GROWTH

Growth is an irreversible increase in size. It may be evaluated by measurements of mass, length or height, surface area or volume.

Growth is restricted only to living cells and is accomplished by metabolic processes involving synthesize of macromolecules, such as nucleic acids, proteins, lipids and polysaccharides at the expense of metabolic energy.

Growth at cellular level is also accompanied by the organization of macromolecules into assemblages of membranes, plastids, mitochondria ribosomes and other cell organelles. Cells do not definitely increase in size but divide, giving rise to daughter cells. An important process during cell division is synthesis and replication of nuclear DNA in the chromosomes, which is then passed into the daughter cells. Therefore, the term growth is used to denote an increase in size by cell division and cell enlargement, together with the synthesis of new cellulose materials and the organization of cellulose organelles.

Growth is also defined as a vital process which brings about a permanent change in any plant or its part in respect to its size, form, weight and volume.

Growth regions

Typical growth regions in plants are the apices of shoot and root. Such growing regions are know as apical meristemes, primary meristems or regions of primary growth. These apical meristems are responsible for the increase in length, differentiation of various appendages and formation of plant tissues.

Phases of growth

Growth is not a simple process. It occurs in meristematic regions where before completion of this process, a meristematic cell has to pass through the following 3 phases.

1. Cell formation phase
2. Cell elongation phase
3. Cell differentiation (cell maturation)

The cell formation phase is represented by meristematic zone and cell enlargement phase by cell elongation zone.

The dividing meristematic cells are thin walled and have dense protoplasm with a large nucleus and without or with very small vacuoles. The intercellular spaces are also absent. The newly formed cells after the first phase of cell division have to pass through the second phase of cell enlargement. During the second phase of cell elongation on account of large quantities of solutes inside the growing cell, water enters the cell due to osmotic effect resulting in the increased turgidity and expansion and dilation of the thin and elastic cell wall. This phase also results in appearance of large vacuoles.

In the last phase or cell maturation, second walls are laid down and cell matures and gets differentiated into permanent tissue.

Growth curve

Whether the growth rate of a cell, a plant organ, a whole plant or the whole life cycle of plant or the whole life cycle of plant is measured in terms of length, size, area, volume or weight. It has been found that different growth phases result in ‘S’ shaped curve or sigmoid curve. In initial stages during the phase of cell formation, the growth rate increases slowly while it increases rapidly during the phase of cell elongation or cell enlargement and again slows down during the phase of cell maturation.

The period during the growth shows increase is known as grand period of growth. Thus, in a standard growth curve three well marked regions can be observed, the initial growth stage (lag phase), the grand period of growth (exponential or log phase) and the steady stage (maturity stage or senescence or stationary phase). The overall growth may be affected by external or internal factors but the S- shaped curve of grand period of growth is never influenced.

This growth curve suits well to the entire life of an annual plant when measured interms of dry weight against time.

Early growth of the plant is limited by the amount of food reserves in the seed. When the emerged seedlings develops an adequate root system and enough leaf surface to support vigorous photosynthesis and anabolism, a period of rapid increase in size is possible.

High metabolic rates are not maintained indefinitely and eventually processes are set in motion that lead to cessation of growth. The factors responsible for the decrease in growth are competition for essential metabolities, growth substances, water, light or the accumulation of inhibitors, toxic substances or waste materials.

The English plant physiology is V.H. Blackman (1919) suggested that the growth of the plants can be represented by equation.

$$W_1 = W_o e^{rt}$$

Where W_1 is the final size (Wt and ht etc) after time t. W_o is the initial size at the beginning of the time period. r is the rate at which plant substance is laid down during time ‘t’ and is the base of natural laagering. Blackman pointed out that equation describes the way in which money placed at compound interest increases with time; the term compound interest law is used to describe such phenomenon. Bank usually apply compound interest quarterly or annually so that the increase in amount occurs as a jump.

With plant system, compound interest is applied continuously and size increase follows a smooth curve.

From the equation, the final size of an organism (W_1) is sent to depend on the initial size (W_o). Larger seed give a larger plant.

In addition, equation shows that plant size also depends on the magnitude of r, the relative growth rate. Blackman suggested that r might be used as a measure of the ability of the plant to produce new plant material and called r the efficiency index. The plants with high efficiency index could be expected to outperform plants with low efficiency index.

Growth analysis

LAI	-	Williams (1946)
LAD	-	Power *et al*. (1976)
SLA	-	Kvet *et al*. (1971)
SLW	-	Pearce *et al*. (1968)
NAR	-	Williams (1946)
CGR	-	Watson (1956)
RGR	-	Williams (1946)

$$LAD = \frac{LII + LIII}{2} \times t_2 - t_1$$

$$LAR = \frac{\text{Leaf area}}{\text{Total plant DW}}$$

$$NAR = \frac{W_2 - W_1}{t_2 - T_1} \times \frac{L_n L_2 - L_m L_1}{L_2 - L_1} \quad \text{Mg/cm}^2\text{/day or mg/g/day}$$

$$RGR = \frac{\text{Log } W_2 - \log W_1}{W_2 - W_1} \quad \text{mg/g/day}$$

$$CGR = \frac{W_2 - W_1}{P\,(t_2 - t_1)} \quad \text{mg/cm}^2\text{ /day}$$

$$LAI = \frac{\text{Leaf area / plant}}{\text{Space occupied by the plant (spacing)}}$$

LAD = Leaf area duration (days)

$$\frac{LAI\,(1) + LAI\,(2)}{2} \times t_2 - t_1$$

LAI (I) & II = Leaf area index at first and second stage

$t_2 - t_1$ = time interval between the two stages

LAR = Leaf area ration

$$LAR \quad \frac{\text{Leaf area plant}^{-1}}{\text{Whole plant dry weight}}$$

SLA = Specific leaf weight (cm^2/g)

$$SLA \quad \frac{\text{Leaf area}}{\text{Leaf dry weight}}$$

SLW = Specific leaf weight (mg/cm^2)

$$SLW = \frac{\text{Leaf dry weight}}{\text{Leaf area}}$$

$$\frac{}{\text{Leaf area}}$$

NAR = Net assimilation rate (mg/cm^2/ day)

$$NAR = \frac{\text{Loge } L_2 - \text{Loge } L_1}{L_2 - L_1} \times \frac{W_2 - W_1}{t_2 - t_1}$$

RGR = Relative growth (mg/g/ day)

$$RGR = \frac{\text{Loge } W_2 - \text{Loge } W_1}{t_2 - t_1}$$

CGR = Crop growth rate (mg/m^2/day)

$$CGR = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

P = Spacing of the crop

GERMINATION AND DORMANCY OF SEEDS AND BUDS

Dormancy of seeds

All the viable seeds have capacity to germinate if placed under suitable conditions necessary for germination. But some seeds fail to germinate for sometimes even if placed under the condition favourable for germination. This may be due to some internal factors or due to specific requirement for some environmental factors. During this period, the growth of the seeds remains suspended and they are said to be in rest stage or dormant stage and this phenomenon is called as dormancy of seeds.

Factors causing dormancy of seeds

1. Seed coats impermeable to water

The seeds of certain plants especially those belonging to the families leguminosae, solanceae, malvaceae, etc. have very hard seed coats which are impermeable to water. The seeds remain dormant until the impermeable layer decay by the action of soil micro-organisms.

2. Seeds coats impermeable to oxygen

In many plants such as cocklebur and may grasses, the seed dormancy is due to the impermeability of the seed coat to oxygen. However, during the period of dormancy the seed coat gradually become more permeable to oxygen so that they may germinate.

3. Immaturity of the Embryo

In certain orchids, the seed dormancy is due to the immaturity of the embryos which fail to develop fully by the time the seeds are shed. In such cases, the seeds germinate only after a period or rest during which the development of embryo inside the seed is completed.

4. Germination Inhibitors

In certain seeds, the dormancy of the seeds is due to the presence of certain germination inhibitors like coumarin, ferulic acid, abscisic acid, etc. These may be present in endosperm, embryo, testa or juice or pulp of fruit.

5. Chilling or low temperature requirement

In certain plants such as apple, rose, peach etc, the seeds remain dormant after harvest in the antum because they have a low temperature or chilling requirement for germination. In nature this requirement is fulfilled by the winter temperatures. In such case the seeds remain dormant throughout the winter season and germinate only in the following spring.

6. Light sensitive seeds

In many species, the germination of the seeds is affected by light resulting in seed dormancy. Such light sensitive seeds are called photoblastic seeds of lettuce, tomato and tobaccor – are positively photoblastic and germinate only after they have been exposed to light. On the other hand, the seeds of certain plants are negatively photoblastic and their germination is inhibited by light.

Advances of dormancy

1. In temperature zones, the dormancy of seeds helps the plants to tide over the severe colds which may injurious for their vegetative and reproductive growth.
2. In tropical regions, the dormancy of seeds resulting from their impermeable seed coats ensures good chances of survival.
3. Dormancy of seeds in many cereals is of utmost importance to mankind. If these seeds would germinate immediately after harvest in the field, they will become useless to man for consumption as food.

SEED GERMINATION

The process of seed germination starts with the imbibition of water by seed coats and emergence of growing root tip of embryo.

Physiological and biochemical changes during seed germination

1. Water uptake

Seed germinatin starts with the imbibition of water by dry seed coat. Due to imbibition of water the seed coats become 1) More permeable to O_2 and water and 2) less resistant to outward growt of embryo.

2. Respiration

Rapid increase in respiration rate of embryo occurs. Sucrose is probably the respiratory substrate at this stage which is provided by endosperum.

3. Mobilization of presence materials

As germination progresses there is mobilization of reserve materials to provide.

i) Building blocks for the development of embryo

ii) Energy for the biosynthetic process

iii) Nucleic acids for control of protein synthesis and embryonic development

Changes in these component are as follows

i) Nucleic acids

In monocots during imbibition, there is a rapid decrease of DNA and RNA content in the endosperum with a simultaneous increase in the embryonic axis probably due to the transportation. High concentration of RNA in the embryonic axis proceeds cell division. Due to more cell division DNA content is increased.

ii) Carbohydrates

Insoluble carbohydrates like starch are the important reserve food of cereals in the endosperum. During germination, starch is hydrolysed first into maltose in the presence of α-amylase and β - amylase and then maltose is converted into glucose by maltase. The glucose is further converted into soluble sucrose and transported to growing embryonic axis.

During germination the embryonic axis secretes gibberellic acid, into the aleusove layer which causes synthesis of α-amylase.

3. Lipids

Many plants like castor bean, peanut, etc, store large amount of neutral lipids or fats as reserve food in their seeds. During germination, the fats hydrolyzed into fatty acids and glycerol by lipase enzyme. Fatty acids are further converted into acetyl – COA by the processes β - oxidation. The acetyl COA is further converted into sucrose via glyoxylate cycle and is transported to the growing embryonic axis.

4. Proteins

Some plants store proteins as reserve food in their seeds in the form of aleurone grains. Proteins are hydrolysed into amino acids by peptidase enzme. The amino acids may either provide energy by oxidation after deamination (removal of amino group) or may be utilized in the synthesis of new proteins.

5. Inorganic materials

A number of inorganic materials such as phosphate, calcium, magnesium and potassium are also stored in seeds in the form of phytin. These stored materials are liberated during germination due to the activity of various phosphatases including phytase.

