Chapter - 13
Plant Growth

Growth is a characteristic feature of every living organism and this process continues through out life. It is a complex process which depends on many physiological activities. As a result of this process, permanent changes are seen in the shape and size of living beings.

The growth is the result of many metabolic functions due to which there are various types of organic substances and formation of the protoplasm takes place. Moreover, some other factors like hormones are also essential for growth.

Definition : Growth is the permanent and irreversible change in the shape and size of living beings which results in increase in their dry weight of the body.

During growth both size and dry wight of the body increases. It is not necessary that increase in shape of the body is always the result of growth. For example : size of a dry seed expands after absorbing water but it loses its size when it is dried and the weight also does not change.

Plant Growth Sites

In lower category plants (like algae) growth takes place in their whole body while in higher category plant, growth occurs in some particular parts. The growing tissue found here is called Meristem. The calls of Meristem have the efficiency of division and continuity.

Meristem is of 3 kinds based on their positions:

(1) Apical Meristem

(2) Intercalary Meristem

(3) Lateral Meristem

(1) Apical Meristem : This tissue is found at the top of stem and root in which calls are formed by cell division which forms permanent tissues by elongation and differentiation. As a result mainly the height and minorly width of the plant increase. This is called primary Growth.

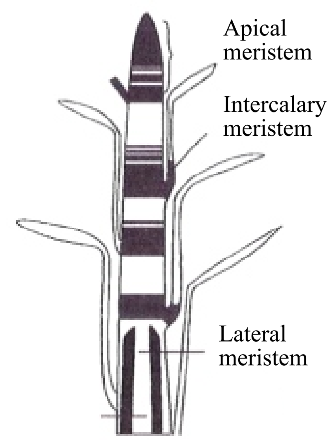


Fig. 13.1 Types of meristem according to their position

(2) Intercalary Meristem : It is always found above the joint of the stem nodes and as a result of the functions of this tissue, the stem grows longer due to elongation in internodes. Example : grass, sugarcane, bamboo etc.

(3) Lateral Meristem : Thickness of stem and roots increases often due to active presence in gymnosperms and dicotyledons. Connective cambium and cork cambium are examples of Lateral Meristem. The growth occurs due to this is called secondary growth. This growth is mostly found in perennial plants.

Phases of Growth

The cells of meristem form new cells by mitosis. Permanent tissues are formed in these calls by elongation and differentiation. Growth can be divided in three stages-

1. Phase of cell formation
2. Phase of cell elongation
3. Phase of cell differentiation

1. Phase of cell formation or phase of cell division : In this Phase meristem cells are continuosly divided by mitosis. The nucleus of these divisible cells is large, protoplasm is dense and the cell wall is thin. This stage is also called pre-formation stage because during this stage plants prepare themselves for rapid growth.

2. Phase of cell elongation : This is the second stage of growth. In this stage the cells formed in the meristem by division increase irreversibly in size. In this stage many small vacuoles are found in which water and solid substances are collected. These small vacuoles together form the big central vacuole. In this stage nucleus and cytoplasm remain present in the periphery of cells. The dry weight of the plant increases during this stage.

3. Phase of cell differentiation : In this stage cells are transformed in permanent tissues by differentiation. The shape and size of the cells changes greatly. Consequently the cells are differentiated according to their function. The cell wall of mechanical tissues turns thick. Xylem and phloem are differentiated. Cells change their physiological and biochemical functions. As a result, of these changes, structural, physiological and biochemical differentiation takes place in the cell.

Growth Kinetics

The growth which takes place in a particular organ or the size or weight of a particular plant in a certain time is called its Growth Rate. Growth rate can be expressed geometrically and arithmetically. According to geometrical growth, two daughter cells formed from a single cell are divided again. So the newly formed cells are doubled gradually after every division Example- 1→2→4→8→16 etc. geometrical growth can be seen during primary divisions of zygote. In arithmetic growth one cell from two new cells formed by every division turns into permanent cell and only one is able to do division further. In this way, only one cell is increases after every division.

Example - 1 →1→1→1→1 etc. Such division happens on stem apex and root apex.

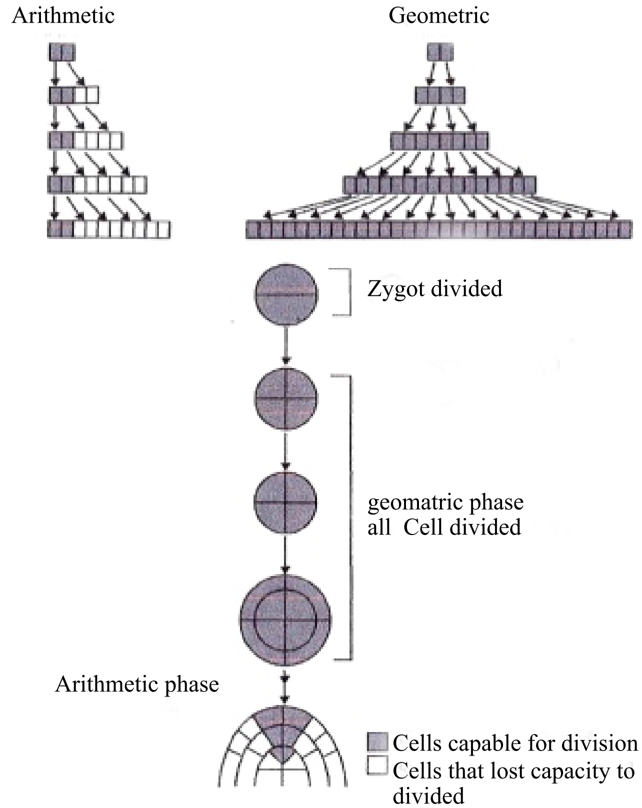


Fig 13.2 Arithmetic and geometric growth

If we measure the growth of cell, organ of a plant or a whole plant, keeping the factors same affecting the growth rate same, then we find that their growth rate is not same. If we make a graph of growth rate with the time, then we have S-shaped or Sigmoid shaped graph. This is called Growth curve. A complete growth curve can be divided in four parts:

(1) Lag period : This is the primary stage of growth in which the growth rate is low. In this stage internal changes happen in cells and the dry weight decreases due to the use of collected food materials. New cell are formed as result of cell division which in gradual increase in the shape of plants.

(2) Log period : in this stage growth takes place rapidly because of elongation in cells.

