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UNIT -V

Plant Growth

Growth is the most fundamental characteristic of any living organism. It is defined as "an irreversible, permanent increase in the size of an organ or its parts, or even of an individual cell". Generally, growth is accompanied by metabolic processes (catabolic and anabolic) that spend energy.

Characteristics of Plant Growth

Plant Growth is Indeterminate

Plants have the unique ability to grow indefinitely throughout their life due to the presence of 'meristems' in their body. Meristems in the roots and shoots of plants are responsible for 'primary growth of the plant'. These increase the height of the plant. On the other hand, lateral meristems increase the width of the plant. This is known as the 'secondary growth of the plant'.

Plant Growth Is Measurable

growth is measured in terms of increase in cell number, area, volume, length etc.

Phases of Plant Growth

Meristematic Phase

The cells in the root and shoot apex of a plant are constantly dividing. They represent the meristematic phase of growth.

Elongation Phase

The cells in the zone just after the meristematic region represent the phase of elongation. The characteristics of cells in this zone are cell enlargement, increased vacuole formation and new cell wall deposition.

Maturation Phase

Just close to the phase of elongation, but away from the apex lies the phase of maturation. The cells in this region reach their maximum size with respect to their protoplasm and cell wall thickening.

Growth Rates

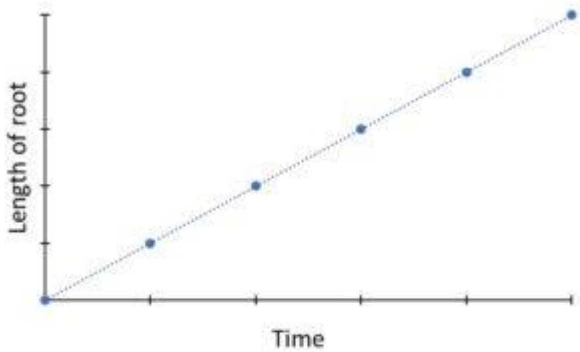
The increased growth per unit time is termed as the growth rate. This can be expressed mathematically.

There are two types of growth rates – Arithmetic and Geometric.

Arithmetic Growth Rate

Following mitotic cell division, only one cell continues to divide while the other begins to differentiate. A simple example of this is the elongation of a root at a constant rate. When you plot this increase in length against time, you get a linear curve as shown below. This is expressed mathematically as –

$L_t = L_0 + rt$ (where, L_t is the length at time 't', L_0 is the length at time 'zero', r is the growth rate)



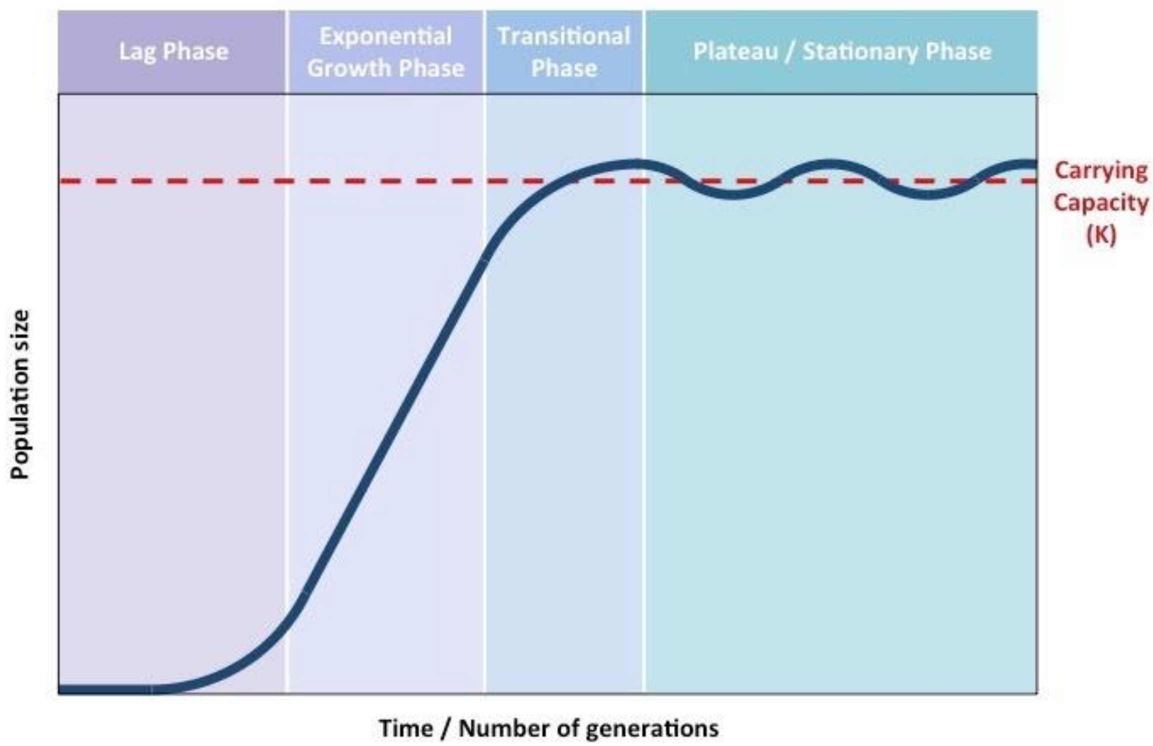
Geometric Growth Rate

Most biological systems show an initial growth phase which is slow. This is the 'lag phase'. This phase is followed by a period of exponential growth and is called 'log phase' or 'exponential phase'. Here, following mitotic cell division both the daughter cells continue to divide.

