during a long dark period.

- **Day - neutral plants:** these plants are insensitive to photoperiod requirement for flower induction e.g., *Gossypium hirsutum, Oryza sativa, Zea mays.*

Photoperiod Induction: In short as well as long day plants only a few days exposure to appropriate photoperiod is enough for inducing flowering, even if the treated plant is then kept in unfavourable photoperiods. This initial important effect on the flowering of a plant is called photoperiod induction.

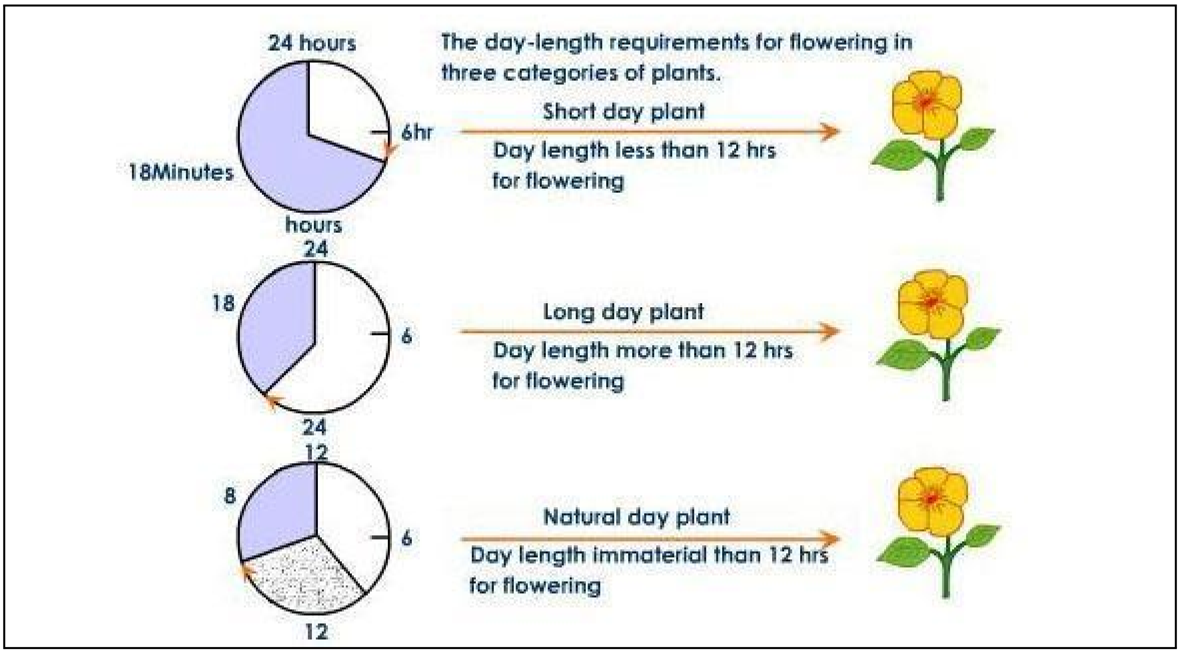

Figure 15.15: Classification of plants based on photoperiodism

Perception of light stimulus: Russian physiologist M.K. Chailachkyan was the first one to demonstrate in *Chrysanthemum* that photoperiodic stimulus is perceived by the leaves of a plant in. Defoliated plants fail to flower even with proper light treatment whereas proper light stimulus received by even a single leaf is sufficient to induce flowering. Moreover mature leaves are more sensitive to photoperiodic stimulus while very young and very old leaves are generally insensitive. Photoperiodic stimulus may be localized showing response only in the region exposed to the stimulus or systemic where even if only a part of the plant is exposed to correct photoperiod stimulus still response is shown by complete plant.

Photoperiodism and Quality of Light: Green colour of the visible spectrum is ineffective in inducing flowering, whereas blue colour induces poor flowering. The red wavelengths from 580 nm to 680 nm in the red portion of the spectrum has been found to be most effective in inducing flowering in both long and short day plants.

Flowering Hormone: Two important pieces of evidence strongly support the existence of flowering hormone in plants.

- There is spatial separation of site of stimulation and site of response. The stimulus is perceived by leaves and then transmitted to buds in the form of flowering hormone.
- The existence of flowering hormones is supported by a number of grafting experiments. A short day plant kept in long day condition can be induced to flower, if a properly photoinduced plant is grafted onto it. It clearly indicates that a diffusible flowering hormone has moved from one plant to the other and has induced the latter to flower.