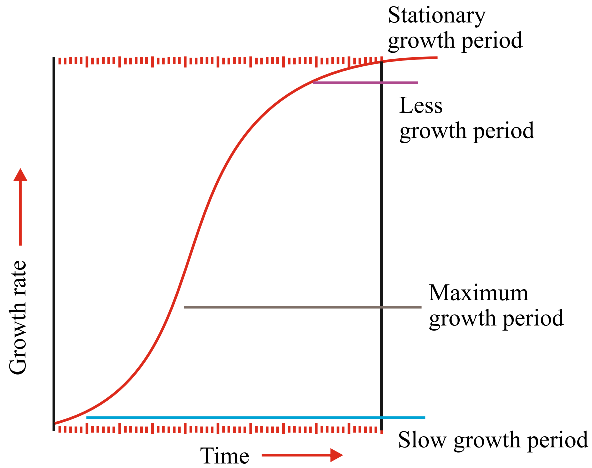


Fig 13.3 Sigmoid growth arch

(3) Diminishing growth period or decline period : In this period growth rate again slows down. Cells become mature in this period and also the metabolism activities get slow down.

(4) Stationary period : In this stage growth almost becomes stable due to maturity of cells.

It is the maximum growth period in which maximum growth takes place. Sachs (1882), has called it grand period of growth.

Growth measurement

Growth rate in plants can be measured by the growth in shape, size or its organs (leaves, flower, fruits). Growth can be measured in plants in following ways:

1. By increase in the number of cells

2. By increase in the shape of cells, tissues and organs

3. By increase in dry weight

4. By linear measurement

Different methods and applications for growth measurement are as follows:

(1) Simple or direct method : This is the Simple method of growth measurement in which the primary length of a plant organ is measured by a scale. Then, after certain time its height is measured again. The increase length found in that particular time gap shows the growth taken place in that particular time.

(2) By Auxanometer : Generally growth of a plant is measured by linear method only. Auxanometer is use to execute this method. Here a simple arc auxanometer has been described.

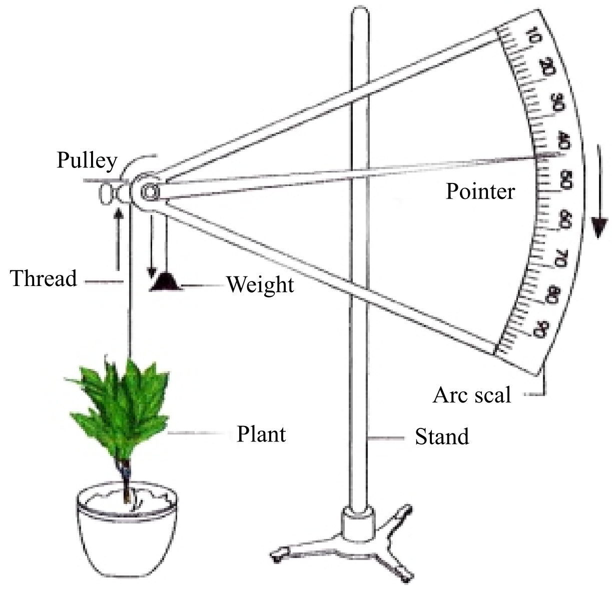


Fig. 13.4 Arc auxanometer

Arc Auxanometer : the growth taken place in the height of a plant is measured with the arc auxanometer as shown in above fig. A small Pulley is attached at the top stand of this apparatus an indicator remains connected with the Pulley which works on a scale. By folding a thread on the top of the stem of the plant that is growth, it is taken over the pulley and some weight is tied on the other end. When the stem increases, the thread tied to the weight pulls the thread downward resulting in the pulley to rotate. Since, the indicator remains attached with the pulley, so when the pulley rotates, the indicator moves on the scale which shows the increase in length.

Increase is seen in magnified form by the arc indicator and its value depends on the diameter of the pulley and length of the indicator.

Factors affecting growth

Plant growth is affected by many factors. These factors belongs to both environmental and physical functions. Absorption of water and minerals, photosynthesis, respiration etc. are counted in physical function factors while weather and soil related factors are counted in environmental factors. Some important factors affecting the growth of a plant are as follows :

(1) Light : Light affects growth in many ways like:

(a) Light intensity : Excess intensity of light slows down the growth. High light intensity increases dwarfism in plants because the cell of stem become small and even the leaves also become smaller in size.

(b) Quality of light : The pigment found in plants absorbs light waves with fixed wavelength. Reddish light is most suitable for growth. Opposite to this ultraviolet and infrared light rays limit plant growth.

(c) Duration of light : The duration of light has a significant effect on the growth of physiological and reproductive structures. A fixed duration of light for flowering in plants is called photo period. The flowering stops due to lack of essential photo period.

(2) Water : Supply of water is also directly related to growth. Quantity of water available to the plant affects the growth and shape. All the biological function like absorption, osmosis, transpiration, photosynthesis, respiration, germination etc. depends upon water.

(3) Temperature: Temperature also directly or indirectly affects the growth. Generally ordinary growth occur in the high class plants between 5^0C to 35^0C temperature. The plants are damaged if the temperature rises more than 35^0C and Germplasma becomes inactive if the temperature falls down to 0^0C and the cells are damaged.

(4) Oxygen supply : Quantity of oxygen increases the growth in plants because it helps to change static reaction into dynamic energy helping the plants in respiration for many biological functions including growth.

(5) Mineral salts : Many deficiency diseases occur in plants due to less of mineral salts. It results in slowing down growth of plants.

(6) Plant hormones : Plant growth is controlled by some carbonic compounds available in very less quantity. These compounds are called plant hormones or growth promoting substance. Growth of plant stops due to deficiency of them.

Growth Regulatory Substances

Some chemical substances, which are synthesized in plants in less quantity, control the growth effectively are called Growth Regulatory Substances. First German scientist J. Von Sachs (1882), presented the concept of growth promoting hormones in plants. Sterling (1902) used the term 'Hormones' first and Thimann (1948) used the term 'Phytohormone' for plants hormone. According to him, “Plant hormones are the complex carbonic substance which transfer to other originating naturally in a part of plant where their very less quantity affects the growth.” Generally, these substances affect and control the physiological activities.

Classification of Hormones

Plant hormones can be classified into two major groups :

(i) Growth promoting hormones : The hormones which promoting growth or increases growth rate are called Growth Promoting Hormones.

In this category Auxin, Gibberellin, Cytokinin and Ethylene etc. are included.

(ii) Growth inhibitory hormones : The hormones which reduce the growth rate of plants are called Growth inhibitory hormones. Abscisic acid is a growth inhibitory hormone.

Growth Promoting Hormones : The hormones which increases the growth rate are called Growth Promoting Hormones. Following are the growth promoting hormones:

1. Auxin 2. Gibberellin
3. Cytokinin 4. Ethylene

1. Auxins

The term 'Auxins' has been derived form Greek word 'Auxein' which means 'to grow'. Auxins is such a plant hormone growth which was discovered first and it promoting elongation in the shoot apex cells of plants. It was firstly isolated from human urine. Indole Acetic acid and all similar natural and synthetic substances are called Auxins.