However, due to limited nutrient supply, the growth slows down giving rise to the 'stationary phase'. When we plot this growth, we get a sigmoidal curve or S-curve as shown below. This growth curve is typical for all cells, tissues, organs and is characteristic of an organism living in a natural environment. Mathematically, it is expressed as –

$W_1 = W_0 e^{rt}$ (where W_1 is final size, W_0 is initial size, e is base of natural logarithm, r is the growth rate and t is the time of growth). Note: Here, r is the growth rate and is also the measure representing the ability of the plant to produce new plant material. This is the 'efficiency index'.

Growth rate can also be described as absolute or relative. The **absolute growth rate** is the measurement of total growth per unit time. The **relative growth rate** is also the growth of a given system per unit time but relative to another parameter like initial size, weight etc.



Conditions for Growth

- Water – Water is essential for cell enlargement, extension and for keeping plant cells upright. It also provides the medium for enzymatic activities which is needed for growth. Oxygen – Metabolic energy is needed for plant growth activities. Oxygen helps to release this metabolic energy.
- Nutrients – Macro and micronutrients are sources of energy for plants. They are also needed to make protoplasm.
- Light – Light controls growth and its phases in plants.
- Temperature – Every plant has an optimum temperature range suitable for its growth.

Plant Development

It is defined as all the changes that an organism goes through during its life cycle, right from seed germination to senescence. Development of plants (i.e. growth and differentiation) is influenced by extrinsic factors (light, temperature, water) and intrinsic factors (genes and plant growth regulators).

PLANT MOVEMENTS

- The movement of higher plants are chiefly in the form of bending, twisting, and elongation of certain plant parts or organs.

- **Spontaneous movement or autonomic movements:** There are other plant movements which take place spontaneously, without any external stimuli.
- **Induced or paratonic movement** : Some plant movements are caused in response to certain stimuli and they are said to be induced.

PARATONIC OR INDUCED MOVEMENTS

1. TROPIC MOVEMENTS :

- Growth movements, which occur in response to unidirectional external stimuli & result in positioning of the plant part in the direction of the stimulus, are said to be tropic movements.
- Depending upon the nature of stimuli, these movements are of following types:-
- A) Phototropism
- B) Geotropism
- C) Hydrotropism
- D) Chemotropism

A. Phototropism:

- These curvature movements occur when a plant is provided with artificial or natural light only from one direction. Stems which generally show a curvature toeard the source of light are said to be positively phototropic. Roots which grow away from the source of light are called negatively phototropic.

B. Geotropism

- Growth movements induced by stimulus of gravity are said to be geotropism. Primary roots always grow downward in the direction of gravity and thus are positively geotropic, whereas the main shoots grow upward away from the gravity and are thus negatively geotropic.
- The secondary lateral roots and shoots show a weaker response to gravity and thus take up a position at an angle to the gravitational stimulus and are called diageotropic.

C. Hydrotropism

- Growth movements in response to unilateral stimulus of water are known as hydrotropism.
- Roots are positively hydrotropic as they bend towards the source of water.

D. Chemotropism

- This is the movement caused by unilateral stimulus of some chemicals.

- Movement of pollen tube through the style towards the ovary is an example of chemotropism.

2. TACTIC MOVEMENTS

- Tactic movements are movements of locomotion, which are induced by some unidirectional external stimuli.
- Depending upon the nature of stimuli, these movements are of following types:-

- A) Phototactic
- B) Chemotactic
- C) Thermotactic

A. Phototactic :

- These tactic movements are in response to unidirectional light.
- Examples: Free swimming algae, zoospores, gametes when swim towards the diffused light are said to be positively phototactic and when they move away from the strong light, they are called negatively phototactic.

B. Chemotactic

- The unidirectional movements of locomotion in response to certain chemicals is called chemotactic.
- The movement of antherozoids of bryophytes and pteridophytes towards egg due to chemicals.

C. Thermotactic

- The movement of locomotion in response to certain unidirectional temperature stimulus.
- Examples: Rapid rotational cytoplasmic movement in the leaf of *Vallisneria* due to increase in temperature and movement of algae form a cloder to a warmer place.

Photoperiodism

The plants in order to flower require a certain day length i.e., the relative length of day and night which is called as photoperiod. The response of plants to the photoperiod expressed in the form of flowering is called as photoperiodism.

Physiology of flowering

The phenomenon of photoperiodism was first discovered by Garner and Allard (1920, 22) .He concluded that 'the relative length of the day is a factor of the first importance in the growth and development of plants'.

Depending upon the duration of the photoperiod, they classified plants into three categories.

