CHAPTER - 00
PLANT GROWTH AND DEVELOPMENT

The development of a mature plant from a zygote follows a precise and highly ordered succession of events. During this process a complex body organisation is formed that produces roots, leaves, branches, flowers, fruits and seeds and eventually they die

The first step in the process of plant growth is seed germination

It requires favourable conditions for growth in the environment. If there are no such conditions then seeds donot germinate and goes into a period of suspended growth or rest (dormancy)

Once the favourable conditions return, seeds perform metabolic activities and growth takes place

There are both intrinsic or internal and extrinsic or external factors which govern and control the developmental processes in plants

Types of Seed Germination

There are 2 types of seed germination

They are epigeal germination $\rightarrow$

EPIGEAL GERMINATION

In this germination of a plant takes place above the ground. Here hypocotyl of the embryo elongated Ist to push the cotyledons above the ground

Eg: Common bean, Castor (avanuku) sunflower, pumpkin, watermelon guards, cucumber, lillies

HYPOGEAL GERMINATION

Germination occurs below the ground. Here epicotyl elongates first. So cotyledons remain in the soil

Eg. green peas *(Pisum sativum),* horse gram *(Dolichos lablab*),maize, coconut

Thus we can conclude that development is concerned as sum of growth and differentiation

Development in plants is under the control of intrinsic and extrinsic factors

Intrinsic factors includes both intracellular (genetic) or intercellular factors (chemicals such as plane growth regulators) extrinsic factors include light temperature, water, O_2, nutrition etc.

Growth

It is an irreversible permanent increase in size of an organ or its parts or even of an individual cell

Growth is accompanied by metabolic process both anabolic and catabolic that occur at the expense of energy

Type of plant growth

Overall the plant growth is indeterminate. Plants retain the capacity for unlimited growth throughout their life

This is due to the presence of meristems at definite locations in their body

This form of growth where in new cells are being added to the body by the activity of meristem is called open form of growth

Growth of the plants consist of 1° growth and 2° growth. Primary growth of the plants contribute to the elongation of plants along their axis

In dicots and gymnosperms the lateral meristems-vascular cambium and cork cambium appear later in life. These meristems cause the increase in girth of organs. This is known as 2° growth of the plant

Growth is Measurable

In plants growth is measured by a variety of parameters like

- Increase in the amount of protoplasm in cell
- Increase in fresh weight and dry weight
- Increase in length, area, volume and cell number

Growth of a pollen grain is measured by its length. Eg. Growth in a dorsiventral leaf is measured as an increase in surface area

In plants the period of growth is generally divided into 3 phases mainly meristematic, elongation and maturation

All these 3 phases are seen in root and stem

1. The phase of meristem

The cells in this region are rich in protoplasm.

They posses a large conspicuous nuclei.

The cell walls are primary in nature

Cell wall is thin & cellulose with abundant plasmodesmatal connection

2. Phase of Elongation

The cells are seen proximal to the meristematic zone (away from tip) These cells show increased vacuolation (vacuole formation), cell enlargement and new cell wall deposition

3. Phase of Maturation

The cells are seen proximal to the phase of elongation these cells attain the maximal size in terms of wall thickening and protoplasmic modification

For the Parallel line technique refer text NCERT (241)

Growth Rates

Growth rate is the increased growth per unit time. It can be expressed mathematically. There are 2 types of growth rate : Arithmetic and Geometric growth rate

Arithmetic Growth rate

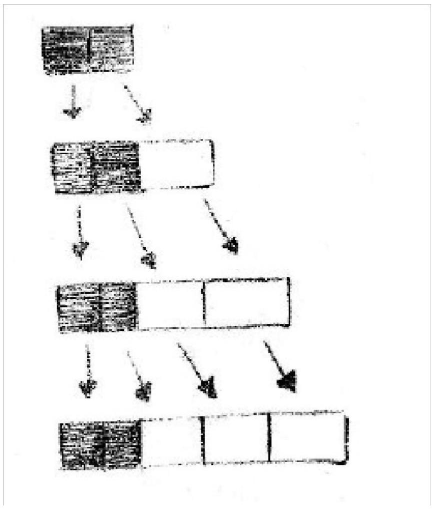
In arithmetic growth, following mitotic cell division only one daughter cell continues to divide, while the other differentiates and matures