Discovery of Auxins : Charles Darwin, the propagator of organic evolution theory, was the first man who the experiments made on *Phalaris canariensis* in their book, ' The Power of movemanent in Plants'. According to Darwin, Coleoptile moves in the direction of light if is turn light once. He concluded on the basis of their experiments that if coleoptiles are given plane polarized light, then the substances, which are formed at the top level, shifts downward resulting formation of curve in this part. Boysen Jensen and Paal took the experiment of Darwin further ahead.

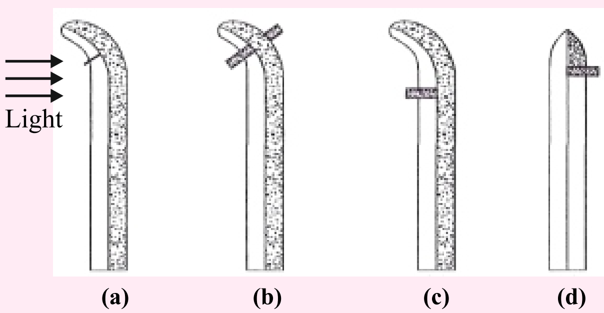


Fig. 13.5 Expriment of Boysen Jensen

Boysen Jensen (1910-13) executed experiments on *Avena sativa* and said that if we cut the top of coleoptiles, is does not show phototropism or curve. If we keep cuted part back to its place then the capacity of phototropism and curving is restored. If we keep a piece of Gilletine between top head and stump, the curving capacity remains the same.

If we join a mica plate on a horizontal slit in the half portion of darkside of coleoptiles, then it does not move towards light but if the slit and mica plate are attached on the illuminated side, the coleoptiles moves towards light. Boysen, on the basis of this experiment, concluded that the substance or the catalyst responsible for phototropism or curving moves downward from darkside.

Paal (1919) also experimented a lot regarding this theory and proved that the growth promoting chemicals remain in the upper side. He also said that substance originating at the top is soluble in water.

The credit of discovering Auxin goes to **F.W. Went** (1926-28). He succeeded in isolating growth promoting substances, He after cutting the top of coleoptiles of *Avena sativa* kept on the cube of Ager. Then, the Agar is separated from the top and divided in many small pieces and after setting up the pieces on stump of coleoptiles, he found that growth took place equivalently. Opposite to this growth pauses if an ordinary agar cube is kept on the stump of coleoptiles. It makes clear that some substances which are responsible for growth shift downwards in agar portion. Went, based on his experiments, found that quantity of auxins decrease in the illuminated side if the coleoptiles are lighted from one side. In his other experiments, he kept the top of *Avena sativa* between the two cubes of agar, in which a thin plate of mica was attached in such a position, so that the vertex may remain hal-half on both the cubes. When one side is light, 65 percent of hormones accumulated in the cube of dark side.

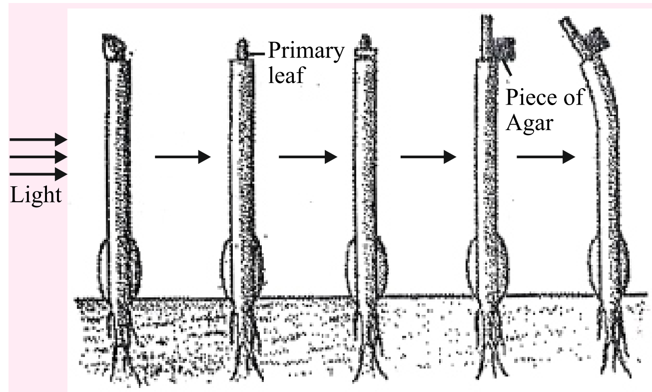


Fig. 13.6 Went's experiment

The cells of the dark side grow too much due to excess quantity of hormones and the stem turns towards light.

Therefore, some other scientists proved that if coleoptiles and main vertex are kept horizontally, then shifting and flow of hormones occur downwards due to gravitation. Enough concentration of auxins in the lower cells promotes growth in the lower cells of stem vertex and it turns upward. But, in root top auxin retards the growth in main vertex. Thus, the lower cells turn downward due to lesser growth.

Definition of Auxin-"Those organic substances which promote the elongation of stem in less then 0.01 molar concentration."

Chemical nature of auxin

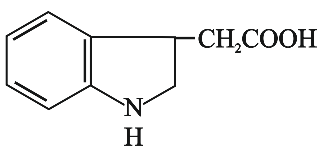
Kogl (1931) named those substances which are capable to promote curve in coleoptiles of *Avena sativa* is Auxin. Kogl and Haagen-Smit (1931) separated a substance from urine of human being. He named this Auxin-A and its formula is $C_{18}H_{32}O_5$ .There are two kinds of Auxins- (1) Natural auxins (2) Synthetic auxins

1. Natural Auxins : Kogl and coworkers again separated a substance from human urine which was named Heteroauxin. Its molecular formula is $C_{10}H_9O_2N$ and it is called Indole-3-acetic acid or IAA. This is a natural auxin found in plants. Other natural auxins are found as derivatives of IAA. Natural auxins are formed in apical meristem and its synthesis is done by amino acid called triptophane. Zn is essential for synthesis.

2. Synthetic Auxins : Some synthetic chemical compounds also work as auxins. These are called synthetic auxin like Naphthalene Acetic Acid (NAA), Indole 3-Butyric Acid (IBA), 2-4 Dichloro phenoxy acetic acid (2-4 D), Indole 3-Propionic acid (1PA). Few quantity of auxins remain present in every part of plants but these are found much in growing or transforming tissues. They move from top to bottom and move from one cell to another by diffusion.

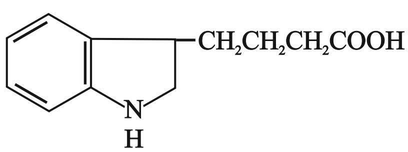
Natural auxins

(i) Indole-3-acetic acid (IAA)

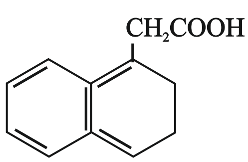


Synthetic auxins

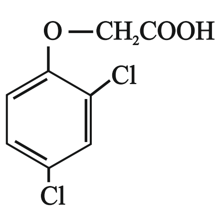
(ii) Indole-3-Butyric acid (IBA)



(iii) Nephthalen Acetic acid (NAA)



(iv) 2, 4-Di, Chloro-phenoxy acetic acid (2, 4-D)



(v) 2, 4, 5-Tri, Chloro-phenoxy acetic acid (2, 4, 5-T)

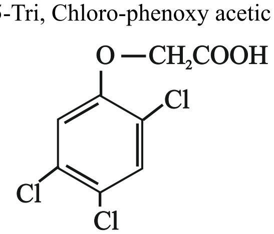


Fig. 13.7 Main Auxins

Physiological effects of Auxins

1. Apical dominance : Presence of apex bud stops completely or partly the growth of lateral and auxiliary buds. This is called Apical dominance. Auxins which move downwards are synthesized by Apex Buds. Consequently growth of lateral buds stops. If the apex bud is removed, then lateral and auxiliary buds resume growing. As a result, the plant becomes like a bush. The apex buds of Chickpeas and Hennah are plucked.