(1) Short Day Plants (SDP):

These plants require a relatively short day light period (usually 8-10 hours) and a continuous dark period of about 14-16 hours for subsequent flowering (Fig. 18.1A). Some examples of these plants which are also known as long-night-plants are Maryland Mammoth variety of tobacco (*Nicotiana tabacum*) Biloxi variety of Soybeans (*Glycine max*), Cocklebur (*Xanthium pennsylvanicum).*

i. In short day plants the dark period is critical and must be continuous. If this dark period is interrupted even with a brief exposure of red light (660-665 mµ wavelength), the short day plant will not flower (Fig. 18.1B).

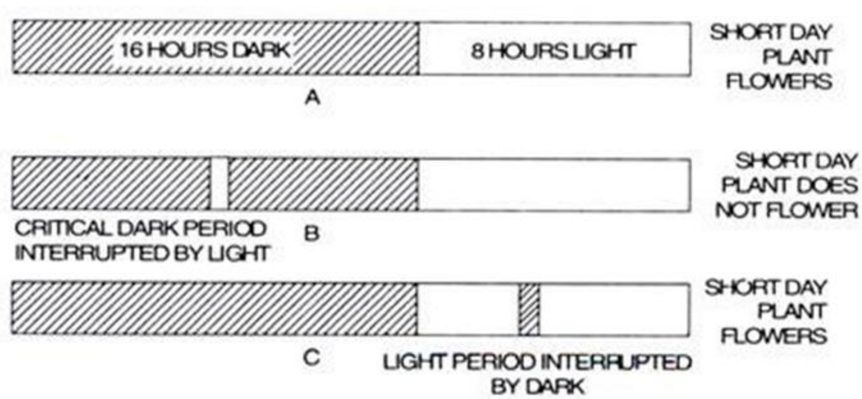


Fig. 18.1. Effect of a brief exposure of red light during dark and interruption of light period by dark on flowering in a short day plant.

ii. Maximum inhibition of flowering with red light occurs at about the middle of critical dark period.

iii. However, the inhibitory effect of red light can be overcome by a subsequent exposure with far-red light (730-735 mu wavelengths).

iv. Interruption of the light period by dark does not have inhibitory effect on flowering in short day plants (Fig. 18.1 C).

v. Prolongation of the continuous dark period initiates early flowering in short day plants.

(2) Long Day Plants (LDP):

These plants require a longer day light period (usually 14-16 hours) in a 24 hours cycle for subsequent flowering. Some examples of these plants which are also called as short night plants are *Hyoscyamus niger* (Henbane) *Spinacea* (spinach) *Beta vulgaris* (Sugar beet).

i. In long day plants the light period is critical.

ii. A brief exposure in the dark period or the prolongation of the light period stimulates flowering in long day plants.

(3) Day Neutral Plants:

These plants flower in all photoperiods ranging from 5 hours to 24 hours continuous exposure. Some of the examples of these plants are tomato, cotton, sunflower, cucumber and certain varieties of peas and tobacco. During recent years certain intermediate categories of plants have also been recognised. They are,

Long Short Day Plants:

These are short day plants but must be exposed to long days during early periods of growth for subsequent flowering. Some of the examples of these plants are certain species of *Bryophyllum.*

Short-Long Day Plants:

These are long day plants but must be exposed to short days during early periods of growth for subsequent flowering. Some of the examples of these plants are certain varieties of wheat (*Triticum*) and rye (*Secale).*

Florigen Concept

1. It is a hypothetical flower-inducing growth hormone which has still not been isolated.
2. It is produced in response to a specific period of day length typical of a plant.
3. Florigen is considered to be the same in all the flowering plants.
4. It induces only flowering. It is neither a growth promoter nor a growth inhibitor

Some of the theories supported the florigen concept

C/N Relationship Theory:

Klebs in 1913 concluded that flowering is controlled by the nutritional status of the plant. He enunciated the carbohydrate/nitrogen (the C/N ratio) relationship theory which indicates that a high endogenous C/N ratio is essential for flowering and vice versa. However, the later workers believed that Klebs theory was too simple to explain the complexity of the flowering process and many subsequent observations have failed to confirm Klebs theory which was soon discarded.

Trace Element Nutrition Theory:

Trace elements, particularly copper and iron are critically involved in photoperiodic induction in duckweeds and other plants. Hillman postulated that Cu acting as a SH-inhibitor interferes with phytochrome action, possibly by influencing some metal-sensitive membrane system.

Water Stress Theory:

Brenchart demonstrated that a period of water shortage is absolutely required for flower initiation. This observation suggests that limitation of water supply during certain developmental period may have a direct action on flower formation.

Florigen Theory:

Julius Sachs in the 19th century was probably the first person to support the idea that 'flower-forming substances' are present in flowering plants In 1937, Chailakhyan proposed that the signal generated in the leaf is a substance of hormonal nature and named it 'florigen'. In 1937, Melchers reported transmission of a flower stimulus in biennial Hyoscyamus formed as a result of low temperature vernalization and called it 'vernalin' as the product of vernalization. There was, however, no evidence of transport of a stimulus formed as a result of cold treatment alone indicating lack of mobility of the product of vernalization. Melchers assumes that vernalin is the physiological precursor of florigen.