Emergence of seedling out of the seed coat

All the changes described above gradually result in splitting of seed coat and emergence of the growing seedlings.

First the radical comes out and grows downward, then plumule comes out and grows upward. Due to continued growth of this seedling, the later comes out of the soil, exposed to light and develops its own photosynthetic apparatus.

Splitting of seed coat may take place either 1) by imbibitional pressure 2) by internal pressure created by the growing primary root 3) by hydrolytic enzymes which act on cell wall contents of seed coat and digest it eg. cellulose, pectinase etc. sometimes the seed coat may be extensively rotted by the activity of micro-organisms in the soil.

APSORPTION OF WATER

Mechanism of absorption of water

In higher plants water is absorbed through root hairs which are in contact with soil water and form a root hair zone a little behind the root tips.

Root hairs are tubular hair like prolongations of the cells of the epidermal layer (when epidermis bears root hairs it is also known as piliferous layer) of the roots. The walls of root hairs are permeable and consist of pectic substances and cellulose which are strongly hydrophitic in nature root hairs contain vacuoles filled with cell sap.

When roots elongate, the older root hairs die and new root hairs are developed so that they are in contact with fresh supplies of water in the soil.

Mechanism of water absorption is of 2 types

1. Active absorption of water

In this process the root cells play active role in the absorption of water and metabolic energy released through respiration is consumed active absorption may be of two kinds.

(A) Osmotic absorption

Water is absorbed from the soil into the xylem of the roots according to osmotic gradient.

(B) Non-osmotic absorption

Water is absorbed against the osmotic gradient.

2. Passive absorption of water

It is mainly due to transpiration, the root cells do not play active role and remain passive.

I. Active osmotic absorption of water

First step in osmotic the osmotic absorption of water is the imbibition of soil water by the hydrophilic cell walls of root hairs.

Osmotic pressure of the cell sap of root hairs is usually higher than the OP of the soil water. Therefore, the DPD and suction presume in the root hairs become higher and water from the cell walls enters into them through plasma membrane by osmotic diffusion. As a result, OP, suction pressure and DPD of root hairs how become lower, while their turgor presume is increased.

Now the cortical cells adjacent to root hairs have high OP, SP & DPD in comparison to the root hairs. Therefore, water is drawn into the adjacent cortical cells from root hairs by osmotic diffusion.

In the same way, by cell to cell osmotic diffusion gradually reaches the inner most cortical cells and the endodermis.

Osmotic diffusion of water into endodermis takes place through special thin walled passage cells because the other endodermal cells have casparian strips on thin walls which are impervious to water.

Water from endodermal cells is down into the cells of pericycle by osmotic diffusion which now become turgid and their suction pressure in decreased.

In the last step, water is drawn into xylem from turgid pericycle cells (In roots the vascular bundles are radical and protoxylem elements are in contact with pericycle). It is because in the absence of turgor presume of the xylem vessels, the SP of xylem vessels become higher than SP of the cells of the pericycle when water enters into xylem from pericycle a presume is developed in the xylem of roots which can raise the water to a certain height in the xylem. This presume is called as root presume.

(b) Active non-osmotic absorption of water

Sometimes, it has been observed that absorption of water takes place even when OP of soil water is high than OP of cell sap. This type of absorption which is non-osmotic and against the osmotic gradient requires the expenditure of metabolic energy probably through respiration.

2. Passive absorption of water

Passive absorption of water takes place when rate of transpiration is usually high. Rapid evaporation of water from the leaves during transpiration creates a tension in water in the xylem of the leaves. This tension is transmitted to water in xylem of roots through the xylem of stream and water rises upward to reach the transpiring surfaces. As the results soil water enters into the cortical cells through root hairs to reach the xylem of roots to maintain the supply of water. The force of this entry of water is created in leaves due to rapid transpiration and hence, the root cells remain passive during this process.

External factors affecting absorption of water

1. Available soil water

Sufficient amount of water should be present in the soil in such form which can easily be absorbed by the plants. Usually the plants absorb capillary water i.e water present in filums in between soil particles other forms of water in the soil eg. hygroscopic water, combined water, gravitational water etc. are not easily available to plants.

Increased amount of water in the soil beyond a certain limit results in poor aeration of the soil which retards metabolic activities of root cells like respiration and hence, the rate of water absorption is also retarded.

Concentration of soil solution

Increased concentration of soil solution (due to presence of more salts in the soil) results in higher OP. If OP of soil solution will become higher than the OP of cell sap in root cells, the water absorption particularly the osmotic absorption of water will be greatly suppressed. Therefore, absorption of water is poor in alkaline soils and marshes.

Soil air

Absorption of water is retarded in poorly aerated soils because in such soils deficiency of O_2 and consequently the accumulation of CO_2 will retard the metabolic activities of roots like respiration. This also inhibits rapid growth and elongation of the roots so that they are deprived of fresh supply of water in the soil. Water logged soils are poorly aerated and hence, are physiologically dry. They are not good for absorption of water.

Soil temperature

Increase in soil temperature up to about 30°C favours water absorption. At higher temperature water absorption is decreased. At low temperature also water absorption decreased so much so that at about 0°C, it is almost decreased. This is probably because at low temperature.

1. The viscosity of water and protoplasm is increased
2. Permeability of cell membrane is decreased
3. Metabolic activity of root cells are decreased
4. Root growth and elongation of roots are checked.

Field capacity or water holding capacity of the soil

After heavy rain fall or irrigation of the soil some water is drained off along the slopes while the rest percolates down in the soil. Out of this water, some amount of water gradually reaches the water table under the force of gravity (gravitational water) while the rest is retained by the soil. This amount of water retained by the soil is called as field capacity or water holding capacity of the soil.

Field capacity is affected by soil profiles soil structure and temperature.

Permanent wilting percentage or wilting coefficient

The percentage of soil water left after the plants growing in that soil has permanently wilted is called as permanent wiling percentage or the wilting coefficient.

WATER POTENTIAL

Water is said to be the liquid of life. Because life originated in an argons environmental and in the course of evolution it became fully dependent upon water in a number of ways.

Importance of water to plants

1. Water is the main constituent of protoplasm comprising up to about 90-95 per cent of its total weight. In the absence of water, protoplasm becomes inactive and is oven killed.
2. Different organic constituents of plants such as carbohydrates proteins, nucleic acid and enzymes etc. lose their physical and chemical properties in the absence of water.
3. Water participates directly in many metabolic processes. Inter conversion of carbohydrates and organic acids depends upon hydrolysis and condensation reaction.
4. Water increases the rate of respiration. Seeds respire fast in the presence of water.
5. Water is the source of hydrogen atom for the reduction of CO_2 in the reaction of photosynthesis.
6. Water acts as a solvent and acts as a carrier for many substance. If forms the medium in which several reactions take place.
7. Water present in the vacuoles helps in maintaining the turgidity of the cells which is a must for proper activities of life and to maintain this from and structure.
8. Water helps in translocation of solutes
9. In tropical plants, water plays a very important role of thermal regulation against high temperature.
10. The elongation phase of cell growth depends on absorption of water.

Water potentials

Every component of a system possesses free energy capable of doing work under constant temperature conditions. For non-electrolytes, free energy / mole is known as chemical potential. With refeuce to water, the chemical potential of water is called as water potential. The chemical potential is denoted by a Greek letter Psi, ψ.

For a pure water, the water potential is O. The presence of solute particles will reduce the free energy of water or decrease the water potential. Therefore it is expressed in vegetative value.

It is therefore, water potential of solution is always less than O so in negative value.

For solutions, water potential is determined by three internal factors i.e.

ψ_w = $\psi_w + \psi_s + \psi_p$

ψ_S = is the solute potential or osmotic potential

ψ_p = pressure potential or turgor potential

ψ_w = is the matric potential. Matric potential can be measured for the water molecules adhering on the soil particles and cell wall.

In plant system, the matric potential is disregarded.

Therefore,

$\psi_w = \psi_s + \psi_p$

Osmotic pressure

Osmotic pressure is equivalent to osmotic potential but opposite in sign.

Osmotic pressure in a solution results due to the presence of solutes and the solutes lower the water potential. Therefore osmotic pressure is a quantitative index of the lowering of water potential in a solution and using thermodynamic terminology is called as osmotic potential.

Osmotic pressure and osmotic potential are numerically equal but opposite in sign.

Osmotic pressure has positive sign

Osmotic potential has negative sign (ψ_s)

For eg.

I_A OP = 20 atm.

ψ_w = - 20 atm

Turgor pressure

In plant cell, the turgor pressure results due to the presence of water molecules is turgor pressure. The potential created by such pressures is called presume potential (ψ_p)

In a normal plant cell, the water potential

$\psi_w = \psi_s + \psi_p$ – partially turgid cell

(High)

ψ_w = Zero - Fully turgid cell

(Highest)

$\psi_w = \psi_s$ - Flaccid cell or plasmolysed cell

(Lowest)

Water relation

Water form the major constituent of living (cells) things an the cells originated in a highly aquem medium and all the vital processes of the life are carried out in it. Besides, water predominately arts as a source of hydrogen to plants and is released by the photolysis of water during photosynthesis.

In living tissue, water in the medium for many biochemical reations and extraction process. Inorganix nutrients, photosynthesis, bases and hormones are all transported in aqueom solution. Evaporation of water can control the temperature of leaf on canopy soil nutrients are available to plant roots only when dissolved in water. In short, water is essential for life and plays a unique role in virtually all biological process.

Example:

There are 2 cells A and B in contact with each other, cell A has a pressure potential (turgor pressure) of 4 bars and certain sap with an osmotic potential of -12 bars.

Cell B has presume potential of 2 bars and certain sap with osmotic potential of -5 bar.

Then,

ψ_w of cell A $= \psi_s + \psi_p$

$= -12 + (+4)$

$= -8$ bars

ψ_w of cell B $= -5+(+2)$

-3 bars

Hence, water will move from cell B to cell A (i.e., towards lower or more negative water potential) with a form of (-8-(-3) = -5 bars.

Diffusion, osmosis and imbibition

The movement of materials in and ant of the cells in plants taken place in a solution or gareoss form. Although the exert process of this is not very clear, three physical process are usually involved in it. They are diffusion, osmosis and imbibition.

The movement of particles or molecules from a region of higher concentrations to a region of lower concentration is called as diffusion. The rate of diffusion of gases is faster than liquids or solutes. The differently panicles have a certain pressure called as the diffusion pressure which is directly proportional to the number as concentration of the diffusing particles. These form the diffusion takes place always from a region of higher diffusion pressure to a region of lower diffusion pressure (i.e) along a diffusion pressure gradient. The rate of diffusion increases if,

i) the diffusion pressure gradient is steeper

ii) the temperature is increased

iii) the density of the differing particles is lesser

iv) the medium through which diffusion occurs is less concentrated.

Diffusion of more than one substance at the same time and place may be at different rates and in different direction, but is independent of each other. A very common example of this is the gaseous exchange in plants.

Beside osmotic diffusion the above mentioned simple diffusion also plays a very important role in the life of the plants.

- It is an essential step in the exchange of gases during respiration and phytosynthesis
- During passive salt uptake, the ions are absorbed by diffusion
- It is important in stomatal transpiration as the last step in the pollen, where diffusion of water vapour from the interrelation space into the outer atmosphere occurs through open stomata.