2. Cell elongation : The main function of auxin is to increase length of shoot apex cells formed as a result of division. In shoot apex, concentration of auxin promotes elongation. Therefore, the shoot apex is the positive phototropism and negative geotropism.

3. Root initiation: Auxin helps the roots to grow. Some plants like rose, bougain villea, lemon, orange etc. are prepared by stem cutting . If the lower part of the cutting is planted after dipping in the solution of auxin, the roots grow very soon on the dipped area. Specially, Indole butyric acid (IBA) has been proved useful in this work.

4. Parthenocarpy : Fruits developed from the unfertilized ovary are called parthenocarpy fruits and this process is called parthenocarpy. These fruits are seedless like orange, lemon, watermelon, brinjal, grapes etc. If the auxin is sprayed on the stigma by removing the stamens from the flowers in the bud stage, the seedless parthenocarpy fruits are produced.

5. Prevention of lodging : Many crops like wheat plant falls from the root due to weakness under the effect of by speedy winds. If the solution of auxin is sprayed on the plants, the lower part of the plants become strong and their possibility of falling down becomes very less.

6. Control of dormancy : Auxin retains dormancy in seeds and tubers. Auxin prevents sprouting of seedlings and buds by which they can be stored for long time. By spraying NAA, potato tubers can be stored approximately for 3 years.

7. Thinning of flowers : In some trees like mango, flowers bloom in a particular year in huge quantity in some particular species. Thus, quantity of fruits increase but they remain small in size. Unnecessary flower blooming can be controlled by spraying NAA like Auxin.

8. Effect on abscission: Falling of leaves, flowers and fruits from the trees before maturity is called abscission. It happens due to lack of Auxin. Auxin prevents the formation of abscission layer. It can be prevented by spraying NAA, 2-4D, IBA etc.

9. Eradication of weeds : In agricultural fields, often, some unnecessary plants grow with the crops. These plants compete with the crops for water, minerals etc. which affect the growth of the crops. These unnecessary plants can be destroyed by using Auxin. Weeds having wide leaves can be destroyed by 2-4 D (Dichloro phenoxy acetic acid) and 2-4-5 T (Tri chloro phenoxy acetic acid) while grassweeds can be destroyed by 2 : 2 Di-chloro propionic acid (Delopan) can be destroyed by synthesized auxins.

10. Shortening of inter nodes : Fruits are produced on the small branches of plants like in pineapple, apple etc. The number of small branches can be increased by shortening the inter nodes of long branches of these plants by spraying NAA.

11. Tissue culture : Artificial culture of tissue and parts of plants can be done widely by tissue culture technology. In this technology auxin plays an important role in root formation and callus differentiation.

2. Gibberellins

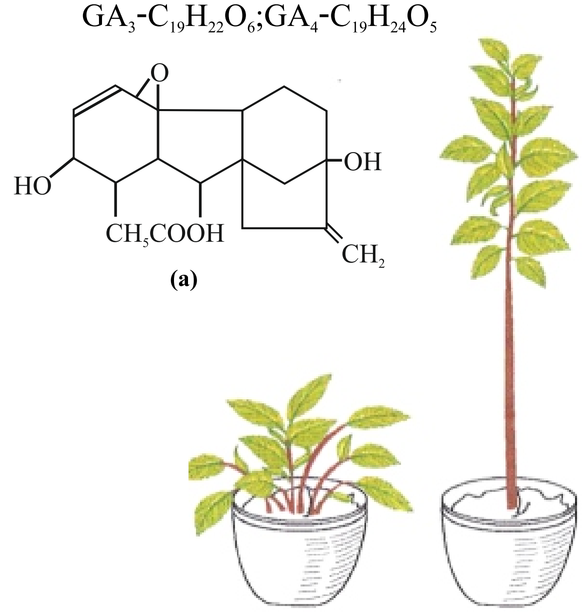
Gibberellin, related to a disease of rice, was first discovered in Japan. In Japan in 1890 some plants were found in rice fields they are unnecessarily long and they lacked flowers. This disease was named Bakanae disease. Hori studied this disease in 1898 and found that the plants affected by this disease are abnormally long and thin. They don't blossom and they are incapable to produce fruits and seeds. Thus,they were called Foolish Seedling. This rice disease is caused by fungus *Gibberella fujikuroi*. Kurosawa (1926) proved that this disease develops by spraying the secretion of this fungus. Yabuta and Hayashi (1939) obtained the pure crystal chemical from this fungus and named it Gibberellin. Brian and coworkers got the pure form of gibberellin in 1954 and called it gibberellic acid. More than 100 types of gibberellins have been found yet from different fungus and high class plants. These are known as GA_1 GA_2 $GA_3$$GA_4$ ……. GA_{100} etc. Among these GA_3 was discovered at first and it is one of those generally found gibberellins.

Chemical Nature

Chemically all the gibberellins are gibberellic acid. Structure of all the gibberellins is same. A giben ring is found in them .There are 19 carbons in some giben rings while 20 carbons in some other rings. Chemical formula of some gibberellins are :

GA_1- $C_{19}H_{24}O_6$;GA_2-$C_{19}H_{24}O_6$

GA_3-$C_{19}H_{22}O_6$;GA_4-$C_{19}H_{24}O_5$



(b) (c)

Fig 13.8 (a) Gibberellin acid (GA_3)
(b) Rosette plant (c) Increasing the length of Rosette plant due to the effect of Gibberellin (Bolting)

Chemically all the gibberellins are Terpenes. Their transfer is non-polar and is not affected by light.

Physiological Effects of Gibberellins

physiological effects of gibberellins are following :

1. Internode elongation : Gibberellin promotes growth in the height of plants by motivating the inter node elongation in plants. It also helps the leaves to grow in size. In the binnial plants with rosette nature this leads to the formation of a long leafless inter node. This long leafless inter node is called Bolt and this process is called bolting. Genetically dwarf plants can also be made tall by gibberellin treatment. Change in height and size of rosette nature plants is called bolting.

2. Seed germination : Gibberellin play significant role in seed germination of crops like wheat, maize and barley. The seeds of these food grains become thick by absorbing the water and embryo synthesizes gibberellin which is diffused in aleurone layer. It also activate synthesis of enzymes like amylase, protease, lipase, ribonuclease. These enzymes digest the food substances available in embryo. In this way the products formed after digestion helps in the growth of embryo.