Eg: Root elongating at a constant rate. Mathematically it can be represented as $L_t = L_o + rt$

Where $L_t \rightarrow$ length at time t

$L_0 \rightarrow$ length at time 0

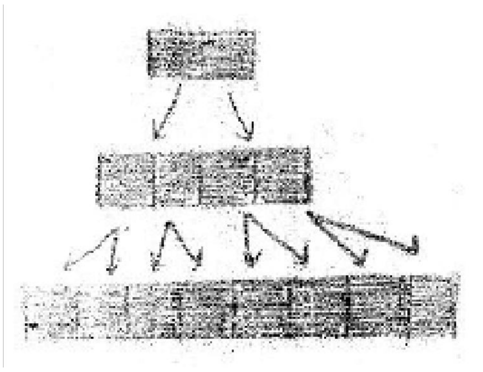
$r \rightarrow$ growth rate of elongation per unit time



on plotting the length of organ against time, a linear curve is obtained

Geometric Growth rate

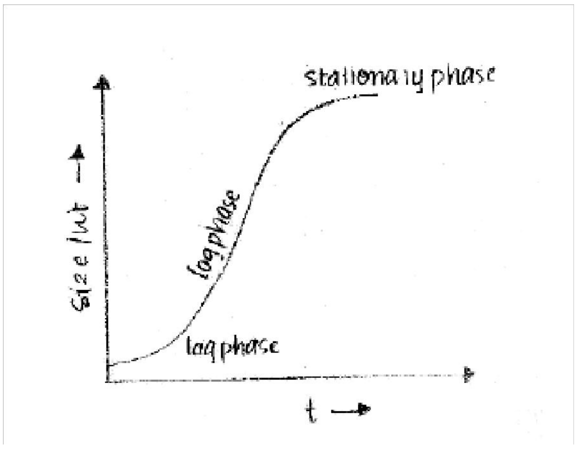
In this, both the progeny cells following mitotic cell division, retain the activity to divide and continue to do so



In most system, the initial growth is slow (lag phase) and increase rapidly at an exponential rate (log or exponential phase) with limited nutrient supply the growth slows down leading to a stationary phase

If we plot the parameter of growth against time we get a sigmoid or S-curve

A sigmoid curve is a characteristic of using organism growing in a natural environment



The exponential growth can be expressed as $W_1 = W_0 e^{rt}$

where $W_1 \Rightarrow$ final size

$W_0 \Rightarrow$ initial size at the beginning of period

$r \Rightarrow$ growth rate

$t \Rightarrow$ time of growth

$e \Rightarrow$ base of logarithm

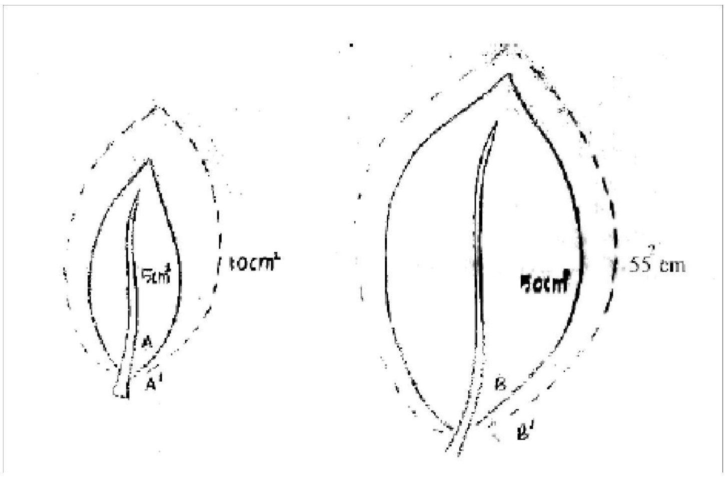
Quantitative comparisons between growth of living system