(a) Transport of the Floral Stimulus:

The main characteristic of a hormone is translocation. Regarding the pattern of transport, Lang has indicated that the floral hormone moves only through living tissue. Initially the movement probably occurs from cell to cell through the mesophyll of the leaf blade until loaded into the phloem. The phloem tissue is the path of further transport in the petiole and stem.

(b) Nature of Florigen:

The gibberellin-like materials are present in these extracts, so their activity can be ascribed to the presence of gibberellins. The active material is highly water-soluble containing a carboxyhc acid and so it has been referred to as 'florigenic acid'.

Floral Inhibitor Theory:

In the years 1949-50, Lona, Von Denffer and others postulated that plants grown in conditions un-favourable for flowering produce floral inhibitors. The conditions that induced the plants to flower either prevent the production of these inhibitory compounds or lower the concentration of the inhibitors below threshold value. It is nothing but the counter-theory to that of the floral hormone.

Plant Age Theory:

In the juvenile phase, the plants are not able to show photoperiodic response, whereas at the end of the juvenile phase, they become adult and sensitive to conditions that promote floral induction. The juvenile phase is obviously the result of several physiological systems and there are many reasons to account for the inability of the young plant to flower even when subjected to favourable conditions. First, insufficient leaf area has been found to delay or reduce flower initiation which may be related to the supply of photosynthetic products to the shoot apex. . A second reason for juvenility is the relative insensitivity of the young leaves to favourable day length conditions. The third is the inhibitory influence of the root system on flower initiation in the aerial shoots. The fourth reason supports the idea that juvenility is probably located in the meristems and not in the leaves

Vernalization

Vernalization is the induction of a plant's flowering process by exposure to the prolonged cold of winter, or by an artificial equivalent. After vernalization, plants have acquired the ability to flower.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 (Fig. 15.33).

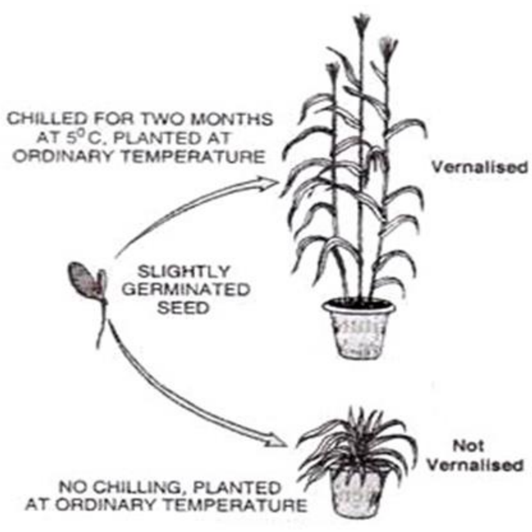


Fig. 15.33. Experiment to show effect of vernalization on Winter Rye.

Site for Vernalization:

The stimulus of vernalization is perceived only by the meristematic cells, e.g., shoot tip, embryo tips, root apex, developing leaves, etc..

Requirements of Vernalization:

(i) Low Temperature:

Low temperature required for vernalization is usually 0°—5°. It is 3°—17° in case of biennial Henbane (*Hyoscyamus niger*). Low temperature treatment should not be immediately followed by very high temperature (about 40°C) otherwise the effect of vernalization is lost. The phenomenon is called de-vernalization.

(ii) Period of Low Temperature Treatment:

It varies from a few hours to a few days.

(iii) Actively Dividing Cells:

Vernalization does not occur in dry seeds. The seeds must be germinated so that they contain an active embryo. For this the seeds are moistened before exposing them to low temperature. In whole plants, an active meristem is required.

(iv) Water:

Proper protoplasmic hydration is must for perceiving the stimulus of vernalization.

(v) Aerobic Respiration

(vi) Proper Nourishment.

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. Vernalization prepares the plant to flower. The induction of flowering depends upon the presence of other favourable conditionsThus, Henbane is a long-day plant which also requires cold treatment. Unless and until both are provided the plant will not come to flower (Fig. 15.34).

Fig. 15.34. Effect of vernalization and photoperiods on Henbane.

Importance of Vernalization:

(i) Vernalization can help in shortening the juvenile or vegetative period of plant and bring about early flowering. It is not only applicable to temperate plants but also to some tropical plants, e.g., Wheat, Rice, Millets, Cotton,

(ii) It increases yield, resistance to cold and diseases, and

(iii) Kernel wrinkles of Triticale can be removed by vernalization.

Biological clock

Like all other living organisms, the plants are and have always been exposed to strong and rhythmic environmental changes caused by planetary movements. It is but natural, that these environmental rhythmicities or periodicities find their counterparts in biological rhythms which control many behavioural and physiological activities of living organisms including plants. When the period of biological rhythmicities matches with those of the cycles of day and night, such rhythms are called as circadian rhythms .