Osmosis

The diffusion of solvent molecules into the solution through a semi permeable membrane is called as osmosis (some times called as *Osmotica diffusion*). In case there are two solutions of different concentration separated by the semi permeable membrane, the diffusion of solvent will take place from the less concentrated suitable into the more concentrated solution till both the solutions attain equal concentration.

Osmotic pressure

As a result of the separation of solution from its solvent (or) the two solution by the semi permeable membrane, a pressure is developed in solution to the pressure by dissolved solutes in it. This is called as osmotic pressure (O.P). OP is measured interms of atmospheres and is directly proportional to the concentration of dissolved solutes in the solution. More concentration solution has higher O.P. O.P of a solution is always higher than its pure solvent.

During osmosis, the movement of solvent molecules taken place form the solution whose osmotic pressure is lower (i.e less concentration as hypotonic) into the solution whose osmotic pressure is higher (i.e, more concentrated as hypertonic).

Osmotic diffusion of solvent molecules will not take place if the two solutions separated by the semi permeable membrane are of equal concentration having equal *Osmotic pressures* (i.e., they are isotonic). In plant cells, plasma membrane and tonoplant act as selectively permeable or differentially permeable membrane.

Endo osmosis

Of a living plant cell is placed in water or hypotonic solution whose O.P is lower than cell sap, water interms into the cell sap by osmosis and the process is called endo osmosis. As a result of entry of water with the cell sap, a pressure is developed which press the protoplasma against the cell wall and the become turgid. This pressure is called an turgor pressure.

Consequence of the turgor pressure is the wall pressure which is exerted by the elastic cell wall against the expanding protoplasm. At a given time, turgor pressure (T.P) equals the wall pressure (W.P).

T.P = W.P

Exosmosis

If on the other hand, the plant cell is placed in hypertonic solution (whose O.P is higher than cell sap) the water cover out the cell sap into the outer solution and the cell becomes flaccid. This process is known as exosmosis. Cell (or) tissue will remain as such in isotonic solution.

Significance of osmosis in plants

1. Large quantities of water are absorbed by roots from the soil by osmosis
2. Cell to cell movement of waster and other substances dissolve is involves osmosis
3. Opening and closing of stomata depend upon the turgor pressure of guard cells
4. Due to osmosis, the turgidity of the cells and hence the shape or from of them organs is maintained.
5. The resistance of plants to drought and frost increases with increase in osmotic pressure to later cells
6. Turgidity of the cells of the young seedling allows them to come out of the soil.

Imbibition

Certain substances if placed in a particular liquid absorb it and swell up. For example, when some pieces of grass or dry wood or dry seeds are placed in water they absorb the water quickly and swell up considerably so that their volume is increased. These substances are called as imbibants and the phenomenon as imbibition, certain force of attraction is existing between imbibants and the involved substance. In plants, the hydrophilic colloids *viz*., protein and carbohydrates such as starch, cellulose and pertic substance have strong altercation towards water.

Imbibition play a very important role in the life of plants. The first step in the absorption of water by the roots of higher plants is the imbibition of water by the cell walls of the root hairs. Dry seeds require water by imbibition for germination.

As a result of imbibition, a pressure is developed which is called as imbibitioin pressure or matric potential (ψ_m). It is analogous to the osmotic potential of a solution. With referece to pure water, the values of ψ_m are always negative. The water potential of an imbibant is equal to its matric potential plus any turgor or other pressure (pressure potential) which may be imposed upon the imbibant.

$$\psi_m = \psi_m + \psi_P$$

If the imbibant is unconfined to turgor or such pressure, the equation can be significant to

$$\psi_m = \psi_m$$

Plasmolysis

When a plant cell or tissue is placed in a hypertonic solution water cover out from the cell sap into the outer solution of exosmosis and the protoplasm begins to sprinkler or contract. The protoplasm separate from the cell wall and assures a spherical form and them phenomenon is called plasmolysis. Incipient plasmolysis is stage where protoplasm begins to contract from the cell wall. If a plasmolysed cell in tissue is placed in water, the process of endosmosis take place. Water enter into the cell sap, the cell becomes turgid and the protoplasm again assumes it normal shape and position. This phenomenon is called deplasmolysis.

Advantages of plasmolysis

1. It indicates the semi permeable nature of the plasmo membrane.
2. It is used in determinating the osmotic pressure of the cell sap.
3. Plasmolysis is used in salting of meat and fishes. Addition of concentrated sugar solution to jam and jellies check the growth of fungi and bacteria which become plasmolysed in concentrated solution.

Diffusion pressure deficit (DPD)

(Suction pressure)

Diffusion pressure of a solution is always lower than its pure solvent. The difference between the diffusion pressure of the solution and its solvent at a particular temperate and atmosphere conditions is called as diffusion pressure deficit (D.P.D). If the solution is more concentrated D.P.D increases but it decreases with the dilution of the solution,

D.P.D of the cell sap or the cells is a measure of the ability of the cells to absorb water and hence is often called as the suction pressure (S.P). It is related with osmotic pressure (O.P) and turgor pressure (T.P) of cell sap and also the wall pressure (W.P) as follows.

D.P.D. (S.P) = O.P – W.P

But

(W.P) = T.P

D.P.D = O.P – T.P

Due to the entry of the water the osmotic pressure of the cell sap decreases while its turgor pressure is increased so much so that in a fully turgid cell T.P equals the O.P

O.P = T.P = D.P.D = O

In fully plasmolysed cells : T.P = O

So D.P.D = O.P

D.P.D. incase of plant cells is not directly proportional to their osmotic pressure or the concentration of the cell sap but depend both on O.P and T.P. Higher osmotic pressure of the cell sap is usually accompanied by lower turgor pressure so that its D.P.D is greater and water enters into it. But sometimes it is possible that two cells are in contact with each other one having higher O.P and also higher turgor pressure than the other cell and still its does not draw water. It is because of its lower D.P.D., no matter is O.P is higher.

Cell a			Cell b		
O.P = 25 atm.	→	O.P = 30 atm			
T.P = 15 atm.		T.P =10 atm.		A	
D.P.D = 10 atm.		D.P.D = 30 atm.			

Cell a		Cell b	
O.P = 35 atm.	←	O.P = 40 atm	
T.P = 10 atm.		T.P = 20 atm.	B
D.P.D = 25 atm.		D.P.D = 20 atm.	

ENTRY OF WATER INTO THE CELL DEPENDS ON D.P.D AND NOT ON O.P ONLY

ABSORPTION OF MINERAL SALTS

Mechanism

Previously it was thought that absorption of mineral salts takes place along with water absorption. But it is now understood that mineral salt absorption and water absorption are two different processes.

Mineral salts are absorbed from the soil solution in the form of ions. They are chiefly absorbed through the meristematic regions of the roots near the tips.

Plasma membrane of the root cells is not permeable to all the ions. It is selectivity permeable. All the ions of the same salt are not absorbed at equal rate but the is unequal absorption of ions.

First step in the absorption of mineral salts is the process of Ion exchange which does not require metabolic energy.

Ion exchange

The ions adsorbed on the surface of the plasma membrane of the root cells may be exchanged with the ions of same sign from external solution for eg. the cation K^+ of the external soil solution may exchanged with H^+ ions adsorbed on the surface of the plasma membrane. Similarly anion may be exchanged with OH ions. There are two theories regarding the mechanism of ion exchange.

1. Contact exchange theory

According to this theory the ions adsorbed or the surface of root cells and clay particles are not held tightly but oscillate within small volume of space. If the roots and clay particles are in close contact with each other, the oscillation volume of ions adsorbed on root surface may over by the oscillation volume of ions adsorbed on clay particles, and the ions adsorbed on clay particle may be exchanged with the ions adsorbed on root surface directly without first being dissolved in soil solution.

2. Carbonic acid exchange theory

According to this theory, the CO_2 released during respiration of root cells combines with water to form carbonic acid (H_2CO_3). Carbonic acid dissociates into H^+ and an anion HCO_3 in soil solution. These H^+ ions may be exchanged for cations adsorbed on the clay particles. The cations thus released into the soil solution from the clay particles, may be adsorbed on root cells in exchange for H^+ ions or as in ion pairs with bicarbonate. Thus, the soil solution plays an important role in carbonic acid exchange theory.

The further processes of the absorption of mineral salts may be of two types.

1. Passive and 2. Active

1. Passive absorption

When the concentration of mineral salts is higher in the outer solution than in the cell sap of the root cells, the mineral salts are absorbed according to the concentration gradient by simple process of diffusion. This is called as passive absorption because it does not require expenditure of metabolic energy.

2. Active absorption of mineral salts

It has been observed that the cell sap in plants accumulates large quantities of mineral slats ions against the concentration gradient. For eg. in alga Nitella the cell sap accumulated K and phosphate ions ot such an extent that their concentration were thousands and hundred times greater than in the pond water in which the plant was growing.

The accumulation of mineral salts against to concentration gradient is an active process which involves the expenditure of metabolic energy through respiration.

The active absorption of mineral salts involves the operation of a carrier compound present in the plasma membrane of the cells.

The carrier concept

According to this theory, the plasma membrane is impermeable to free ions. But some compounds present in it acts as carrier and combines with ions to form carrier- ion-complex which can move across the membrane. On the inner side of the membrane this complex leaves releasing ions into the cell while the carrier goes back to the outer surface to pick up fresh ions.

They are two hypotheses based on the carrier concept to explain the mechanism of active salt absorption. Although they are not universally accepted.

1. Lundegardhs cytochrome pump theory

Lundegardh and Burstrom (1933) believed that there was a definite correlation between respiration and anion absorption. Thus when a plant is transferred from water to a salt solution the rate of respiration increases. This increase in rate of respiration over the normal respiration has been called as anion respiration or salt respiration.

Lundegardh (1954) proposed cytochrome panp theory which is based on the following assumptions.

1. The mechanism of anion and cation absorption is different
2. Anions are absorbed through cytochrome chain by an active process.

(cytochromes are ion – porphyrin proteins that act as enzymes and helps in election transfer during respiration).

3. Cations are absorbed passively.

According to this theory

1) dehydrogenase reactions on inner side of the membrane give rise to protons (H^+) and electrons (e^-).
2) The electrons travels over the cytochrome chain towards outside the membrane, so that the Fe of the cytochrome becomes reduced (Fe^{++}) on the outer surface and oxidized (Fe^{+++}) on the inner surface.
3) On the outer surface, the reduced cytochrome is oxidized by oxygen releasing the electron (e^-) and taking an anion (A^-).
4) The electron thus released unites with H^+ and oxygen to form water
5) The anion (A^-) travels over the cytochrome chain towards inside.

Diagrammatic representation of the Lundegardhs' cytochorme pump theory

6) On the inner surface the oxidized cytochrome becomes reduced by taking an electron produced through the dehydrogenase reactiosn and the anion (A) is released.
7) As the result of anion absorption, a cation (M) moves passively from outside to inside to balance the anion.

2. Bennert – Clark's protein Lecithin Theory

In 1856, Bennet – clark suggested that because the cell membranes chiefly consist of phospholipids and proteins and certain enzymes seem to be located on them, the carrier could be a protein associated with the phosphatide called as lecithin. He also assumed the presence of different phosphatides to correspond with the number of known competitive groups of cations and anions.