It can be made in 2 ways

They are absolute growth rate and relative growth rate

Absolute growth rate

Measurement and the comparison of total growth per unit time



In both the leaves, absolute growth rate is same $\rightarrow$ absolute growth per unit time

Relative growth rate

This is the growth of a given system per unit time expressed on a common basis

Eg. Per unit initiate parameter

The relative growth of leaf is more than that of 2nd leaf ie 1st leaf shows 100% of growth in a particular period and 2nd leaf shows only 10%

Conditions for growth

Several environmental factors are needed for normal growth of a plant they are water, O_2, nutrients, light, temperature etc. The plant cells grow in size by cell enlargement for this turgidity of cells helps in extension growth water also provides the medium for enzymatic activities needed for growth. O_2 helps in releasing metabolic energy essential for growth activities

Both macro and micro essential elements are required by plants for the synthesis of protoplasm and act as source of energy

Every plant has an optimum temperature range best suited for its growth

Environmental signals like and gravity also effect certain stages of growth

Eg. stem is positively phototropic and –ve geotropic and –ve hydrotropic

Roots are –ve phototropic, +ve geotropic, +ve hydrotropic

Differentiation

In this, the cells stop division and enlargement and become matured to perform specific functions

The cells undergo major structural changes both in their cell walls and protoplasm

- Simple & permanent complex tissues to form a tracheary element, the cells would loss their protoplasm. They develop a long elastic, lignocellulosic 2° cell walls to carry water to long distances

Dedifferentiation

In some cases the living differentiated cells regain the capacity of division under certain conditions

For eg formation of interfascicular cambium from the parenchyma cells of medullary rings cork cambium formed from outer cortical cells of stem and outer pericycle cells of root

Redifferentiation

There are the tissues which all getting differentiated from dedifferentiated tissues

Eg. 2° xylem, 2° phloem, phelloderm, phellem

Growth in plants is open, ie it can be indeterminate and determinate (leaves, flowers, fruits etc)

Plant growth is open due to the following reason also cells or tissues arising out of same meristem have different structures at maturity

It is also determined by the location of cell within. For example cells away from root apical meristem (to the tip differentiate as root cap cells while those pushed to the periphery mature and differentiation of apical meristem

Leaf primordia

Axillary Bud

Intercalary meristem etc

DEVELOPMENT

All changes that an organism goes through during its life cycle germination of the seed to senescence. (ageing)

A meristematic cell can enter into 2 pathways

1. After showing a certain plasmatic growth the meristematic cell once gain divide and this cell retains its meristematic activity, throughout its life span
2. A meristematic cell stops its division and show plasmatic growth and get expanded, differentiated and get matured to become a specific permanent cell
3. After doing specific functions the cell gets senescent and die

PLASTICITY

The ability of plants to follow different pathways in response to environment or different phases of life to form different kinds of structures is called plasticity

Heterophylly is a typical example for plasticity

It is the presence of different types of leaves on a single plant it is of 2 types

Habitual heterophylly and environmental heterophylly

Habitual Heterophylly

In this different types of leaves are seen in different phases of life

Eg. Cotton, Artocarpus, Larkspur Coriander

Environmental hydrophilly

In this case difference in shapes produced in air and those produced in water

eg: Buttercup *(Rannunculus)*

Limnophila heterophilla

PLANT GROWTH REGULATORS

There are small simple molecules of diverse chemical composition

They are variously described as plant growth substances plant hormones or phytohormones

The PGRS are broadly divided into 2 groups based on their functions in a living plant body

They are growth promoters and growth inhibitors growth promoters are involved in growth promoting activity such as cell division cell enlargement pattern formation tropic growth, flowering, fruiting and seed formation

GROWTH INHIBITORS

They involved in various growth inhibiting activities such as dormancy and abscission

Some of these PGRS play an important role in plant responses to wounds and stresses of biotic and abiotic orgin. The most important plant growth promoters are auxin, cytokinin gibberellins

The 2 growth inhibitors are ABA (Abscisic acid) and Ethylene. Ethylene could fit either of the growth promoters but it is largely and inhibitor of growth activity