Besides circadian rhythms, the organisms have also developed many other endogenous rhythmicities during their long evolutionary history. The rhythmicities or periodicities whose periods match to those of lunation are called as circalunar rhythms (period ~ 29 days), to those of tide are called as circatidal rhythms (period ~ 12.4 or 24.8 hrs), to those of seasons are called as circaannual rhythms (period ~ a year) or to those of time between successive spring-low waters are called as circa semilunar rhythms (period ~ 14.7 days).

Endogenous non circadian rhythms with comparatively very short periods from a few minutes to some hours are called ultradian rhythms.

Endogenous Versus Exogenous Rhythms:

The discovery by De Mairan led to the firm establishment of distinction between the concepts of endogenous and exogenous rhythms. Exogenous rhythms found in many plants occur under natural conditions but they fail to persist in uniform environment since they are controlled solely by some environmental parameter. For example, the rhythmicity observed in discharge of spores in cultures of the fungus *Pilobolus crystallinus* under natural conditions is lost if the cultures are transferred to uniform environmental conditions.

Physiology of senescence

As the young plant grows, it undergoes ageing and develops into mature plant in an orderly fashion. The later part of the developmental process which ultimately leads to death is called senescence. Senescence may be defined as the period between reproductive maturity and death of a plant or a part of it. It is characterized by a collective, progressive and deteriorative developmental process which ultimately leads to complete loss of organization and function of the plant or parts of it. The study of plant senescence is called phytogerontology.

Abscission and Senescence

The process of separation of leaves, flowers, and fruits from the plant is called abscission. It is essential, when these parts are removed that the plant seals off its vascular system to prevent loss of water and nutrients and to exclude bacteria, fungal spores and other pathogens. An abscission zone, a layer of specialized cells is formed at the base of each part before it is lost, to separate it form the main body. The cells in this layer die and become hardened by the deposition of ligning and suberin. So, by the time the leaf or fruit drops, the vascular system has been sealed off.

Types of Senescence

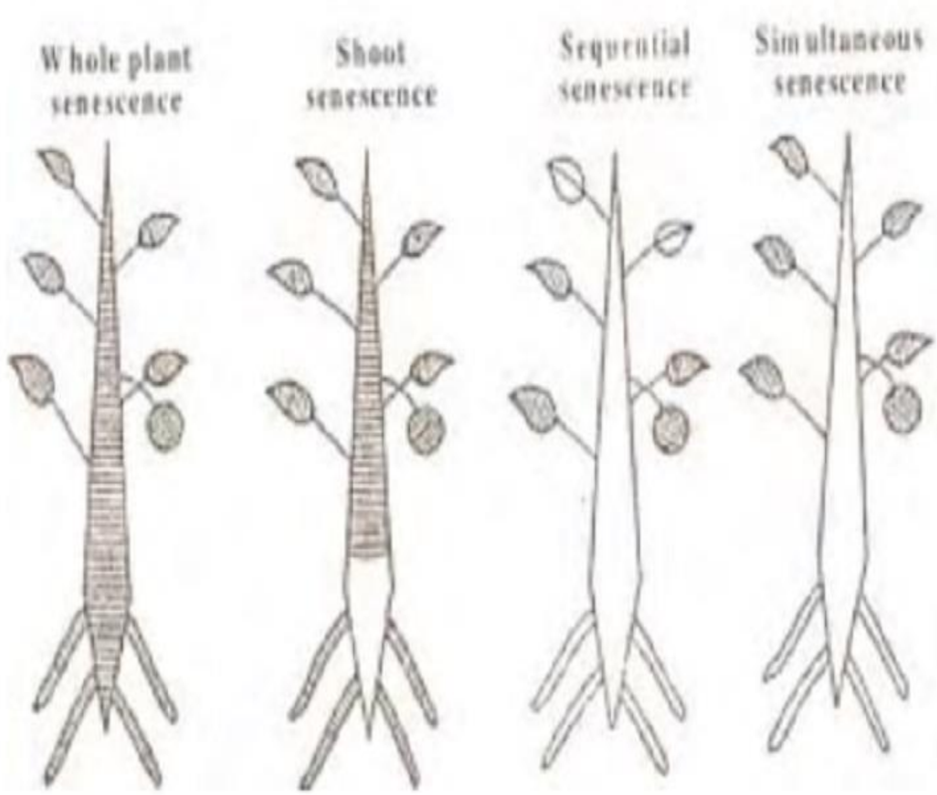


Fig. Types of senescence

Leopold(1961) has recognized 4 types of senescence patterns, which are as follows:-

1. Whole plant senescence
2. Shoot Senescence
3. Sequential senescence of Organ senescence
4. Simultaneous senescence

1. Whole plant senescence

It is found in monocarpic plants which produce flower and fruit only once in their life cycle. The plants may be annual(e.g. rice, wheat, gram, mustard etc.), biennials(e.g.cabbage, henbane) or perennials (e.g. certain bamboos). The plant dies soon after ripening of seeds.