According to this theory

1. Phosphate group in the phosphatide is regarded as the active centre binding the cations and the basic choline group as the anion binding centre.
2. The ions are liberated on the inna surface of the membrane by decomposition of lecithin by the enzyme lecithinase.
3. The regeneration of the carrier lecithin form phosphatidic acid and choline takes place in the presence of the enzyme choline acethylene and choline esterase and ATP. The latter acts as a source of energy.

Ponnans' Equilibrium

The accumulation of ions inside the cells without involving expenditure of the metabolic energy can be explained to some extent by Donnan's equilibrium theory.

According to this theory there are certain pre existing ions inside the cell which cannot diffuse outside through membrane. Such ions are called as indiffusible or fixed ions. However, the membrane is permeable to both anions and cations of the outer solutions.

Suppose there are certain fixed anions in the cell which is in contact with outer solution containing anions and cations. Normally equal number of anions and cations would have diffused into the cell through an electrical potential to balance each other, but to balance the fixed anions more cations will diffuse into the cell. This equilibrium is known as Donnan's equilibrium. In this particular case, there would be an accumulation of cations inside the cell.

If however, there are fixed cations inside the cell, the Donan's equilibrium will result in the accumulation of anions inside the cell.

MINERAL NUTRITION

- The chemical compounds required by an organism are termed as nutrients
- Nutrition may be defined as the supply and absorption of chemical compounds needed for plant growth and metabolism
- For plant growth and metabolism, 16 elements are essential. They are

  C, H, O, N, P, K, Ca, S, Mg, Fe, Mn, Zn, B, Cu, Mo and Cl

  These essential elements are classified into two groups

1. Major elements (macro nutrients)
2. Minor elements (Micro nutrients) (Trace elements)

Major elements

The essential elements which are required by the plants in comparatively large amounts are called as major elements or macro nutrients.

They are C, H, O, N, P, K, Ca, S, Mg.

Minor elements

The essential elements which are required in very small amounts or traces by the plants are called as minor elements or micronutrients or trace elements.

They are Fe, Zn, Mn, B, Cu and Mo.

The term essential mineral elements was proposed by Arnon and Stout (1939). There authors concluded that for an element to be considered essential, three criteria must be met.

1. A given plant must be unable to complete its life cycle in the absence of mineral elements.
2. The function of the element must not be replaceable by another mineral element

3. The elements must be directly involved in plant metabolism. For eg. as a component of an essential plant constituents or it must be required for a distinct metabolic step such as an enzyme reaction.

Based on the mobility, elements are also classified into three types.

1. Mobile elements : N, P, K, S and Mg
2. Immobile elements : Ca, Fe and B
3. Intermediate in mobility : Zn, Mn, Cu, Mo

Specific roles of essential mineral elements

A. The macronutrients

1. Nitrogen specific role

- Nitrogen is important constituent of proteins, nucleic acids, porphyries (chlorophylls & cytochromes) alkaloids, some vitamins, coenzymes etc
- Thus N plays very important role in metabolism, growth, reproduction and heredity.

Deficiency symptoms

- Plant growth is stunted because protein content cell division and cell enlargement are decreased
- N deficiency causes chlorosis of the leave i.e yellowing older leaves are affected first
- In many plants eg. tomato, the stem, petiole and the leaf veins become purple coloured due to the formation of anthocyanin pigments.

2. Phosphorus

- It is important constituent of nucleic acids, phospholipids, coenzymes NADP, NADP H_2 and ATP

- Phospholipids along with proteins may be important constituents of cell membranes
- P plays important role in protein synthesis through nucleic acids and ATP
- Through coenzymes NAD, NADP and ATP, it plays important role in energy transfer reactions of cell metabolism eg. photosynthesis, respiration and fat metabolism etc.

Deficiency symptoms

- P deficiency may cause premature leaf fall
- Dead necrotic areas are developed on leave or fruits
- Leaves may turn to dark green to blue green colour. Sometimes turn to purplish colour due to the synthesis and accumulation of anthocyanin pigments.

Potassium

Specific role

- Although potassium is not a constituent of important organic compound in the cell, it is essential for the process of respiration and photosynthesis
- It acts as an activator of many enzymes involved in carbohydrate metabolism and protein synthesis
- It regulates stomatal movement
- Regulates water balance

Deficiency symptoms

- Mottled chlorosis of leaves occurs
- Neurotic areas develop at the tip and margins of the leaf
- Plants growth remains stunted with shortening of internodes.

Calcium

- It is important constituent of cell wall
- It is essential in the formation of cell membranes
- It helps to stabilize the structure of chromosome
- It may be an activation of may enzymes

Deficiency symptoms

- Calcium deficiency causes disintegration of growing meristematic regions of root, stem and leaves
- Chlorosis occurs along the margins of the younger leaves
- Malformation of young leaves takes place

Magnesium

- It is very important constituent of chlorophylls
- It acts as activation of many enzymes in nucleic acid synthesis and carbohydrate metabolism
- It plays important role in binding ribosomal particles during protein synthesis.

Deficiency symptoms

- Mg deficiency causes mottled chlorosis with veins green and leaf tissues yellow or white appearing first on older leaves
- Dead neurotic patches appear on the leaves
- In cotton Mg deficiency leads o reddening of leaves and disorder is called as reddening in cotton.

Sulphur

Specific role

- It is important constituent of some amino acids (cystine, cysteine and methionine) with which other amino acids form the protein
- S helps to stabilize the protein structure
- It is also important constituent of vitamin i.e biotin, thiamine and coenzyme A
- Sulphhydryl groups are necessary for the activity of many enzymes.

Deficiency symptoms

- Deficiency causes chlorosis of the leaves
- Tips and margins of the leaf roll in ward
- Stem becomes hard due to the development of sclerenchyma.

Micronutrients

Iron

Specific role

- Important constitudnet of iron porphyrin – proteins like cytochromes, peroxidanes, catalases, etc.
- It is essential for chlorophyll synthesis
- It is very important constituent of ferredoxin which plays important role in photochemical reaction in photosynthesis and in biological nitrogen fixation.

Deficiency symptoms

Iron deficiency causes chlorosis of young leaves which is usually interveinal.

Zinc

Specific role

- It is involved in the biosynthesis of growth hormone auxin (indole 3 acetic acid)
- It acts activator of many enzymes like carbonic anhydrase and alcohol dehydrogenase, etc.

Deficiency symptoms

- Zinc deficiency causes chlorosis of the young leaves which starts from tips and the margins
- The size of the young leaves is very much reduced. This disorder is called as 'little leaf disease'
- Stalks will be very short.

Manganese

- It is an activator of many respiratory enzymes
- It is also an activator of the enzyme nitrite reductase
- It is necessary for the evolution of oxygen (photolysis) during photosynthesis

Deficiency symptoms

- The young leaves are affected by mottled chlorosis
- Veins remain green
- Small necrotic spots developed on the leaves with yellow strips

Copper

Specific role

- It is an important constituent of plastocyanin (copper containing protein)
- It is also a constituent of several oxidizing enzymes.

Deficiency symptoms

- Copper deficiency causes necrosis of the tip of the young leaves
- It also causes die-back of citrus and fruit trees
- Also causes reclamation disease or white tip disease of cereals and leguminous plants.

Boron

Specific role

- Boron facilitates the translocation of sugars by forming sugar borate complex.
- It involves in cell differentiation and development since boron is essential for DNA synthesis
- Also involves in fertilization, hormone metabolism etc.

Deficiency symptoms

- Boron deficiency causes death of shoot tip
- Flower formation is suppressed
- Root growth is stunted
- The other diseases caused by B deficiency is
- Heart rot of beet
- Stem crack of celery
- Brown heart of cabbage
- Water core of turnip
- Internal cork formation in apple
- Hen and chicken in grapes

Molybdeneum

- It is constituent of the enzyme nitrate reductase and thus plays an important role in nitrogen metabolism
- It is essential for flower formation and fruit set.

Deficiency symptoms

- Molybdenum deficiency causes interveinal chlorosis of older leaves
- Flower formation is inhibited
- Causes whiptail disease in cauliflower plants.

SOILLESS GROWTH OR HYDROPONICS

The practice of growing plants in nutrient enriched water without soil is called as soilless growth or hydroponics.

However, the term hydroponics is now being applied to plants rooted in sand, gravel or other similar matter which is soaked with a recycling flow of nutrient – enriched water.

According to a recent limited nations report on hydropnics: In area of tropics, where the water deficiency is the limiting factor in crop production, the soilless methods hold out much promise because of the more economical use of water.

The report also indicated that in some areas, lack of fertile soil or very thin soil layers may also move soilless methods worth serious consideration.

Besides these the other advantages of growing cucumbers, egg plants, peppers, lettuces, spinach and other vegetables hydroponically under controlled environment are

1. The regulation of nutrients
2. Control of pets and diseases
3. Reduction of labour cost
4. Sometimes quicker yield

But there is two main drawbacks of hydroponics farming.

1. Firstly the cost of settling up the system is very high
2. Secondly it requires skills and knowledge its operation

Foliar Nutrition

Foliar nutrition is fertilizing certain crop plants through aerial spraying.

Mechanism

Penetration of the spray solution or nutrient solution occurs through cuticle the layer of polymerized wax which occurs on outer surface of the epidermal cells of leaves.

After penetration in the cuticle, further penetration take place through fine, thread like semi-microscopic structure called ectodesmata. This extends through the outer epidermal cell wall, from the inner surface of the cuticle to the plasma membrane.

When the substance reaches plasma membrane of an epidermal cell, it will be observed by mechanism similar to those which operate in root cells.

Advances

1. Foliar nutrition may serve as a mean of applying supplemental macronutrients during critical growth periods when it is impracticable to apply fertilizers to soil. Eg. unusual period of dry weather.
2. Foliar nutrition may afford a remedy for the time lag between soil applied and plant absorbed. Time is too long because of fast growing rates.

Translocation of organic solutes

The movement of organic food materials or the solutes in soluble from one place to another in higher plants is called as

Translocation of organic solutes

Directions of translocation

Translocation of organic solutes may take place in the following directions.

1. Downward translocation

Mostly, the organic material is manufactured by leaves and translocated downward to stem and roots for consumption and storage.

2. Upward translocation

It takes place mainly during the germination of seeds, tubers etc. When stored food after being converted into soluble form is supplied to the upper growing part of the young seedling till it has developed green leaves.

Upward translocation of solutes also takes place through stem to young leaves, buds and flowers which are situated at the tip of the branch.

3. Radical translocation

Radical translocation of organic solutes also takes place in plants from the cells of the pith to cortex.

Path of the translocation of organic solutes

1. Path of downward translocation

Downward translocation of the organic solutes takes place through phloem. This can be proved by the ringing experiment.

2. Path of upward translocation

Although translocation of organic solutes take place through phloem, but under certain conditions it may take place through xylem.

3. Path of radical translocation

Radical translocation from pit to control takes place through medullary rays.

Mechanism of translocation

Various theories have been put forward to explain the mechanism of phloem conduction. Among them Munchs' (1930) hypothesis is mot convincing.