3. Breaking of dormancy : Gibberellin helps the buds and seeds of trees to germinate. The high concentration of Gibberellin can make dormancy ineffective.

4. Flowering : Gibberellin is capable to replace vernalization or photoperiod for flowering in some plants.

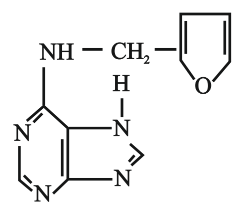
5. Parthenocarpy : Gibberellin is comparatively more effective in parthenocarpy than Auxin. Parthenocarpy Can be carried out in tomato, apple, pineapple or pome or fruits with seeds more easily by gibberellin than auxin.

3. Cytokinins

G. Haberlandt 1913 first observed that some soluble substance were present in the phloem of some plants and they help in cell division. Later J. Van Overbeek 1941 said that coconut water has some such substances that helps in cell division. Skoog and Miller (1955) separated a significant useful substance from the DNA of yeast for cell division and named it kinetin. Letham 1963 called the Kinetin as cytokinin. Letham and Miller 1964 separated a substance similar to Kinetin from embryo of maize and it was called Zeatin. Zeatin is the first cytokinin found naturally.

Chemical nature

Cytokinin is produced from the decomposition of nucleic acids. Structurally these are aminopurine in which furfuryl ring is found. Therefore, the name of the first identified cytokinin is 6- Furfuryl Amino Purin. Synthesis of cytokinin in plant part, that part where cell division occur eg.-Stem shoot, root shoot developing buds, young fruit. Cytokinin act as the structure component in cytoplasm of t-RNA.



Cytokinin
(Kinetin-6-furfural amino acid)

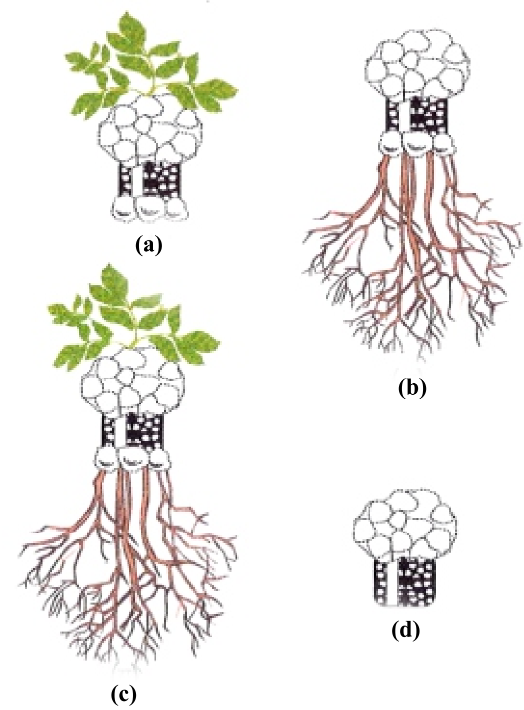


Fig. 13.9 (a) Development of shoot in more cytokinin, less auxin (b) Development of root in less cytokinin and more auxins (c) Development of shoot and root in average cytokinin and auxin (d) Development of cells in average cytokinin and less auxin.

Physiological effects of Cytokinins

1. Cell division : Cytokinin in presence of auxin promotes cell division. It promotes the process of formation of Meristem tissue in plant.

2. Cell elongation : Cytokinin promotes cell elongation. The root cells of tobacco were found elongated 4 times more than ordinary being affected by cytokinin. Cytokinin exhibits this effet in the presence of auxin and ethylene.

3. Cell differentiation : Cell differentiation is also affected by this. It controls formation of body parts in plants along with Auxin. Cytokinin produces various effects in different ratios in presence of auxin.

Shoot development from callus is motivated in nutrient medium in process of tissue culture by more cytokinin and less auxin. Less cytokinin and more auxin promote formation and differentiation of roots. Stem and the root both are developed equally in equal proportion of cytokinin and auxin. Plant growth controller is very useful in tissue culture and genetic engineering because tissue culture has proved very useful in developing new plant varieties.

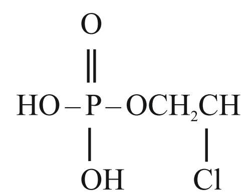
4 Prevention of apical dominance : Apical dominance is stopped by spraying cytokinin and lateral buds begin to grow.

5. Destroying dormancy : Dormancy of seeds and tubers is destroyed by cytokinin and helps them in germination.

6. Delaying of senescence : Cytokinin prevents senescence in plants. Generally decomposition of protein, nucleic acid etc. Starts before senescence in leaves. But due to the effect of cytokinin, their decomposition slows down and hence the effect of senescence delays. Effect of delaying of senescence by cytokinin is call Richmond Lang effect.

4. Ethylene

Ethylene is a gaseous hormone. It is unsaturated hydrocarbon. R. Gane (1934) had proved that ethylene is a natural gaseous hormone. It is synthesized by every organs of plant and it also works as a catalyst in maturing and growing of fruits. Its high concentration is found in leaves, dormant buds and flowers. Production of Ethylene increases with ripeness of fruits. Ethylene is a gaseous substance. Its molecule are small and water soluble. Therefore, it is transported in the intercellular spaces by the common diffusion method in plant tissues. Ethephon is used for its artificial production. Ethylene is obtained from 'Ethephon' or 2- chloro phosphoric acid.



2-chloro ethel phosphoric acid

Physiological effects of Ethylene

1. Influence on growth : Ethylene generally prevents the growth in the height of stem and root and promotes the growth in thickness. The formation of adventitious roots increases and the horizontal growth increases in plant.

2. Ripening of fruits: Ethylene plays significant role in natural ripening of fruits. Some genes being affected by ethylene synthesize such enzymes which play important role in ripening of fruits. Such fruits are called climacteric fruits which produces ethylene during ripening

3. Effect of flowering : Ethylene puts an adverse effect on flowering in plant in several species. But it increases flowering in mango, pineapple etc. It improve female character flower and increase number of female flower

4. Abscission: Ethylene increases abscission in leaves, fruits and flowers.

5. Senescence: Ethylene increases senescence in plants by which leaves become yellowish and fall. Metabolic activities stop due to high concentration which results in fading of flower petals and falling apart.

Growth inhibitors

The hormones or substances which decrease growth rate are called growth inhibitors. These substances are essential for control and balance of growth. Abscisic acid is the main hormone under inhibitors.

Abscisic Acid

Abscisic acid is naturally found in plants. This is the main growth inhibitor hormone. It helps the plant to face the adverse environmental conditions. Therefore, it is also called stress hormone.

Wareing, (1963) separated a growth inhibiting material from the leaves of the plant Acer and this substance was named Dormin. Addicott and colleagues (etal. 1963) removed a substance from cotton flower buds and named abscisin. Later it proved that dormin and abscisin are same substances and their name was kept abscisic acid.