2. Shoot senescence

This type of senescence is found in certain perennial plants which possess underground perennating structures like rhizomes, bulbs, corm etc. The above ground part of the shoot dies each year after flowering and fruiting, but the underground part (stem and root) survives and puts out new shoots again next year. E.g.banana, gladiolus, ginger etc.

3. Sequential Senescence

This is found in many perennial plants in which the tips of main shoot and branches remaining a meristematic state and continue to produce new buds and leaves. The older leaves and lateral organs like branches show senescence and die. Sequential senescence is apparent in evergreen plants. e.g. *Eucalyptus, Pinus* etc.

4. Simultaneous or Synchronous senescence

It is found in temperate deciduous trees such as elm and maple. These plants shed all their leaves in autumn and develop new leaves in spring. Because of this shedding of leaves, autumn season is also called fall. Such a senescence of leaves or plant organs is called synchronous.

Physiology of senescence

The process of senescence involves a number of structural and physiological changes in the senescing organs. Some of the important changes are:

i) Cells undergo reduction in their size.

ii) The membrane bound sub-cellular inclusions are disrupted.

iii) Photosynthesis is reduced and starch content decreases in the cells.

iv) Breakdown of chlorophy II is accompanied by synthesis and accumulation of anthocyanin pigments.

v) Protein synthesis is decreased and protein break down enhances.

vi) Amino acids are withdrawn from senescing leaves and transported to the growing regions.

vii) RNA content is decreased.

viii) Chromatin material changes its property and DNA molecules degenerate.

Importance of senescence

1. It maintains efficiency since the old and inefficient organs are replacedby young efficientparts like leaves, buds, flowersand fruits. etc.,

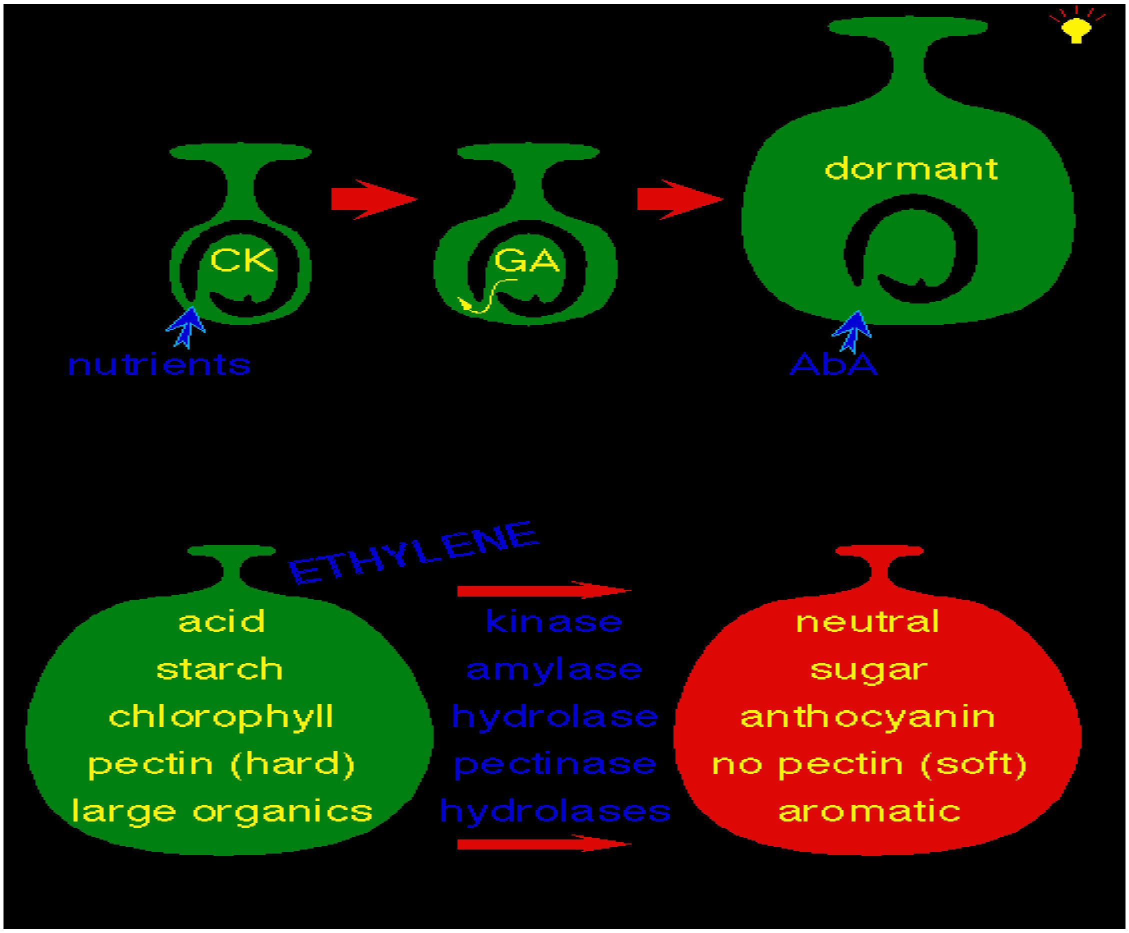
2. During senescence, the celluar breakdown results in release of many nutrients including amino acids, amides, nnucleotides, simple sugars and minerals. The same are withdrawn from the senescing organs into the main trunk and later utilized in the growth and development of new parts.