Munchs mass flow on pressure flow hypothesis

According to this hypothesis put forward by Much (1930) and others, the translocation of organic solutes takes place enmass though phloem along a gradient of turgor presume from the region of higher concentration of soluble solutes (supply end) to the region of lower concentration (consumption end).

The principle involved in this hypothesis can be explained by a simple physical system as shown in Fig.

Two members X and Y permeable only to water and dipping in water are connected by a tube T to form a closed system membrane X contains more concentrated sugar solution than in membrane Y.

Due to higher osmotic presence of the concentrated sugar solution in the membrane X, water artus into it so that its turgor pressure is increased. The increase in turgor pressure results in mass flow of sugar solution to membrane Y though the T till the concentration of sugar solution in both the membrane is equal.

In the above system it could be possible to maintain continuous supply of sugars in membrane X and its utilization on conversion into insoluble form in membrane Y, the flow of sugar solution from X to Y will continue indefinitely.

According to this theory, a similar analogous system for the translocation of organic solutes exists in plants. As a result of photosynthesis, the mesophyll cells in the leaves contain high concentration of organic food material in them in soluble form and correspond to membrane X or supply end.

The cells of stem and roots where the food material is utilized or converted into insoluble form correspond to membrane Y or consumption end. While the sieve tubes in phloem which are placed and to end correspond to the tube T.

Mesophyll cells draw water from the xylem of the leaf due to higher osmotic pressure and suction presume of their sap so that their turgor presume is increased. The turgor presume in the cells of stem and the roots is comparatively low and hence, the soluble organic solutes begin to flow en mass from mesophyll through phloem down to the cells of stem and the roots under the gradient of turgor presume. In the stem and the roots, the organic solutes are either consumed or converted into insoluble form and the excess water is released into xylem through cambium.

Mechanism of solute translocation in plants according to munch hypothesis.

ENVIRONMENTAL STRESS DROUGHT (WATER STRESS)

Drought is defined as "deficiency of water severe enough to check the plant growth". Drought has been classified into two broad categories.

1. Soil drought
2. Atmospheric drought

Soil drought leads to atmospheric drought. Atmospheric drought occurs due to low atmospheric humidity, high wind velocity and high temperature which cause a plant to lose most of its water.

Physiological changes occur due to drought (Effect of drought on plants)

1. Functioning of stomata

In general stomata lose their function and may die, because wilting after certain limit denatures the starch in the guard cells and also in the mesophyll cells.

2. Carbohydrates metabolism in green leaves

The very first effect of drought on carbohydrates metabolism is that starch disappears from the wilted leaves and sugar accumulates simultaneously.

3. Photosynthetic activity

CO_2 diffusion into the leaf is prevented due to decrease in stomatal opening (pure) and there by reduces photosynthetic activity in green cells.

4. Osmotic pressure

Because of reduced amount of water during drought, the osmotic pressure of plant cell increases. This increase in osmotic pressure permits the plant to utilize better soil moisture.

4. Permeability

Because of drought, permeability increases specially to water, urea etc.

5. Biochemical effects

Water shortage alters the chemical composition. For example, starch is converted to sugar, besides this, there is a considerable increase in nitrate nitrogen protein synthesis is adversely affected.

Adaptation to drought

Drought resistance

Drought resistance is defined as “the capacity of plants to survive during the period of drought with little or no injury”.

There are three important categories of plants growing in the areas facing drought.

1. Ephemerals
2. Succulents
3. Non-succulent perennials

1. Ephemerals

are short lived plants and they complete their life cycle within a short favourable period during rainy season. They pass dry periods in the form of seeds. They are called as drought escaping plants.

2. Succulent plants

Accumulated large quantities of water and use it slowly during dry period. Thus they pass dry periods on drought without facing it. Such plants develop several morphological adaptations for reducing transpiration such as thick cuticle, reduced leaf area, sunken stomata, etc.

3. Non succulent plants

are in fact real drought enduring (tolerant) plants. They tolerate drought without adapting any mechanism to ensure continous supply of water. They develop many morphological adaptations which are collectively called xeromorphy.

They develop, in general, grayish colour, reflecting surfaces, smaller leaves, extensive root system, leaf fall during dry season sunken stomata and thick cuticle etc. They develop an elaborated conducting system. The stomata remain closed mostly in dry periods.

The plants develop several protoplasmic peculiarities such as cell size, cell structure, increased permeability, increased imbibitional power, elasticity, small vacuoles, higher osmotic pressure etc.

Temperature stress

Temperature stress includes both

1. High temperature stress
2. Low temperature stress

Low temperature stress causes

1. Chilling injury
2. Freezing injury

1. Chilling injury

The tropical origin plants are injured when the temperature drops to some point above 0°C. The injury which occurs due to low temperature but above zero degree centigrade is called chilling injury.

2. Freezing injury

Freezing injury occurs at 0°C.

Effect of freezing and chilling injury plants

- The lipid molecules in cell membrane get solidified i.e. changed from liquid state to solid state. So the semi-permeable nature of the membrane is changed membrane becomes leaky.
- Inactivation of mitochondria
- Streaming of protoplasm is stopped
- Accumulation of respiratory metabolites which become highly toxic
- Ice formation inside the cell occurs.

Prevention of cold injury

Some plants change the pattern of growth.

- The growth is completely arrested during this period.
- In cell membrane unsaturated fatty acid content is increased.
- Intracellular ice formation is reduced.
- The quantity of free enzymes, sugars and proteins increases.

High temperature stress

- Effect of high temperature is Heat Injury. Heat Injury occurs when plant temperature is higher than that of environment (exceeds 35°C).

General effects of high temperature

High temperature affects

1. Seedling growth and vigour
2. Root growth
3. Water uptake
4. Nutrient uptake
5. Solute transport
6. Photosynthesis
7. Respiration
8. General metabolic processes
9. Fertilization
10. Maturation

Salt stress

Salt stress occurs due to excess salt accumulation in the soil. As a result, water potential of soil solution decreases. Therefore exosmosis occurs. This leads to physiological drought.

Physiological drought

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Disturbance of physiological process

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Wilting of the plant

Classification of saline soil

1. Saline soil
2. Alkaline soil

1. Saline soil

is defined as a soil whose electrical conductivity is greater than 4 ds/m, exchangeable sodium percentage is less than 15% and pH is less than 8.5. These soils are dominated by Cl^- and SO^{2-}_4 ions.

2. Alkaline soil

also termed as sodic soil whose electrical conductivity is less than 4 ds/m, exchangeable sodium percentage is greater than 15% and pH of the soil is greater than 8.5. These soils are dominated by CO^-_3 and HCO^-_3 ions.

Plants are classified into two types based on the tolerance to salt stress.

A. Halophytes
B. Glycophytes

A. Halophytes

are the plants which are able to grow in high concentration of salt. Halophytes are again divided into two types based on extreme of tolerance.

1. Euhalophytes : which can tolerate extreme salt stress

2. Oligohalophytes : which can tolerate moderate slat stress

B. Glycophytes

are the plants which cannot grow in high concentration of salt.

Effect of salt stress on plant growth and yield

1. Seed germination

Salt stress delays seed germination. The reason is the enzyme α-amylase activity is affected by salinity.

2. Seedling growth

Earlier seedling growth is more sensitive. There is a significant reduction in root emergence, root growth and root length.

3. Vegetative growth

When plants attain vegetative stage, salt injury is more severe only at high temperature and low humidity. Because under these conditions, the transpiration rate will be very high as a result uptake of salt is also high.

4. Reproductive stage

Salinity affects

1. Panicle imitiation
2. Spiklet formation
3. Fertilization and pollen grain germination

5. Photosynthesis

Salinity drastically declines photosynthetic process. Thylakoids are damaged by high concentration of salt. Chlorophyll ‘b’ content is drastically reduced.

Mechanism of salt tolerance

1. Some plants are able to maintain high water potential by reducing the transpiration rate.
2. Salts are accumulated in stem and older leaves in which metabolic processes take place in a slow rate.
3. Na^+ (sodium ion) toxicity is avoided by accumulating high amount of K^+ ions.
4. Accumulation of toxic ions in the vacuole but not in the cytoplasm.

5. Accumulation of proline and abscisic acid which are associated with tolerance of the plants to salt.

UV Radiation stress

UV radiation is divided into there

1. UVA – Wavelength ranging from 320-400 nm this is less lethal to the plants.
2. UVB – Wavelength ranges from (280-320 nm) which is lethal to the plants.
3. UVC – less than 280 nm- Highly lethal to all biological system.

These three UV radiations cause environmental stress because the cell constituents like proteins and nucleic acids absorb UV radiation in the range of 250-400 nm (UVA and VVB) and cause death of the tissues.

In general, on the outer atmosphere of the earth, CO_2, ozone and water vapour form a layer and this layer prevent the energy of UV radiation. However ozone depletion causes easy entry of VU radiation. In general, 1% reduction in ozone (O_3) gas causes 2% increased in UV radiation.

UV radiation and plant response

1. UV radiation slows down the growth of plants
2. Damage the process of photosynthesis
3. Prevent maturation and ripening process
4. Accelerate genetic mutation.

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 photoperodism.

The phenomenon of photoperiodism was first discovered by Garner and Allard (1920).

Depending upon the duration of photoperiod, they classified plants into 3 categories.

1. Short day plants (SDP)
2. Long day plants (LDP)
3. Day neutral plants (DNP)

1. Short day plants

These plants regime a relatively short day light period (usually 8-10 hours) and a continuous dark period of about 14-16 hours for subsequent flowering.

Some examples

Maryland mammoth variety of tobacco

Biloxi variety of soybean

Cocklebur (Xanthium)

These plants are also known as long-night-plants.

- In short day plants, the dark period is critical and must be continuous. If this dark period is interrupted with a brief exposure of red light (660-605 mm wavelength), the short day plant will not flower.

- Maximum inhibition of flowering with red light occurs at about the middle of critical dark period.
- However, the inhibitory effect of red light can be overcome by a subsequent exposure with far-red light (730-735 mm wavelength)
- Interruption of the light period with red light does not have inhibitory effect on flowering in short day plants.
- Prolongation of the continuous dark period imitates early flowering.

2. Long day plants

These plants regime longer day light period (usually 14-16 hours) in a 2 4 hours cycle for subsequent flowering.

Examples

Hyoscyamus niger (Henbane)

Spinach

Sugar beet

These plants are also called as short night plants.

- In long day plants, light period is critical
- A brief exposure of red light in the dark period or the prolongation of light period stimulates flowering in long day plants.

3. Day neutral plants

These plants flower in all photoperiod ranging from 5 hours to 24 hours continuous exposure.

Some of the examples

Tomato

Cotton

Sunflower

Cucumber

Peas varieties

Certain varieties of tobacco

During recent years intermediate categories of plants have also been recognized. They are

1. Long short day plants
2. Short long day plants

1. 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.

2. Short –long day plants

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

Photoperiodic Induction

Plants may regime one or more inductive cycle for flowering. An appropriate photoperiod in 24 hours cycle constitutes one inductive cycle. If a plant which has received sufficient inductive cycle is subsequently placed under infavourable photoperiod, it will still flower. Flowering will also occur if a plant receives inductive cycles after intervals of unfavourable photoperiods (i.e. discontinous inductive cycle). This persistence of photoperiodic after effect is called as photoperiodic induction.