AUXIN

- Discovery of Auxin had been accidental
- It was noticed by charles Darwin and his son Francis Darwin
- When they observed that coleoptile of canary grass responded to unilateral illumination by going towards the light source (phototropism)
- Auxin was Ist isolated from human urine
- The word Auxin was derived from a Greek word auxein (to group)
- After a series of experiments it was concluded that tip of coleoptile was the site of transmittable influence that caused the tending of entire coleoptile

F.W went performed the bioassay of auxin

It is the Avena curvature test

He isolated auxin from tips of oats seedlings

Bioassay $\rightarrow$ it is the measurement of the concentration or potentany of a substance by its effect on living cells or tissues

Auxins are basically indole compounds

They are of natural or synthetic

Natural auxins $\rightarrow$ I A A = Indole -3-acetic acid

I B A = Indole -3- butyric acid

Synthetic Auxin $\rightarrow$

$\rightarrow$ N.A.A - Naphthalene acetic acid

$\rightarrow$ 2,4,-D=2,4-Dichloro phenoxy acetic acid

$\rightarrow$ 2,4,5-T=2,4,5-Trichloro phenoxy acetic acid

All these auxins have been used externally in agricultural and horticultural practices

PRACTICAL APPLICATIONS OF AUXIN

1. Widely used for plant propagation as it helps to initiate rooting in stem cuttings
2. It is a rooting hormone
3. It helps to prevent fruit and leaf drop at early stage but promotes the abscission of older mature leaves and fruits. It moves away from mature regions to younger regions so that abscisic acid, accumulate in the older regions
4. Removal of shoot tip (decapitation) results in the growth of lateral bud

This is because the growing apical bud inhibits the growth of lateral buds are axillary buds. This phenomenon is called apical dominance

By removing the apex, we are removing the action of auxin and there cytokinin can activate the lateral buds

The decapitation of shoot tips is widely applied in tea plantations and hedge making

5. Auxins can induce parthenocarpy in plants like tomato, grapes, orange watermelon
6. They are widely used as herbicides (weedicides)

   2,4-D is a selective weedicides

   it is widely used to kill dicot weeds

   it doesn't affect mature monocot plants

   So it is used to prepare event free lawns by gardeners
7. It controls xylem differentiation and helps in cell division

GIBBERELLINS

- The presence of this was first reported by E. Kurosawa in 1926
- He noticed that the Bakanae (foolish seedling disease) of rice seedlings was caused by a fungus called *Gibberella fujikuroi*
- He reported the symptom's appearance of disease in dry seedlings when they where treated with sterile filtrates of the fungus
- The active substances where later identified as gibberellic acid
- Gibberellic acids are derivatives of terpenes (derived lipid)
- There are more than 100 gibberellins identified from fungi & higher plants they are denoted as GA, GA_2, GA_3 and soon
- GA_3 was one of the 1^{st} gibberellins to be discovered and most common type of gibberellins in plants

All gibberellins are acidic, they produce a wide range of physiological responses in plants

1. It has the ability to cause an increase in length of axis so it is used to increase length of grape stalks. It causes fruits like apple to elongate and improve its shape
2. It delays senescence this the fruits can be left on the so as to extend the market period
3. Gibberellin is used to speed up the malting process in training industry. Gibberellins break the seed dormancy by increasing the nutrient to mobilisation during seed germination. It enchances the production of amylases by embryonic cells. Thus malting of starch occurs so it is called antidormin.
4. Spraying sugarcane crop with gibberellins increases the length of the stem sugarcane stores carbohydrate as sucrose in their stem. Thus increasing the yield by as much as 20 tones per acre gibberellins causes internodal elongation by activity the intercalary meristems in monocot
5. Spraying juvenile conifers with gibberellins halling the maturity period thus leading to early seed

production

Gibberellins promotes bolting (internode elongation first prior to flowering) in beets, cabbage and many plants with rosette habits