3. Shoot senescence is a mechanism to help the plants perennate during the unfavorable periods.

4. Simultaneous or synchronous leaf fall occursin autumn prior to winter. It reduces transpiration, which is essential for survival in winter, when the soil is frozen and roots cannot absorb water.

5. Liter of fallen leaves and twigs is an important source of humus and mineral replenishment for the soil.

FruitRipening



In the diagram above on the left is an unripe fruit. It is hard, green, sour, has no smell, is mealy (starch present), and so on. The way fruits ripen is that there is commonly a ripening signal...a burst of ethylene production. Ethylene is a simple hydrocarbon gas ($H_2C{=}CH_2$) that ripening fruits make and shed into the atmosphere. Sometimes a wound will cause rapid ethylene production...thus picking a fruit will sometimes signal it to ripen...as will an infection of bacteria or fungi on the fruit. This ethylene signal causes developmental changes that result in fruit ripening. amylase to accelerate hydrolysis of starch into sugar, pectinase to catalyze digestion of pectin (the glue between cells), and so on. Ethylene apparently "turns on" the genes that are transcribed and translated to make these enzymes. The enzymes then catalyze reactions to alter the characteristics of the fruit.

The action of the enzymes cause the ripening responses. Chlorophyll is broken down and sometimes new pigments are made so that the fruit skin changes color to red, yellow, or blue. Acids are broken down so that the fruit changes from sour to neutral. The digestion of starch by amylase produces sugar. This reduces the mealy quality and increases juiciness (by osmosis, a process we will study later). The breakdown of pectin between the fruit cells unglues them so they can slip past each other. That results in a softer fruit. Finally enzymes break down large organic molecules into smaller ones that can be volatile (evaporate into the air) and we can detect as an aroma.

Plant hormones and its physiological role

Plants need sunlight, water, oxygen, minerals for their growth and development. These are external factors. Apart from these, there are some intrinsic factors that regulate the growth and development of plants. These are called plant hormones or **"Phytohormones".**

- Plant hormones are chemical compounds present in very low concentration in plants. They are derivatives of indole (auxins), terpenes (Gibberellins), adenine (Cytokinins), carotenoids (Abscisic acid) and gases (Ethylene).
- These hormones are produced in almost all parts of the plant and are transmitted to various parts of the plant.
- They may act synergistically or individually. Roles of different hormones can be complementary or antagonistic.
- Hormones play an important role in the processes like vernalisation, phototropism, seed germination, dormancy etc. along with extrinsic factors.
- Synthetic plant hormones are exogenously applied for controlled crop production

Plant hormones control all the growth and development activities like cell division, enlargement, flowering, seed formation, dormancy and abscission.

Based on their action, plant hormones are categorised into two categories:

- Plant Growth Promoters
- Plant Growth Inhibitors

Auxin Hormone

Auxin means "to grow". They are widely used in agricultural and horticultural practices. They are found in growing apices of roots and stems and then migrate to other parts to act.

- Natural: Indole-3-acetic acid (IAA), Indole butyric acid (IBA)
- Synthetic: 2,4-D (2,4-Dichlorophenoxyacetic acid), NAA (Naphthalene acetic acid)

Functions:

- Cell elongation of stems and roots
- **Apical dominance**, IAA in apical bud suppresses the growth of lateral buds
- Induces parthenocarpy i.e. development of fruit without fertilisation e.g. in tomatoes
- Prevents premature fall of leaves, flowers, fruits
- Useful in stem cuttings and grafting where it initiates rooting
- Promotes flowering e.g. in pineapple
- 2,4-D is widely used as a herbicide to kill undesirable weeds of dicot plants without affecting monocot plants
- Helps in cell division and xylem differentiation

Gibberellins Hormone

- There are more than 100 gibberellins (GA_1, GA_2, GA_3…..) that are known. They are acidic in nature. These are found in higher plants and fungi.

Functions:

- Promotes **bolting,** i.e. sudden elongation of internodes just before flowering in rosette plants like cabbage, beet
- Delays senescence
- Induces parthenocarpy
- Elongation of the stem and reverses dwarfism
- Induces maleness in certain plants like cannabis
- Induces the formation of hydrolytic enzymes such as lipase, amylase in the endosperm of germinating cereal grains and barley seeds
- Breaks seed dormancy

Cytokinins Hormone

- Cytokinins play an important role in cytokinesis process. Cytokinins are naturally synthesised in the plants where rapid cell division occurs e.g. root apices, shoot buds, young fruits, etc. Movement of cytokinins is basipetal and polar.
    - Natural: Zeatin (corn kernels, coconut milk), isopentenyladenine
    - Synthetic: Kinetin, benzyladenine, diphenylurea, thidiazuron

Functions:

- It promotes lateral and adventitious shoot growth and used to initiate shoot growth in culture
- Helps in overcoming apical dominance induced by auxins
- Stimulate the formation of chloroplast in leaves
- Promotes nutrient mobilisation and delay leaf senescence

Abscisic Acid Function

- It is a growth-inhibiting hormone. ABAs act as an antagonist to GAs. It inhibits plant metabolism and regulates abscission and dormancy. It is also called "stress hormone" as it increases tolerance of plants.