- An increase in the number of inductive cycles results in early flowering of the plant. For instance xanthium (a short day plant) requires only one inductive cycle and normally flowers after about 64 days. It can be made to flower even after 13 days if it has received 4-8 inductive cycle. In such case number of flowers is also increased.

- Continuous inductive cycles promote early flowering than discontinuous inductive cycle.

Some of the examples of plants which requires more than one inductive cycle for subsequent flowering are Biloxi soybean (SDP) – 2 inductive cycle.

Salvia (SDP)	- 17 Inductive cycles
Plantago (LDP)	- 25 Inductive cycles

Critical day length

Maryland mammoth tobacco and xanthium, both are short day plants, but Maryland mammoth tobacco is induced to flower when the photoperiod is shorter than 12 hours (12L/12D) whereas xanthium is induced to flower when the photoperiod is shorter than 15.5 hours (15.5L/8.5D). The photoperiod required to induced flowering is referred to as the critical day length. The critical day length for Maryland mammoth tobacco and xanthium are 12 and 15.5 hours respectively. A short day plant is one that flowers on photoperiods shorter than the critical day length.

Long day plants, on the other land, are induced to flower on photoperiods longer than critical day length. For example, the critical day length for *Hyoscyamus niger* is 11 hours (11L/13D) and it is induced to flower on photoperiods longer than 11 hours.

Suppose than xanthium and *Hyoscyamus niger* are exposed to a photoperiod of 14 hours of light and 10 hours of darkness (14L/10D). It can be seen that flowering will be induced in both plants. Xanthium, a short-day plant, will flower because 14,/10 D photoperiod is shorter than critical day length of 15.5 hours. Hyoscyamus, a long-day plant, will flower because 14L/10D is longer than the critical day length of 11 hours.

Perception of photoperiodic stimulus and presence of a floral hormone

Photoperiodic stimulus is perceived by the leaves. As a result a floral hormone is produced in the leaves which is then translocated to the apical tip, subsequently causing initiation of floral primordia.

Photoperiodic stimulus perceived by the leaves can be shown by a simple experiment on cocklebur (xanthium), a short day plant. Cocklebur plant will flower if it has previously been kept under short day conditions. If the plant is defoliated and kept under short day condition, it will not flower. Flowering will also occur if all the leaves of the plant except one leaf have been removed.

Experimental on cocklebur plants to shown that photoperiodic stimulus is perceived by the leaves flowering occurs even if a single leaf is exposed to appropriate photoperiod

If the cocklebur plant whether intact or defoliated is kept under long day condition it will not flower. But if even one of its leaves is exposed to short day condition and the rest are under long day condition, flowering will occur.

The photoperiodic stimulus is transmitted from one branch of the plant to another branch. For example, if in a two branched cocklebur plant one branch is exposed to short day and the other to long day photoperiod, flowering occurs on both the branches.

Flowering also occurs if one branch is kept under long day conditions and other branch from which all the leaves except one have been removed is exposed to short day condition. However, if one branch is exposed to long photoperiod and the other has been defoliated, under short day conditions, flowering will not occur in any of the branches.

Experiments on cocklebur plants to show that the photoperiodic stimulus can be transmitted from one branch of the plant to another

The flowering stimulus : Florigen

Flowering stimulus is produced in leaves and translocated to apical and lateral meristems where flower formation is imitated. Chailakhyan (1937) called the flowering stimulus or flowering hormone as Florigen.

Flowering stimulus is similar in long day plants and short day plants. This can be proved by a grafting experiment and can be translocated from one plant to another.

Maryland mammoth tobacco, a short day plant and *Hyoscyamus niger*, a long day plant, are grafted so that the leafy shoots of both the species are available for experiment. If the grafted plants are exposed to either long-day a short-day conditions, both partners flower. If grafting union is not formed, the flowering stimulus is not translocated from one partner to another partner.

Phytochrome

It has already been seen that a brief exposure with red light during critical dark period inhibits flowering in a short day plant and this inhibitory effect can be reversed by a subsequent exposure with far-red light.

Similarly, prolongation of the critical light period or the interruption of the dark period stimulates flowering in long-day plants.

This inhibition of flowering in short day plant and stimulation of flowering in long day plants involves the operation of proteinaceous.

Pigment called as phytochrome

- The pigment phytochrome exists in two different forms

  (a) red light absorbing form which is designated as P_R and

  (b) far red light absorbing form which is designated as P_{FR}

- These two forms of the pigment are photochemically inter convertible (Borth wick and Hendricks)
- When P_R form of the pigment absorbs red light (660-665 nm), it is converted into P_{FR} form.
- When P_{FR} form of the pigment absorbs far red light (730-735 nm), it is converted into P_R form
- The P_{FR} form of pigment gradually changes into P_R form in dark.

It is considered that during day time the P_{FR} form of the pigment is accumulated in the plants which is inhibitory to flowering in short day plants but is stimulatory in long day plants.

During critical dark period in short day plants, this form gradually changes into P_R form resulting in flowering.

A brief exposure with red light will convert this form again into P_{FR} form thus inhibiting flowering.

Reversal of the inhibitory effect of red light during critical dark period in SDP by subsequent far-red light exposure is because the P_{FR} form after absorbing far-red light (730-354 nm) will again be converted back into P_R form.

Prolongation of critical light period or the interruption of the dark period by red – light in long day plants will result in further accumulation of the P_{FR} form of the pigment, thus stimulating flowering in long-day plants.

Phytochrome is present in roots, coleoplites, stems, lypocotyls, cotyledons, petioles, leaf blades, vegetative buds, flower tissues, seeds and developing fruit of higher plants.

Within cell, phytochrome may be located at membrane surfaces. If shows two components chromophore and protein.

PLANT GROWTH REGULATORS

Plant growth regulators or phytohormoes or natural growth hormones of plants are organic substances produced naturally in higher plants, controlling growth or other physiological functions at a site remote from its place of production and active in minute amounts.

Classifications

Auxins

Gibberellins

Cytokinins

Abscisic acid

Ethylene

Auxins were the hormones first discovered in plants. Later Gibberellins and cytokins were also discovered.

Auxins

IAA is the only naturally occurring auxin in plants. The others such as IAA, IBA, NAA, 2, 4, D and 2, 4, 5 –T are synthetic auxins.

Physiological effects of auxin

1. Cell elongation

The primary physiological effect of auxin in plants is to stimulate elongation of the cell in shoots.

2. Apical dominance

In many plants if the terminal bud is intact and growing, the growth of lateral buds just below it remains suppressed. Removal of the apical bud results in the rapid growth of lateral buds. This phenomenon in which the apical bud dominates over the lateral buds and does not allow the lateral buds to grow is apical dominance.

Skoog and Thimann pointed out that the apical dominance might be under the control of auxin produced at the terminal bud and which is transported downward through the stem to the lateral buds and linders them growth. They removal the apical bud and replaced it with agar block. This resulted in rapid growth of lateral buds. But when they replaced the apical bud with agar block containing auxin, the lateral buds remained suppressed and did not grow.

3. Root initation

In contrast to stem, the higher concentration of auxin inhibits the elongation of roots but the number of lateral roots is considerably increased i.e higher concentration of auxin imitates more lateral branch roots.

Application of IAA in lonolin paste (linolina is a soft fat prepared from wool and is good solvent for auxin) to the cut end of a young stem results in an early and extensive rooting. This fact is of great practical importance and has been widely utilized to promote root formation in economically useful plants which are propagated by cuttings.

4. Prevention of abscission

Natural auxins have controlling influence on the abscission of leaves, fruits etc.

5. Parthenocarpy

Auxin can induce the formation of parthenocarpic fruits (fruit formation without pollination and fertilization). In parthenocarpic fruits, the concentration of auxin in the ovaries is higher than in the ovaries of plants which produce fruits only after fertilization. So concentration increases after pollination and fertilization.

6. Respiration

Auxin stimulates respiration and there is a correlation between auxin induced growth and respiration auxin may increase the rate of respiration indirectly through increased supply of ADP by rapidly utilizing ATP in the expanding cells.

7. Callus formation

Besides cell elongation, auxin may also be active in cell division. In many tissue cultures, where the callus growth is quite normal, the continued growth of such callus takes place only after the addition of auxin.

Distribution of auxin in plants

In plants auxin (IAA) is synthesized in growing tips or meristematic regions from where it is transported to other plant parts. So the highest concentration of IAA is found in growing shoot tips, young leaves and developing auxillary shoots.

In monocost seedling, the highest concentration of auxin is found in coleoptile tip which decreases progressively towards its base.

In dicot seedlings, the highest concentration is found in growing regions of shoot, young leaves, developing axillary shoots.

Within the plants, auxin may be present in two forms. Free auxins and bound auxins. Free auxins are those which are easily extracted by various organic solvents such as diethyl ether. Bound auxins on the other hand, need more drastic methods for their extraction from plants such as hydrolysis, autolysis, enzymolysis etc. Bound auxins occur in plants as complexes with carbohydrates such as glucose, arabionse or sugar alcohols or proteins or amino acids such as aspartate, glutamate or with inositol.

Biosynthesis of auxin (IAA) in plants

Thimann (1935) found that an amino acid tryptophan is converted into indole 3 acetic acid. So tryptophane is the primary precursor of IAA in plants.

IAA can be formed from tryptophan by two different pathways.

1. By deamination of tryptophan to form indole-3-pyruvic acid followed by decarboxylatin to from indole-3-acetaldehyde. The enzymes involved are tryptophan deamintion and indole pyruvate decarboxylase respectively.
2. By decarboxylation of tryptophan to form tryptamine followed by deamination to form indole -3-acetaldehyde the enzymes involved are tryptophan decarboxylase and tryptamine oxidase respectively

Indole 3-acetaldehyde can readily be oxidized to indole 3-acetic acid (IAA) in the presence of indole 3-acetaldehyde dehydrogenase.

Transport of auxin in plant

The transport of auxin is predominantly polar. In stems polar transport of auxin is basipetal i.e it takes place from apex towards base.

Polar transport of auxin is inhibited by 2, 3, 5 Triiodobenzoic acid (TIBA) and Naphthylthalamic acid (NPA). The substances are called as antiauxins.

Synthetic auxins

IAA, IBA, NAA, 2, 4 –D, 2, 4, 5, T

Destruction / Inactivation of auxin in plants

Auxin is destructed by the enzyme IAA oxidase in the presence of O_2 by the process oxidation.

$$IAA + H_2O_2 + O_2 \xrightarrow{\text{IAA Oxidase}} \text{3-methylene oxindole} + H_2O + CO_2$$

Rapid inactivation may also occur by irradiation with x-rays and gamma rays. UV light also reduces auxin levels in plants. Inactivation or decomposition of IAA by light has been called as photo oxidation.

Gibberellins

Discovery

A Japanese scientist Kurosawa found that the rice seedlings infected by the fungus *Gibberella fujikuroi* grow taller and turned very thin and pale. An active substance was isolated from the infected seedlings and named as Gibberellin.

Physiological effects of gibberellins

1. Seed germination

Certain light sensitive seeds eg. Lettuce and tobacco show poor germination in dark. Germination starts vigorously if these seeds are exposed to light or red light. This requirement of light is overcome if the seeds are treated with gibberellic acid in dark.