The chemical formula of abscisic acid is $C_{15}H_{40}O_4$ It is composed of three isoprene units made of five carbon. There is a carboxyl (-COOH) group present in it. Most of the synthesis of ABA occurs when the depletion of the carotenoids is reduced by the reduction of water.

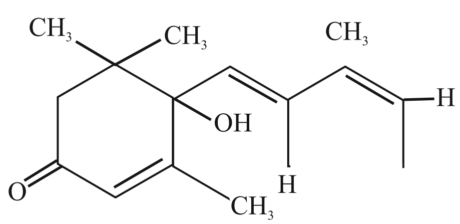


Fig. 13.10 Abscisic Acid

Physiological effects of Abscisic acid

(1) Abscission of leaves : By spraying ABA's solution on the leaves, it is quickly dissociated.

(2) Dormancy of buds and seeds : ABA induces the dormancy of buds and seeds, resulting delay in growth of buds and germination.

(3) Anti transpirant : A small amount of ABA partially closes the stomata of the leaves, which reduces the rate or transpiration.

(4) Inhibition of growth : ABA block both cell division and cell development.

(5) Senescence : ABA induces senescence in many plants, causing severe damage to the chlorophyll, proteins and RNA.

(6) As a stress hormone : The formation of ABA increases in the scarcity of water. Hence the closure of the stoma is induced, which reduces 56% of transpiration and 14% of photosynthesis.

Photoperiodism

After the vegetative growth of plants for certain period of time, the plants enter the genital stage, and it begins process of flowering. Entry from physiological condition into flowering stage in the plants is controlled by many factors. The physiological condition is different in plants. One of these the period of light or photoperiodism.

The study of the effect of photoperiodism on flowering was first done by two American scientists W.W. Garner and H.A Allard, (1920). They noticed that when the Maryland Mammoth variety of tobacco is sown in spring then inspite of good physical growth there is no flowering. But this kind of seeds are sprouted in the green house in autumn and send their newborns to the field in the beginning of spring then these plants flowering at the beginning of the summer season. On the basis of this experiment, they came to the conclusion that the critical factor of influencing flowering is the period of light, called photoperiod. Defining photperiodism, they told that the length of the day, which is favourable to the flowering of the plant, and the response of the plant to the expected length of the day or the expected period of light, is called photoperiodism . According to Hillman, (1969). The response of plants towards the intervals of light and dark periods is called photoperiodism.

Classification of photoperiodism

Based on photoperiodism responses, the plants are divided into following classes:

(I) Short Day plants; SDP : Plant that flower when photo period is available in a shorter period than the definitive critical photo period, are called short days plants. These plants require less than 12 hours long days and continuous long dark period (14-16 hours) to produce flower. So it is more appropriate to say them long night plants. If the period of their continuous darkness is broken by giving a light beam then the flower will not be produced Examples- Tobacco, Soyabean, Sweet potato, Dahlia, Sugarcane, Mustard etc.

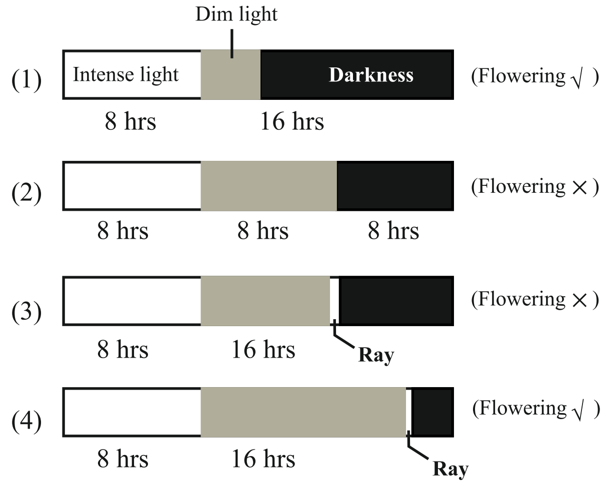


Fig. 13.11 Different stages of short day plants (SDP)

(ii) Long Day Pants; LDP : Long day plants require long-term light from critical photo period for flowering. These plants require continuous more than 12 hours long days and short dark period for flowering. These are also called short night plants. The flowering is blocked when the continuous light period of these plants is interrupted by giving darkness. Examples: spinach, radish. sugar beet, wheat, carrots, potatoes.

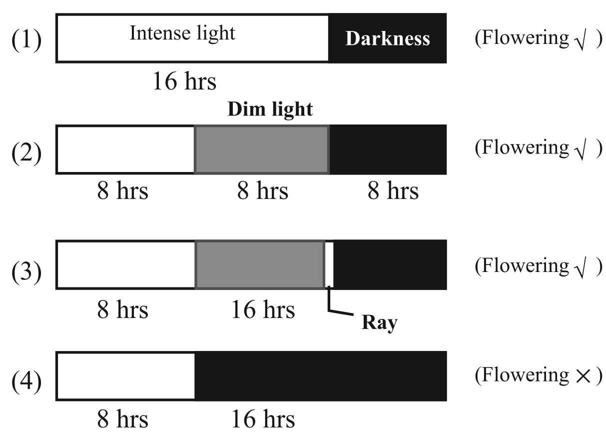


Fig. 13.12 Different stages of long day plants (LDP)

(iii) Day Neutral plants : Those plants whose flowering process is not affected by the photo period and those who flower in almost all photo periods are called day neutral plant. Examples- Tomatoes, cotton, corn, chilli, sunflower etc.

Site of Photoperiodic Stimulus : The task of receiving the photo period is mainly done by the leaves and buds. Choliyakhan (1936) scientist Concluded with his experiments that only one leaf is sufficient to absorb photo periodic stimulus. The full expanded and developed leaves are more sensitive than the young leaves towards light intensity . Sensitivity to stimulation in the mature or old leaves gradually decreases. Transmission of light stimulation is done through the phloem to the flowering buds leaves . But its transmission is independent of the transmission of photo synthetic products.

Mechanism of Photo Periodism

Several theories have been presented for the purpose of clarifying the method of photo periodism in plants. Some of these key principals are as follows:-

1. Florigen hypothesis : This is also called Choliyakhan hypothesis. According to which in a specific photo period, the hormone inducing the formation of flowers which is called florigen. This hormone is formed in leaves.

Florigen hormone is comprised of two compounds:

(i) Gibberellin : Essential for the addition and increase of stem and:

(ii) Anthracenes : Essential for flowering gibberellin is essential for flowering induction is essential for LDP plants and anthracenes is essential for short photo periodic plants. When long photo periodic plants are kept in short-period light then there is anthracenes in higher ammounts and gibberellin is made in small quantities but as soon as the leaves of the said plants get long period light the quantity of gibberellin increases simultaneously and flowering starts in plants.