Functions:

- Induces abscission of leaves and fruits
- Inhibits seed germination
- Induces senescence in leaves
- Accelerates dormancy in seeds that is useful for storage purpose
- Stimulates closure of stomata to prevent transpiration under water stress

Ethylene Plant Hormone

- It acts as a growth promoter as well as an inhibitor. Occurs in gaseous form. It is synthesised in the ripening fruits and tissues undergoing senescence. It regulates many physiological processes and one of the most widely used hormones in agriculture.

Functions:

- It hastens the ripening of fruits
- Controls epinasty of leaves

- Breaks seed and bud dormancy
- Stimulates rapid elongation of petioles and internodes
- Promotes senescence and abscission of leaves and flowers
- Induces root growth and root hair formation thereby increasing the absorption surface
- Stimulates femaleness in monoecious plants
- Apical hook formation in dicot seedlings

Other than the main 5 hormones, there are other hormones too that affect the plant's physiological processes, e.g. brassinosteroids, salicylates, jasmonates, strigolactones, etc.

Plant Growth Regulators in Agriculture

Plant Growth Regulators in Agriculture and Horticulture is a comprehensive text covering the role of plant growth regulators in:

- root formation
- manipulating yield potential
- plant stress protection
- ornamental horticulture
- postharvest life of ornamentals
- manipulating fruit development and storage quality
- citriculture
- reducing fruit drop
- bloom-thinning strategies

Photomorphogenesis

Photomorphogenesis is the development of plants where the pattern of plant growth responds to the spectrum of light. In this process, light is used as a source of energy.

Any change in the structure and function of an organism in response to changes in light intensity is known as photomorphogenesis. Along with plants, it is a common feature of development in fungi, protists, and bacteria.

There are two important stages of photomorphogenesis:

- Pattern specification where the cells and tissues develop the ability to respond to light during some developmental stage.

- Pattern realization during which the photoresponse occurs.

The plant responds to light signals in the following two ways:

- Phytochrome-mediated photoresponse
- Blue-light response or cryptochrome-mediated photoresponse

Phytochrome-Mediated Photoresponse

Many photomorphogenic responses in plants are known to be mediated by phytochrome. It is a proteinaceous pigment that acts as a photoreceptor and absorbs red and far-red light. It also absorbs blue light.

The phytochrome-mediated response can be divided into three categories depending upon the amount of light absorbed.

- **Very Low Fluence Responses**– These responses are non-photo reversible and are initiated by very low fluences.
- **Low Fluence Responses-** These are photo reversible. It includes most of the red and far-red photoresponses, including the lettuce seed germination.
- **High Irradiance Responses-** These require prolonged exposure to light of high irradiance. These saturate at much higher influences than low fluence responses and are non-photo reversible.

Blue Light Response or Cryptochrome-Mediated Photoresponse

These photoresponses are controlled by blue light and are mediated by a group of pigments called cryptochromes. These responses have been reported in fungi, algae, and ferns.

Some of the blue-light responses in plants are:

- Phototropism
- Stomatal opening
- Phototaxis
- Sun tracking by leaves
- Inhibition of hypocotyl elongation
- Stimulation of synthesis of carotenoids and chlorophyll
- Chloroplast movement within the cells

Photoreceptors

Photoreceptors are responsible for photomorphogenesis.

When the seed which was initially in an environment of complete darkness is exposed to light, it results in the activation of photoreceptors in the seed. This is because the seeds are exposed to electromagnetic radiation, especially to red or far-red wavelength of light. The signals are transmitted into the nucleus by the receptors through a signal transduction pathway, which stimulates the genes responsible for growth and development.

A plant has the following types of photoreceptors:

- Phytochrome
- Cryptochrome
- Phototropin
- UVR8

Phytochrome

The phytochrome is a protein covalently bonded to a chromophore. The wavelengths of red to far-red lights are detected by the phytochrome receptors.

A plant has multiple phytochromes that sometimes act independently of one another and sometimes are dependent either at the same time or at different times in the process of development.

Phytochrome exists in two forms-

Pfr and Pr

Pfr is in a biologically active form and absorbs far-red. Pfr is converted to Pr when far-red light is absorbed.

The red wavelengths are absorbed by Pr. When the red light is absorbed, Pr is converted to Pfr.

The red and far-red reversibility defines the responses of the phytochrome proteins. Photomorphogenesis like leaf expansion and stem elongation, is mediated by phytochrome.

Cryptochrome

Cryptochrome perceives green, UVA and blue light.It is a flavin protein with 2 chromophores one each for the blue and green light.

Flavin is used as a chromophore. Leaf expansion, stem elongation, circadian rhythms of plants, all are regulated by cryptochrome.

They are found in plants and animals and are involved in their circadian rhythms.

They can also sense magnetic fields in a number of species.