2. Dormancy of buds

In temperature regions the buds formed in autumn remain dormant until next spring due to severe cold. This dormancy of buds can be broken by gibberellin treatments.

In potato also, there is a dormant period after harvest, but the application of gibberellin sprouts the refer vigorously.

3. Root growth

Gibberellins have little or no effect on root growth. At higher concentration, some inhibition of root growth may occur. The initiation of roots is markedly inhibited by gibberellins in isolated cuttings.

4. Elongation of internodes

The most pronounced effect of gibberellins on the plant growth is the elongation of the internodes. Therefore in many plants such as dwarf pea, dwarf maize etc, gibberellins overcome the genetic dwarfism.

5. Bolting and flowering

In many herbaceous plants, the early period of growth shows rosette habit with short stem and small leaves. Under short days, the rosette habit is retained while under long days bolting occurs i.e. the stem elongates rapidly and is converted into folar axis bearing flower primordia. This bolting can also be induced in such plants by the application of gibberellin even under non-inductive short days.

In *Hyoscyamus niger* (a long day plant) gibberellin treatment causes bolting and flowering under non-inductive short days. While in long day plants the gibberelling treatment usually results in early flowering. In short day plants, its effects are quite variable. It may either have no effect or inhibit or may activate flowering.

6. Parthenocarpy

Germination of the pollen grains is stimulated by gibberellins, likewise, the growth of the fruit and the formation of parthenocarpic fruits can be induced by gibberellin treatment. In many cases, eg. pome and stone fruits where auxins have failed to induce parthenocarpy, the gibberellins have proven to be successful. Seedless and fleshly tomatoes and large sized seedless grapes are produced by gibberellin treatments on commercial scale.

7. Synthesis of the enzyme α - amylase

One important functions of gibberellins is to cause the synthesis of the enzyme α - amylase in the aleurone layer of the endosperum of cereal grains during germination. This enzyme brings about hydrolysis of starch to form simple sugars which are then translocated to growing embryo to provide energy source.

Distribution of gibberellins in plant

Gibberellins are found in all parts of higher plants including shoots, roots, leaves, flower, petals, anthers and seeds. In general, reproductive parts contain much higher concentrations of gibberellins than the negative parts. Immature seeds are especially rich in gibberellins (10-100 mg per g fresh weight).

In plants, gibberellins occur in two forms free gibberellins and bound gibberellins. Bound gibberellins usually occur as gibberellin – glycocides.

Biosynthesis of gibberellins in plants

The primary precursol for the formation of gibberellin in acetate.

Acetate + COA $\rightarrow$ Acetyl COA $\rightarrow$ Mevalonic acid $\rightarrow$ MA pyrophosphate $\rightarrow$ Isoperteyl pyrophosphate $\rightarrow$ Geranyl pyrophosphate $\rightarrow$ GGPP $\rightarrow$ Kaurene $\rightarrow$ Gibberellins.

Cytokinins / Kinetin

Discovery

Kinetin was discovered by Skoog and Miller (1950) from the tobacco pith callus in culture and the chemical substance was identified as 6-furpurcyl aminopurine. Because of its specific effect on cytokinesis (cell division), it was called as cytokining or kinetin. Cytokinins, besides their main effect on cell division, also regulate growth, hence they are considered as natural plant growth hormones.

Some of the very important and commonly known naturally occurring cytokins are

1. Coconut milk factor 2. Zeatin

1. Coconut milk factor

The liquid endosperum of coconut often reffered to as coconut milk, has been found to contain some factors which show kinetin like activity and can stimulate growth in many plant tissues.

Zeatin

Zeatin is the cytokinin present in immature corn grains.

Cytokinins in t – RNA

It was also identified that cytokinin as a constituent of t-RNA.

Physiological effect of kinetins

1. Cell division

One of the most important biological effects of kinetin on plants is to induce cell division especially in tobacco pith callus, carrot root tissue, soybean cotyledon, pea callus etc.

2. Cell enlargement

Like auxins and gibberellins, the kinetin may also induce cell enlargement. Significant cell enlargement has been observed is the leaves of *Phaleolus vulgaris*, pumpkin cotyledons, tobacco pith culture, cortical cells of tobacco roots etc.

3. Concentration of apical dominance

Growth of the lateral buds is inhibited due to presence of IAA in the apical region on the other hand, kinetin stimulates the growth of lateral buds.

4. Dormancy of seeds

Like gibberellins, the dormancy of certain light sensitive seeds such as lettuce and tobacco can also be broken by kinetin treatment.

5. Delay of senescence

The aging process of leaves usually accompanies with loss of chlorophyll and rapid breakdown of proteins. This is called as senescence. Senescence can be postponed to several days by kinetin treatment by improving RNA synthesis followed by protein synthesis.

Distribution and transport of cytokinins

Cytokinins are synthesized in roots and tranlsocted to shoots and leaves of the plant.

Abscisic acid

Addicott (1963) isolated a substance strongly autagonistic to growth from young cotton fruits and named Abscisia II. Later on this name was changed to Abscisic acid. This substance also induces dormancy of buds therefore it also named as Dormin.

Abscisic acid is a naturally occurring growth inhibitor.

Physiological effects

The two main physiological effects are

1. Geotropism in roots
2. Stomatal closing

Besides other effects

1. Geotropism in roots

Geotropic curvature of root is mainly due to translocation of ABA in basipetal direction towards the root tip.

2. Stomatal closing

ABA is synthesized and stored in mesophyll chloroplast. In respond to water stress, the permeability of chloroplast membrane is lost which resulted is diffusion of ABA out of chloroplast into the cytoplasm of the mesophyll cells. From mesophyll cells it diffuses into guard cells where it causes closing of stomata.

3. Other effects

i. Including bud dormancy and seed dormancy

ii. Includes tubrisation

iii. Induces senescence of leaves fruit ripening, abscission of leaves, flowers and fruits

iv. Increasing the resistance of temperate zone plants to frost injury.

Ethylene

Ethylene is the only natural plant growth hormone exists in gaseous form.

Important physiological elects

1. The main role of ethylene is it hastens the ripening of fleshy fruits eg. banana, apples, pears, tomatoes, citrus etc.
2. It stimulates senescence and abscission of leaves
3. It is effective in inducing flowering in pine apple
4. It causes inhibition of root growth
5. It stimulates the formation of adventitious roots
6. It stimulates fading of flowers
7. It stimulates epinastly of leaves.

Growth retardants

There are no. of synthesis compounds which prevent the gibberellins from exhibiting their usual responses in plants such as cell enlargement or stem elongation. So they are called as antigibberellins or growth retardants. They are

1. Cycocel (2- chloroethyl trimethyl ammonium chloride (CCC)
2. Phosphon D – (2, 4 – dichlorobenzyl – tributyl phosphonium chloride)

AMO – 1618

Morphactins

Maleic hydrazide

VERNALIZATION

Besides an appropriate photoperiod certain plants require a low temperature treatment during their early stages of the life for subsequent flowering in the later stages.

This low temperature treatment was termed as vernalization by Lyseko (1928). Due to vernalization, the vegetative period of the plant is cut short resulting is an early flowering winter wheat 0°-5°C spring wheat.

Perception of cold stimulus and presence of floral hormone

The cold stimulus is perceived by the apical meristems. The perception of the cold stimulus result in the formation of a floral hormone which is transmitted to other parts of the plant. In certain cases, the cold stimular may even be transmitted to another plant across a graft union.

For instance if a vernalized henbane plant is grafted to an unvernalized henbane plant, the later also flowers.

The above mentioned floral hormone has been named as Vernalin by Melchers (1939).

Other conditions necessary for vernalization

1. Age of the plant

The age of the plant is an important factor in determining the responsiveness of the plant to the cold stimulus and it differs in different species.

For example

In cereals like winter wheat, the vernalization is effective only if the germinating seeds have received cold temperature treatment for sufficient time.

While in case of biennial variety of henbane (*Hyoscyamus niger*), the plant will respond to the cold treatment, only if they are in rosette stage and completed at least 10 days of growth.

2. Appropriate low temperature and duration of the exposure

Most suitable temperature for vernalizing the plants ranges between 1-6°C. Low temperature at about -6°C is completely ineffective. Similarly at high temperatures from 7°C onwards, the response of the plants is decreased. Temperastures at about 12-14°C are almost is effective in vernalizing the plant.

Besides an appropriate low temperature, a suitable duration of this cold treatments is essential for vernalization. Depending upon the degree of temperature and in different species this period may vary, but usually the duration of the chilling treatment is about one and half months or more.

3. Oxygen

The vernalization is an aerobic process and requires metabolic energy. In the absence of O_2 cold treatment becomes completely ineffective.

4. Water

Sufficient amount of water is also essential for vernalization. Vernalization of the dry seed is not possible.

Mechanism of Vernalizastion

Two main hypothetical theories are given below.

1. Phasic developmental theory

The main points of this theory which was advanced by Lyeuko (1934) are as follows.

(i) The growth (increase in size) and development (i.e. progressive change in the characteristic of the new organs) are two distinct phenomen.

(ii) According to this theory, the process of the development of an annual seed plant consists of a series of phases which must occur in some predetermined sequence.

(iii) Commencement of any of these phases will takes place only when the proceeding phase has been completed.

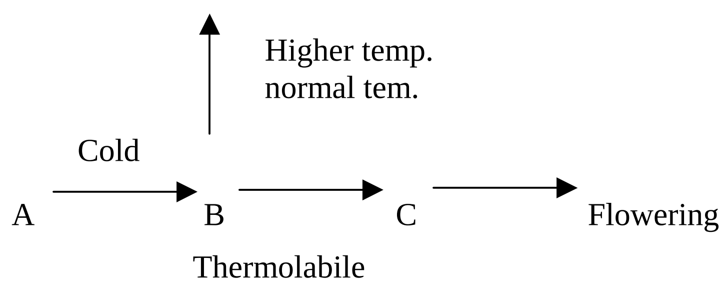
(iv) The phases regime different external conditions for the completion such as light and temperature.

(v) Vernalization accelerates the thermophase i.e that phase of development which is dependent upon temperature.

Thus, in winter wheat variety low temperature is required for the completion of first thermophase. After this the next phase which is dependent upon light (photophase) starts. Vernalization of winter wheat accelerates the first thermophase so that there is an early swing from vegetative to reproductive phase or flowering.

2. Hormonal theories

It has already been described that vernalization probably involves the formation of a floral hormone called as vernaline. Based on this fact, many hypothetical schemes have been proposed by different work us from time to time. This first hormonal theory proposed by Long and Melchers (1947) is schematically shown below.



According to this scheme, the precursor A is converted into a thermolabile compound B during cold treatment. Under normal conditions B changes into C which ultimately causes flowering. But at higher temperature B is converted into D and flowering does not take place (devernalization).

Devernalization

The positive effect of the low temperature treatment on the vernalization of the plant can be contacted by subsequent high temperature. This is called devernalization. The devernalized plant can again be vernalized by subsequent low temperature treatment.

Vernalization and Gibberellins

The gibberellins are know to replace the low temperature requirement is certain biennial plants such as henbane, where the plant normally remains vegetative and retains its rosette habit during the first growing season and after passing through the winter period flowers in the next season. The gibberellins cause such plants to flower even during the first year.