Chailakhayan (1936) explained the role of three compounds A, B and C in flowering hormone "Florigen" biosynthesis. Compound A is synthesised in leaves from CO_2 during the light period which is then converted into compound B during succeeding dark period. If the dark period is interrupted midway, sufficient amounts of B may not be formed and flowering will, therefore not occur. The compound C is synthesised in leaves from B and then translocated to the shoot apex where it initiates flowering. Compound C is believed to be florigen, the flowering hormone but all attempts to extract florigen have, however, so far failed.

Gibberellins and the flowering response: Many long day plants, if supplied with gibberellins, initiate floral primordial under an otherwise unfavourable photoperiod. Brian, Chailakhyan and Naylor gave a hypothesis that carbon dioxide is believed to give rise to a precursor. The precursor leads to the formation of gibberellin like hormone, which is then converted into the floral hormone, florigen.

Vernalisation

The term Vernalisation was coined by T.D. Lysenko in 1920. It is defined as the acquisition of the ability to flower by a chilling treatment. This results in shortening the interval between sowing and flowering. There are plants for which flowering is either quantitatively or qualitatively dependent on exposure to low temperature. Besides the winter annuals (cabbage, carrot, kales) and biennials there are certain perennials which require cold treatment for flowering. Some important food plants, wheat, barley, rye have two kinds of varieties: winter and spring varieties. The 'spring' varieties are normally planted in the spring and come to flower and produce grain before the end of the growing season. Winter varieties, however, if planted in spring would normally fail to flower or produce mature grain within a span of a flowering season. Hence, they are planted in autumn.They germinate, and over winter come out as small seedlings, resume growth in the spring, and are harvested usually around mid-summer. Another example of vernalisation is seen in biennial plants. Biennials are monocarpic plants that normally flower and die in the second season. Sugarbeet, cabbages, carrots are some of the common biennials. Subjecting the growing of a biennial plant to a cold treatment stimulates a subsequent photoperiodic flowering response (Fig 15.16).

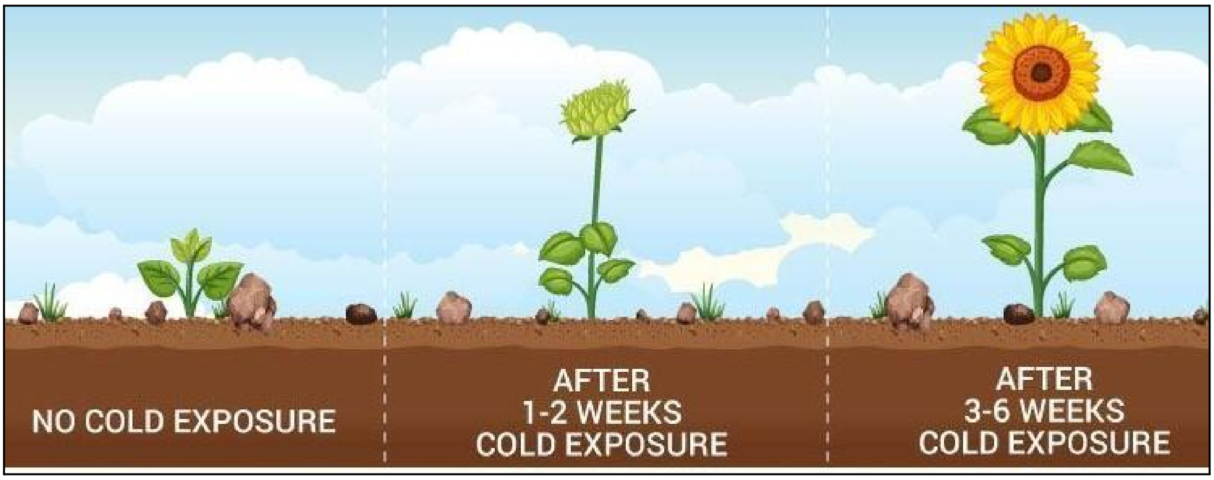

Figure 15.16: Vernalisation effect on flowering

In nature, vernalisation takes place in the sed stage in annuals. In biennials, vegetative growth takes place in the first season, and the vernalization takes place in the following winter. In perennials, like apples and peaches, vernalisation takes place in each successive winter.

The site of vernalisation in plants is the growing points (apical bud). This has been experimentally proved with localised low temperature treatment of different parts of the plant and also by grafting.

According to Chailakhayan the cold treatment resulted in production of "vernalin" and when such plants are sown in long days the vernalin is converted into gibberellins.

Devernalisation: Vernalisation effect is reversible and the process is termed devernalisation. If a vernalised seed or plant is kept at high temperature, the effect of the low temperature treatment is completely lost.

Mechanism of vernalisation: Grafting experiments conducted by Melchers on Henbane, have provided strong evidence for the existence of a new hormone vernalin which is responsible for vernalisation. Gibberellin favours flowering in long day plants even under short day conditions and substitutes for the vernalisation.