Short period plants(SDP) have opposite conditions. When SDP is kept in loag photo period light then there is less quantity of gibberellin and anthracenes. But as soon as the leaves of the shaded plants of get light of short photo period, the amount of anthracenes increases simultaneously and flowering starts in plants. So far the separation or expression of any substance such as anthracenes cannot be done. So this concept could not be established.

2. Phytochrome theory: This theory was proposed by Borthwick and Hendricks, (1950).

According to these scientists, a light receptor pigment is found in the tissues of the leaves of plants called phytochrome. Phytochrome is bright blue/blue-green protein rich substance that is present in interchangeable form. The two form of Phytochrome are respectively P_{730} (photochrome far red; pfr) and P_{660} (photochrome red pr), P_{730} pigment absorbs light (infrared)with 730 nm . P_{660} pigment absorbs light (red radiation) of 660 nm. P_{660} absorbs the light of red radiation and converts to converts to P_{730} . Similerly, the P_{730} form of infrared (for red) radiation is absorbed and converted to $P_{660.}$

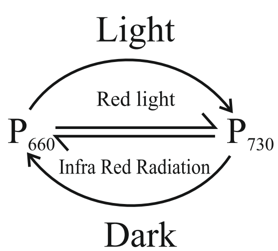


Fig. 13.13. Line diagram of phytochrome theory

During the daytime, the pfr form of phytochrome in the sunlight is sufficiently collected in plants which block the flowering in the SDP while motivate flowering in LDP. When the sun goes down, the opposite process occurs because in pigment form, the pfr converted into Pr form, which increases the amount of Pr which inspire flowering in the SDP while block flowering in LDP. It is believed that these two forms of phytochrome control the formation of flowering hormones which affects flowering.

Dormancy

After complete development of seeds in the plants, their seeds growth stops. In some plants, even if the favorable environment conditions are available, seeds are germinated immediately after their formation. But some in other plants do not germinate even when favorable environment conditions are available that is, these Seeds are physiologically inactive. This phase of seeds is called dormant stage and this phenomenon is called dormancy. Due to dormancy, seed germination is temporarily suspended for some time. Due to this, the seeds remain viable for a long time. Suspension period ranges from 5 to 10 years in xerophytes such as *Acacia*, grass etc. In the arctic tundra, the dormancy of lupin seeds is estimated to be 1000 years. Most of the Crop plants remain dormant for between 2 and 5 year. Dormant stage is absent in some plants such as in seeds of *Rhizophora*, peas etc. Dormancy in seeds results from the effects of endogenous or exogenous factors. Endogenous factors are related to the structure and Development of seeds, whereas the exogenous factors are related to the environment and climate.

Primany and Secondary Dormancy :

When the mature seeds do not immediately germinat even if their internal or structural and functional conditions are favourable, it is called primary dormancy. while some mature seeds have dormancy due to the changes occurring during the storage period, it is called secondary dormancy.

Factors affecting dormancy :

Dormancy in seeds is influenced by many endogenous and exogenous factors, which are as following :

1. Hard seed coat : In many seeds, seed coat is extremely rigid. This seed-coat is impermeable to the water required for germination (examples gram, peas) and Auxin (examples *Zanthium*). Sometimes it does not allow the development of embryo by generating mechanical resistance. Example- *Amaranthas*.

2. Immaturity of embryo: In many plants, the seeds are dispersed before embryos mature. Hence, germination of these seeds is not possible unless the maturation of embryo is complete. Examples-*Ginkgo biloba, Gnetum gnemone*.

3. Requirement of Post Ripening period: The seeds of many plants do not germinate after just getting mature. But after some time of rest, sprout in favourable conditions. During the period of rest, these seeds acquire the capacity of germination. This time of rest is known as Post Ripening period. In many species the post ripening period is of some weeks to some months. Eg- wheat, barley, oats etc.

4. Requirement of Specific temperature and light : Cold treatment is required before the germination of seeds. These seeds cannot germinat until they are not treated under specific cold-heat treatment. They are treated naturally in winter season. The favorable temperature is 0°C to 5°C for cold treatment. Examples-cherry, oak etc. Similarly germination of some seeds is very sensitive to duration of light, its quality and quantity. These seeds are called Photoblastic. Examples-tobacco, cypsela etc.

5. Presence of germination inhibitors : Many substances present in the pulp of pulpy fruit are able to inhibit the germination of seeds, which are called germination inhibitor. Few of these are Absicic acid (ABA), Coumarin, Para - ascorbic acid, phenolic acid etc. With this seed lying in the soil, these substances gradually become neutralized ,which means that they are washed and then the seed gets germinated. The preventive effect of these substances can be removed from the gibberellin.

Methods of breaking seed dormancy

Different types of methods are adopted to break seed dormancy, which depends on the plant and dormancy factor. There are following methods to break seed dormancy.

(1) Scarification : In this method the seed shell is weaken by breaking or scarification of seed coat. Many times the seeds are soften by putting into the solvent of dilute sulphuric acid (H_2SO_4), hot water or fat.

(2) Chilling treatment : Such seeds which require natural cold exposure to break the seed dormancy. Artificial methods of cold treatment can be used to break seed dormancy.

(3) Exposure to alternate temperature : Dormancy of some seeds can be broken by exposure to alternate low and high temperature.

(4) Light : The germination capacity of some positive photoblastic seeds can be increased on the exposure of red light.

(5) Pressure : The germination capacity of some dormant seeds can be increased by keeping them on 2000 atmospheric pressure between 18^0C to 20^0C because in this the seed coat becomes weak and its permeability increases.

(6) Use of growth regulators : Those seeds whose dormancy need cold treatment, post mature period, presence of restraints or specific light, their dormancy can be broken by the use of growth regulators. Gibberellin, ethylene, chlorohydrins and thiourea are, main in this category.

Vernalization

In most plants, there is profound effect of temperature on the process of flowering including suitable photo period. The foremost study of behavior of plants against temperature is done by scientist Lysenko (1920) on the two varieties of rice-one of winter and another spring variety. Light has the main influence on flowering on annual plants, and the effect of temperature is secondary. The situation is different in vernalin plants. There are only vegetative growth in the first year and the action of flowering takes place in the second year, but before flowering, they have to be exposed and treated in the low temperature of the winter seasons. Genetic phase does not start in the absence of cold effect in the vernalin plant and it remains in corporeal condition. In cold varieties the need of low temperature can be fulfilled by artificial cold treatment so that flowering can be done in the summer season. The process of flowering by cold treatment is called Vernalization. Acording to Choird, (1960) acquiring the ability of flowering by cold treatment is call Vernalization. Vernilization technique is very simple. First of all seeds are soaked for germination then germinated seed is kept under temperature 0°C to 5°C. The duration of cold treatment is different for different species and varieties. It may be few hours to few weeks. Cold treatment causes the formation of some substances similar to the hormones in the leaves that control the vernalization. Melchers, (1939), named the substance Vernalin. According to Lanng, (1952), vernalin is the predecessor of the hormone florigen that initiates the flowering process.