Practical utility of vernalization

1. Vernalization shortens the vegetative period of the plant
2. Vernalization increases cold resistance of the plants
3. In cold countries like Russia, where the winters are too severe, vernalization has been of great importance. By this process certain crop plants could be made to escape the harmful effects of severe winter, thus improving the crop production. In warmer countries live India, however, vernalization practice has not been in use mainly because it is a costly process and the winters are comparatively not very severe as to harm the crop plants. Moreover, the vernalization process have resulted only in very little success in India.

4. Early work by Russians has also claimed that vernalization increases the resistance of plants to fungal diseases.

FATS (LIPIDS)

Fats are a heterogenous group of molecules. They contain atom of carbon, oxygen and hydrogen and fats and fat like molecules are generally called as ‘lipids’. They are insoluble in water and soluble in organic solvents. Fats serve as reserve food materials primarily in seeds, whereas the fat live materials mainly phospholipids and glycolipids, are constituents of all cell membrane. The cuticular waxes are also lipids but are quite different in their composition from the fats.

Biosynthesis of lipids

The basic lipid unit is phosphatidic acid which is synthesized from glycerol and fatty acid glycerol is synthesized from glyceroldehyde -3- phosphate or from glucose. The fatty acids are synthesized form acetyl COA. Fatty acids are also the precursor of waxes phosphatidic acid may form triglycerides (neutral fats) or phospholipids by interacting with choline or glycolipids by interacting with sugars. The membrane of chloroplasts and mitochondria contain complex lipid molecules.

Fatty acids consists of even number of C atoms. Fatty acids may be saturated and unsaturated saturated fatty acids Eg. Palmitic acid and Steric acid.

Palmitic acid is commonly found in vegetable fats (palm oil) and linolinic acid is in linseed oil.

Breakdown of fatty acids

Long chain fatty acids are broken by the process of α - oxidation and β - oxidation.

α - oxidation

By this process, the long chain fatty acid is gradually broken down until it is reduced to 12 C- atmos. Fatty acids with less than 13C atoms are not affected by this process. One complete α - oxidation results in the eliminatin of one carbon atom in the form of CO_2 from the COOH group of the fatty acid while α - C atom i.e C atom no. 2 which is adjacent to – COOH) is oxidized.

α - oxidation takes place as follows

1. The fatty acid is oxidatively decarboxylated in the pressure of fatty acid peroxidase and H_2O_2 to form an aldehyde. In this reaction CO_2 comes from COOH (Carboxylic) group and oxidation takes place at α - C-atom which becomes converted into the aldehyde group.

$$\underset{\text{Fatty acid}}{\overset{\text{B}\quad\alpha}{RCH_2CH_2CH_2\,COOH}} \xrightarrow[2(H_2O_2)]{\text{Fatty acid peroxidase}} \underset{\text{Aldehyde}}{RCH_2CH_2CHO} + CO_2 + H_2O$$

2. The aldehyde is further oxidized in the pressure of aldehyde dehydrogenase to form the new fatty acid containing one carbon atom less than in the original fatty acid. NAD is reduced in the reaction.

$$RCH_2CH_2CHO + NAD \xrightarrow[\text{Dehydrogenase } H_2O]{\text{Aldehyde}} \underset{\text{New fatty acid}}{\overset{\alpha}{RCH_2CH_2COOH}} + NADH + H$$

The cuticular waxes are also lipids.

Breakdown of fats

Active breakdown or degradation of fats takes place.

1. During the germination of fatty seeds and decomposition products may enter into glycolysis and krebs' cycle to release energy and also to synthesise soluble sucrose through glyoxylic acid cycle which is then translocated to the growing regions of the germinating seedlings.
2. In plants, when carbohydrates reserve declines, fats may form the respiratory substrates to release energy through oxidation.

Breakdown

Fats are first hydrolyzed in the pressure of the enzymes lipases to yield fatty acid and glycerol.

$$\text{Tiglyceride} \xrightarrow{\text{Lipases}} \text{Fatty acids + Glycerol}$$

Oxidation of glycerol

Glycerol reacts with ATP under the influence of glycerol kinase to form glycerol -3- phosphate which is then oxidized to produce dihydroxy acetone phosphate by glycerol -3- phosphate dehydrogenase and NAD.

$$\text{Glycerol-3-P+ATP+NAD} \xrightarrow[\text{}]{\text{Glycerol-3-P dehydrongease}} \text{Dihydroxy acetone phosphate}$$

$$\text{Dehydroxy acetone phosphate} \xrightarrow[\text{Pathway}]{\text{Glycolytic}} \text{Pyruvic acid + 2ATP + NADH + } H^+$$

This conversion of glycerol to pyruvic acid which takes place in cytoplasm yield 2ATP and 2NADH which in tern produce 4 molecules of ATP. If pyruvic acid enters into Kreb's cycle (TCA), it will produce another 15 ATP mole. Thus a total of 2+4+15 = 21 ATPs with the consumption of one molecule in the glycerol kinase catalysed reaction. Therefore net gain of 20 ATP/glycerol.

Role of plant physiology in agriculture

Plant physiology serves as the foundation for the numerous recent advances in agriculture, horticulture and forestry. Plant physiology has an important role in agricultural research programmes in the near future. Basic aspects of plant physiology can be applied in the crop improvement programme for obtaining greater yields. The following are some of the applied areas of plant physiology.

1. Production physiology
2. Stress physiology
3. Growth regulators physiology
4. Nutriophysiology

1. Production physiology

This branch deals with the relationship between crop productivity and photosynthesis. Photosynthesis is the basic mechanism with which crop plants are able to put forth dry matter accumulation. Increase in dry matter accumulation is important for increased yield. For increase in dry matter accumulation photosynthetic efficiency should be improved. The factors governing photosynthetic efficiency are

1. Net photosynthetic rate
2. Total photosynthetic surface (LAI)
3. Leaf area duration (LAD)

By improving the above factors, photosynthetic efficiency may be improved and hence the yield may be increased. This knowledge will also be useful in incorporating better physiological traits into superior genotypes by breeding.

2. Stress physiology

Crop plants are prove to various stress. Stress can be classified into (1) Biotic and (2) Abiotic, Biotic stress includes attack of insects, pathogens, nematodes and also competition from weeds.

Abiotic stress include drought, heat, cold, high light, pollution, salinity etc. For efficient crop production under these circumstances, the crop should be resistant to these stress resistance.

Resistance to various stresses

is a physiological process. The study of these resistance mechanisms will enable to select resistant crop varieties to a particular type of stress.

3. Growth regulator physiology

Growth regulators play an important role in the plant metabolism. Growth regulators are used in agriculture for (1) Improving yield (2) Improving the quantity of the produce (3) suppressing excessive vegetative growth (4) rooting of cuttings (5) for killing weeds etc.

From the early work on auxins, many number of synthetic auxins were manufactured. Indole butyric acid (IBA) is being successfully used as rooting hormone. 2, 4-Dichlorophenoxy acetic acid (2, 4-D) has been used as weed killer (herbicide).

Interest in the use of growth regulators in crop production arises in recent years. Large increase in crop yields achieved over the past 30 years have utilized the technologies of the green revolution – improved seeds, new varieties of plants, fertilizers, irrigations, pesticides and mechanisation. Yields of many crops have now reached a platean and additional increment of fertilizers, pesticides, water and similar items are no longer economical. Thus agriculturists and horticulturists are looking for ways to break the present yield limits by chemical manipulation of the plant through the use of chemical growth regulator.

Nutriophysiology

At present there are 16 essential nutrients are identified. Supply of the different nutrients in correct proportions is important for increased productivity. In some problem soils, the nutrients may not be available to the plants even though they are present in the soil. In such situation we have to go for foliar fertilization. In this way study of the plant nutrition also be useful for productivity of crop plants.

Source sink relationship

Source	:	Leaves and other green tissues that produce photosynthesis (carbohydrates) are called as sources
Sink	:	Organs which utilize the photosynthates for their growth and then store the photosynthates are called sink.

Source sink relationship

The photosynthates (carbohydrates) which are produced in sources are translocated to sink through phloem in the form of sucrose. Therefore, the sources (leaves) should produce or synthesis maximum assimilates (carbohydrates) and sink should be able to utilize the maximum assimilates and store them. Then only the productivity of the crop will be higher. The transport of assimilates (CH_2O) from source to sink is called assimilate partitioning.

Assimilate partitioning during vegetative stage

During vegetative stage, green tissues are the original sources of assimilates. Developing young leaves, young stems and young roots are the sink. They draw the assimilates from the sources and utilize them for their growth.

Assimilate partitioning during the reproductive phase

During reproductive phase, the flower, fruits and seeds act as sink. They draw the assimilates from sources (green leaves) and utilize for their growth and then store the assimilates. Therefore the crop yield is determined by the capacity of source and sink.

Harvest Index (HI)

Harvest index is the ratio of economic yield to the biological yield. The other terms are Migration coefficient or coefficient of effectiveness.

$$HI = \frac{\text{Grain yield or economic yield}}{\text{Total dry weight of the plant (biological yield)}}$$

Global warming

In general, delicate plants which require protection from weather are grown in green house (Glass house). In green house so many gases are produced like CO_2, water vapour, methane, oxides of nitrogen and chlorofluoro carbon (CFC). These gases are produced from plants and accumulated inside the glass house, as a result glass house gets warming. In natural atmosphere also the same effect occurs i.e. Global warming (due to the release of gases from plants).

But in glass house, glass roof is present to prevent the escape of gases from the glass house. In natural atmosphere, the gases such as ozone, water vapour, CO_2 methane etc. form a layer on the lower atmosphere and this layer prevents the heat escaping from the earth. If heat is released or escaped from earth, the temperature of earth would be below freezing point.

SO accumulation of heat or gases causes the warming of earth surface and leads to global warming.

Global warming will lead to two effects

1. Rise in temperature
2. Average rise in the level of sea (about 6 cm/decade) due to melting of polar ice.
3. CO_2 concentration steady increasing (CO_2 enrichment).

CO_2 enrichment and crop productivity

1. CO_2 enrichment leads to increased photosynthesis and productivity
2. CO_2 enrichment also decreases stomatal conductance by closing the stomata, thee by decrease the transpiration / unit area of the leaf.
3. In C_3 plant the efficiency of RuBp carboxylase enzyme is increased
4. Increased CO_2 concentration inhibits photorespiration in plants
5. CO_2 enrichment increased the yield and yield components.

Other green house gases

1. 1. Oxides of nitrogen (NO, NO_2, N_2O molecular N_2) oxides of nitrogen cause phototoxic, bleaching and necrosis (drying of tissues) in plants.
2. Ozone (O_3) causes ozone injury to the plants.

FAT SYNTHESIS

The synthesis of fats can be studied in 3 phases.

A. Synthesis of fatty acid
B. Synthesis of glycerol
C. Condensation of fatty acids and glycerols into fats

Synthesis of fatty acids

Long chain fatty acids are synthesized in plants from active two carbon units, the acetyl- COA ($CH_3CO.COA$). Synthesis of fatty acids from CH_3COCOA takes place step by step. In each step, two carbon atoms are added to the fatty acid chain. Each step involves three reactions.

Reaction –I

Acetyl COA combines with CO2 to form malongl COA (3-carbon compound) in the presence of the enzyme.