Seed Dormancy

There are certain seeds which fail to germinate even when external conditions are favourable. Such seeds are understood to be undergoing a period of dormancy and such seeds are called dormant seeds. In the majority of cases, true dormancy helps the seed to survive through an unfavourable season e.g., a very cold winter or a very hot summer. Dormancy in seeds may be caused by many external environmental or endogenous factors.

Endogenous Factors

- **Hard seed coat:** a hard seed coat can cause dormancy in three ways: (a) by being impermeable to water, (b) by being impermeable to oxygen and (c) by mechanically restricting the growth of embryo.
- **Immature embryo:** In some families like Orchidaceae the seeds are liberated at the stage when embryo is not fully developed, therefore, the embryo should be allowed to complete development in an environment, which is favourable for germination.
- **Period of after ripening:** seeds of certain plants like apple, peach etc. would not germinate, even when the conditions are favourable. Such seeds germinate after they have completed a period of rest known as after ripening period.
- **Germination inhibitors:** Germination inhibitors are commonly found in the pulp or juice of fruits, seed coat, endosperm and embryo. Some of these inhibitors are ABA, ammonia, pthalids, coumarins and parasorbic acids.

Environmental Factors

- **Water Availability:** Water absorbed through micropyle of seed coat brings about many changes in germinating seed like, permeability to gases, rupturing of seed coat, hydrolysis of stored food in form of sugars, translocation of soluble substances.

- **Oxygen:** it is necessary for the aerobic respiration by which the seed get energy for growth of embryo.
- **Temperature:** Seeds germinate within a normal range of temperature> the minimum, optimum and maximum values of temperature for the germination of seed vary from species to species.
- **Light:** Seeds can germinate well in total darkness. There are, however, a number of seeds, which germinate better, when they are exposed to light. Such seeds are called photoblastic seeds.

Methods to Break Seed Dormancy

- **Scarification:** it is a method by which hard seed coat is ruptured or weakened. There are two ways of scarification, (a) Mechanical – Threshing of seeds by machine, rupturing the seed coat with a hammer, cutting the seed coat by a scalpel etc are certain mechanical methods. (b) Chemical – scarification by incubating the seeds in strong acids or certain organic solvents for some time helps in breaking dormancy.
- **Low Temperature Treatment (chilling):** in many woody and herbaceous plants dormancy can be broken by chilling treatment where temperature just above freezing (0-5ºC) is given to seeds. In field condition this requirement is met by natural winter temperature.
- **Alternating Temperature:** seeds in which embryos are in dormant stage, dormancy may be broken by exposing them to alternating low and high temperature taking care that difference between two extremes should not be more than 10-20ºC.
- **Light Treatment:** The positively photoblastic seeds overcome their dormancy by their exposure to light.
- **Hormone Treatment:** Seed dormancy can be broken by incubating the seeds in different concentrations of gibberellin hormone for different time intervals.

Phytochrome

In 1953, L.H.Flint and E.D.Mc Alister showed that seeds of Lettuce do not germinate in dark but showed very high germination when exposed to light of wavelength 525-700 nm. Further, H.A Brothwick and S.B. Hendricks in USDA confirmed findings of Flint and Alister and gave one more observation that the promontory effect of germination in red light (660-680 nm) can be inhibited if it is followed by far red light (700-740 nm) and therefore effect of red and far red are reversible. Seed response to repeated red and far red light will always depend upon the last treatment given to them. Butler et al. (1959) isolated the pigment responsible for these photomorphogenic responses from etiolated (dark grown) seedlings of corn and named it phytochrome. Phytochrome is universal in distribution and is located within the plasma membrane.It occurs in two interconvertible forms, Pr which absorbs red light (660 nm) and Pfr absorbs far red light (730 nm). Pr is blue green in colour and Pfr is pale green. Phytochrome is made up of two components, apoprotein and chromophore, together called holoprotein. Chromophore component is responsible for capturing light. It is an open chain tetrapyrrole pigment similar to phycobilin. Apoprotein undergoes conformational change on absorbance of light thereby bringing out the response. Pfr is a physiologically active form of phytochrome. Pr form absorbs red light and is converted into Pfr. Pfr on absorbing far red light is converted back into P_r (Fig 15.17).