Winter plant —(Low tempreture)→ Vernalin —(Indused Photo periodism)→ Florigen → Flowering

Vernalin and florigen are both hypothetical hormones whose isolation has not yet been possible. The embryo and meristem of the plant are the receipient organ of cold treatment.

If vernalized seeds or plants are treated in higher temperatures then the effect of vernalization is destroyed, it is called Devernalization.

Senescence

None of the creatures is immortal, any organism present on earth is born at a time and it dies after sometime. The period between birth and death of the organism is called its lifetime. After achieving maturity stage in the life of all living beings, this kind of deteriorative process happens which leads to its death, Therefore, the period from the time of maturity for any organism till death is called senescence. During this period, the creature becomes weak and its functioning become less. Metabolic substances are stored and dry weight decreases. A.C. Leopold, (1961) describes four types of senescence in plants:

(1) Whole plant senescence : After producing fruits in many annual plants such as wheat, gram, tomato etc. the entire plant becomes yellow and eventually becomes dead..

(2) Apex senescence : In this type of senescence, the upper part of the plant dies every year and the underground stem and roots remain alive. The following year, the buds are formed in the underground part, which rebuilds the arial part of plant.

(3) Leaf fall senescence : In many plants, leaves fall in autumn but the root and the stem remain alive, Leaves develop again when favourable conditions occur.

(4) Successive senescence : In the normal condition of most annual plants, the old leaves die before being senescent. After this, other leaves, stems and roots are senescent and died, it is called successive senescence. Growth hormone ABA and ethylene stimulate senescence. ABA primarily intensity foliage senescence and ethylene intensify senescence in fruits. Auxin, gibberellin and cytokinin are able to postpone senescence in most cases.

Abscission

Falling leaves, flowers and fruit separated from mother plant is called Abscission. Abscission is a biological process that result from changes in the cells of the basal part of these plant organs. At these places, mid-pillars and outer walls of cells of a certain area become digested by pectinase and cellulase enzymes, so that the cells begin to separate from each other due to the breakdown of the middle chambers and reefs. The tissues of this area become soft and weak and an abscission layer is formed at this place. The cells below the abscission layer constitute partial disintegration of the cells that form a protective site or a detachment area. As a result of heavy wind blows or rain, a plant parts break down from the place of the abscission layer and separates it from the plant.

Abscission is due to the change in the hormone balance, In this process, abscisic acid plays an important role.

Important Points

1. A permanent and irreversible change in the amount of living is called growth.
2. Growth is influenced by genetic, atmospheric and physiological factors.
3. The growth of plants is usually done in its apical parts.
4. Growth of plants and graph of time is obtained as the sigmoid curve.
5. Measurement of growth is done by Auxanometer.
6. Auxin, gibberellin, cytokinin, ethylene and Abscisic acid are the major growth control hormones.
7. Plant hormones are formed in the apical parts of the plant and are distributed in the whole body by the phloem.
8. Abscisic Acid is the growth inhibitory hormone.
9. Senescence is the characteristic quality of living, which is displayed after attaining mature state.
10. Favorable light duration, which inspires flowering in plants, is called photoperiod and this phenomenon is called Photoperiodism.
11. To obtain the ability of flowering in plants by cold treatment is called vernalization.

12. The temporary suspension of seed germination is called dormancy which can be done more or less than the application of vernalization or hormone.

13. In the leaves of the plant, a light-sensitive pigment phytochrome is found, which inspires flowering action in plants with the effect of light.

Practice Questions

Multiple Choice Questions-

1. The first plant hormone discovered
   (a) Auxin (b) Gibberellin
   (c) Ethylene (d) Cytokinin
2. To convert rosette plant of cabbage into long shoot plant, we need to spray
   (a) IAA (b) ABA
   (c) GA (d) Ethylene
3. The hormone found in Gaseous condition is
   (a) Auxin (b) Gibberellin
   (c) Cytokinin (d) Ethylene
4. Which hormone is most active in plants during autumn?
   (a) IAA (b) ABA
   (c) GA (d) All of these
5. Apical dominance is found
   (a) Due to auxin (b) Due to gibberellin
   (c) Due to cytokinin (d) Due to ethylene
6. Which of the following plant hormone has not yet been isolated
   (a) Auxin (b) Florigen
   (c) Cytokinin (d) Gibberellin
7. The hormone condensing the growth of the root apex is
   (a) Cytokinin (b) Auxin
   (c) Gibblerellin (d) All of these
8. In the fields dicot weed is controlled by
   (a) IAA (b) GA
   (c) IBA (d) 2-4D
9. Which growth controller in plants is called stress hormone ?
   (a) IAA (b) ABA
   (c) IBA (d) NAA
10. Phytochrome was discovered by
   (a) Bothwick and Hendrix
   (b) Bison-Jansen
   (c) Garner-Elard
   (d) Darwin-vent

Very Short Questions

1. What do you understand by grand period of growth ?
2. Which substance is used for artificial maturation of fruits ?
3. What is the favorable temperature of cold treatment
4. What is giatin ?
5. What is Vernaline ?
6. Tell the name of the hormones that stop aging and close stomata ?
7. What is the chemical name of kinetin ?
8. Give two synthetic auxin's names?
9. Which hormones induces parthenocarpy.
10. What do you understand by dormancy ?
11. What is called Photoblastic seeds ?

Short Type Questions

1. What is sigmoid growth curve?
2. Explain the difference between free and bonded auxins ?
3. What is becane disease ?
4. What do you understand by apical dominace.
5. What is Bolting Effect ?
6. Why is their decrease in dry weight in new born at the end of germination ?
7. Why do the gardener cut the top part of Mehndi bushes ?
8. What is phytochrome ? What is the significance of it ?
9. Why is Abscisic acid called stress hormones?
10. Write a short notes on :

(1) Dormancy

(2) post ripening period

(3) Photoperiodism.

Essay Type Questions

1. Write a short note:

   (A) Growth pheses,

   (B) Growth dynamics

2. How is growth measured ? Describe factors affecting growth ?
3. What is Auxin ? Discuss its physiological effect on plant growth ?
4. Describe the experiments done by various scientists regarding the discovery of auxin.
5. What is called dormancy ? Describe the causes of dormancy and the measures to end it ?
6. Write a short note on the following:

   (1) Gibberellin and cytokinin

   (2) Growth inhibitors

   (3) Photoperiodism

   (4) Senescence and abscission

   (5) Vernalization

Answer Key

1.(A)	2.(C)	3. (D)
4.(B)	5.(A)	6.(B)
7.(B)	8.(D)	9.(B)
10(A)		