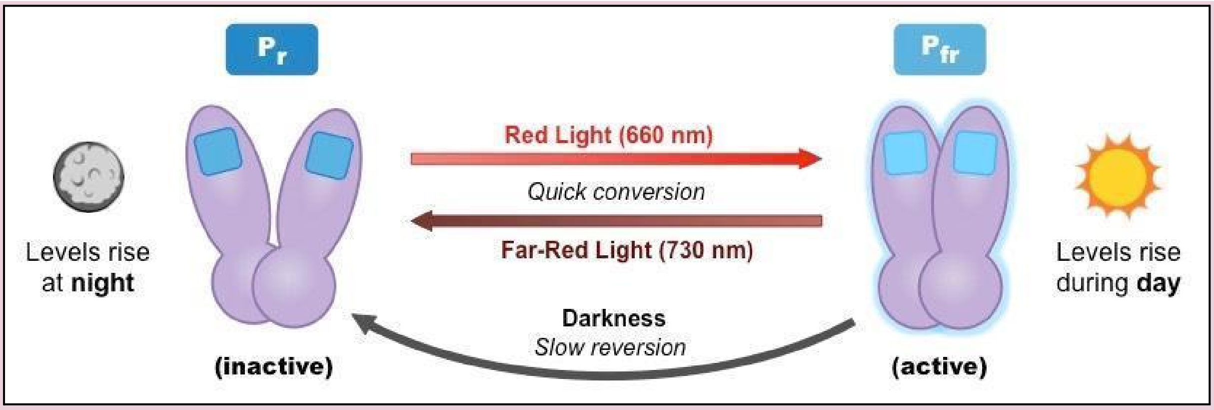

Figure 15.17: Photoreversible forms of phytochrome

Phytochrome Mediated Physiological Responses

- Flowering and seed germination
- **Pigmentation:** Anthocyanin or flavone pigments are formed in response to sunlight. Etiolated seedlings on being exposed to sunlight show rapid chlorophyll synthesis from protochlorophyll already present in plants.
- **De-etiolation:** the developmental stages in a seedling when it is transferred from darkness to light is called de-etiolation.
- Inhibition of internode elongation in normal, light –grown bean seedlings
- Hypocotyl- hook opening

- Unfolding of leaves of wheat seedling
- **Development responses in lower plants:** Bud differentiation, spore germination, rhizoid development etc.
- **Leaflet movements:** Closing of leaflets in *Mimosa pudica* and *Acacia* sp.
- **Tanada effect:** when red light was given the excised root tips of dark grown seedlings of *Hordeum vulgare* and *Phaseolus aureus* stick to walls of a glass beaker which is negatively charged by washing with sodium monohydrogen phosphate.
- Change in permeability to water.
- Motility in lower plants.

Summary

Growth is one of the most conspicuous events in any living organism. It is an irreversible increase expressed in parameters such as size, area, length, height,volume, cell number etc. It conspicuously involves increased protoplasmic material. In plants, meristems are the sites of growth. Root and shoot apical meristems sometimes alongwith intercalary meristem, contribute to the elongation growth of plant axes. Growth is indeterminate in higher plants. Following cell division in root and shoot apical meristem cells, the growth could be arithmetic or geometric. Growth may not be and generally is not sustained at a high rate throughout the life of cell/tissue/organ/organism. One can define three principle phases of growth – the lag, the log and the senescent phase. When a cell loses the capacity to divide, it leads to differentiation. Differentiation results in development of structures that is commensurate with the function the cells finally have to perform. General principles for differentiation for cells, tissues and organs are similar. A differentiated cell may dedifferentiate and then redifferentiate. Since differentiation in plants is open, the development could also be flexible, i.e., the development is the sum of growth and differentiation. Senescence and programmed cell death are other two important processes in growth and development which are regulated by plants' genetic constitution and certain environmental factors. Plants exhibit plasticity in development. Almost all growth and development processes in plants are genetically regulated. Plant growth and development are under the control of both intrinsic and extrinsic factors. Intercellular intrinsic factors are the chemical substances, called plant growth regulators (PGR). There are diverse groups of PGRs in plants, principally belonging to five groups: auxins, gibberellins, cytokinins, abscisic acid and ethylene. These PGRs are synthesised in various parts of the plant; they control different, differentiation and developmental events. Any PGR has diverse physiological effects on plants. Diverse PGRs also manifest similar effects. PGRs may act synergistically or antagonistically. Plant growth and development is also affected by light, temperature, nutrition, oxygen status, gravity and such external factors. Flowering in some plants is induced only when exposed to a certain duration of photoperiod. Depending on the nature of photoperiod requirements, the plants are called short day plants, long day plants and day-neutral plants. Certain plants also need to be exposed to low temperature so as to hasten flowering later in life. This treatment is known as vernalisation. Seed dormancy is also one phase of the growth and development process. It’s the way by which plants survive under unfavourable environmental conditions. Plants have light sensing pigment called phytochrome. This pigment exists in two interconvertible forms in plants regulating several photomorphogenic processes.