So gibberellins can be used for elongating genetically dwarf wheat plant

Bioassay of gibberellins

It is called 'Barley endosperm bioassay

CYTOKININS

- The presence of cytokinins was 1st observed by F skoog and his co-workers
- They noticed that from the internal nodal segments of tobacco stems, callus proliferated only if, in addition to auxin the nutrient medium was supplemented with extracts of vascular tissues, yeast extract, coconut milk or DNA miller etal in 1955 later identified and crystallised the cytokinesis promoting active substances from these extracts
- First cytokinin isolated was kinetin
- It was isolated from autoclaved herring sperm DNA by Skoog and Miller

  But kinetin doesn't occur naturally in plants
- The first cytokinin isolated from plant zeatin from corn keranal, and coconut milk
- After that several naturally occurring cytokinins and some synthetic compounds with cell division promoting activity have been identified

Cytokinins are adenine derivatives

For eg: kinetin is chemically = N^6-furfuryl amino purine

Natural cytokinins are synthesised in regions where rapid cell division occurs

ie root and shoot apexes, buds, young fruits etc

- It is the true cell division factor
- It helps to produce new leaves, chloroplast in leaves, lateral shoot growth, and adventitious shoot formation from the callus

  Cytokinins help to overcome the apical dominance

  They promote nutrient mobilization which helps in the decay of leaf senescence and this property of cytokinins is called Richmond Lang effect

BIOASSAY OF CYTOKININS

The cucumber cotyledon greening bioassay tobacco stem culture

ETHYLENE

It is the only gaseous PGR

In 1910, H.H. cousins confirmed the release of volatile substance from ripened oranges that hastened the unripped bananas later it was identified as ethylene

Ethylene is synthesised in large amounts by tissues undergoing senescence and ripening fruits

Ethylene as a growth inhibition

Ethylene promotes senescence and abscissions of plant organs especially of leaves and flowers

Ethylene is highly effective in food ripening

It enhances the respiration rate during ripening of fruits

This rise in respiration is called respiratory climatic

Ethylene as a growth promoter

- It helps in the horizontal growth of seedlings, swelling of the axis and apical hook formation in dicot seedlings
- It breaks seed and bud dormancy, initiates germination in peanut seed, sprouting of potato tubers
- It promotes stapid internode or petiole elongation in deep water rice plants. Thus it helps leaves of upper part of the shoot to remain above water
- It promotes root growth and root hair formation, thus helping the plants to increase the absorption surface
- It can initiate flowering and synchronising fruit set in pineapple (same time)
- It induces flowering in mango
- The most widely used compound as source of ethylene is ethephon
- Ethephon is an aqueous solution and it is readily absorbed and transported within the plant and releases ethylene slowly

Uses of ethephon

It hastens fruit ripening in tomato and apple

It accelerates abscission in flowers and fruits, its thinning of cotton, cherry and walnut

In these plants a large number of flowers all produced, inorder to get

should tall off inorder to provide more nutrients to the remaining flowers and fruits

It promotes female flowers in cucumber thereby increasing the yield.

- Bioassay of Ethylene - Triple response test
- Horizontal growth of seedlings, swelling of axis and apical hook formation in dicot seedlings

ABSCISIC ACID

The presence of ABA was identified during mid 1960 by 3 independent researches

They reported the purification and chemical characterisation of 3 different kinds of inhibitors. They are

Inhibitor B [Van stevenink]

Abscession II [Addicott]

Dormin [warring]

Later all the 3 were proved to be chemically identical and was named as abscisic acid

ABA are derivatives of carotenoids

It major role in plants is regulating abscission and dormancy

It acts as a general plant growth inhibition and an inhibitor of plant metabolism

It inhibits seed germination: Hence the name dormin. Thus it plays an important role in seed development, maturation and dormancy

- By inducing dormancy it helps seeds to with stand derication and other factors unfavourable for growth
- It also has other wide ranging effects on plant growth and development

  It stimulates the closure of stomata and increases the tolerance of plants to various kinds of stresses so it also called as stress hormone

Conclusion for the action of various hormone in the plant body

In the differentiation and development of plants one or other PGR has some role to play

Such roles could be complimentary or antagonistic (ABA acts as antagonistic to GA)

There could be individualistic and synergetic

Along with intrinsic factors many extrinsic factors like temperature and light control plant group and development through PGRS

Some of them are as follows

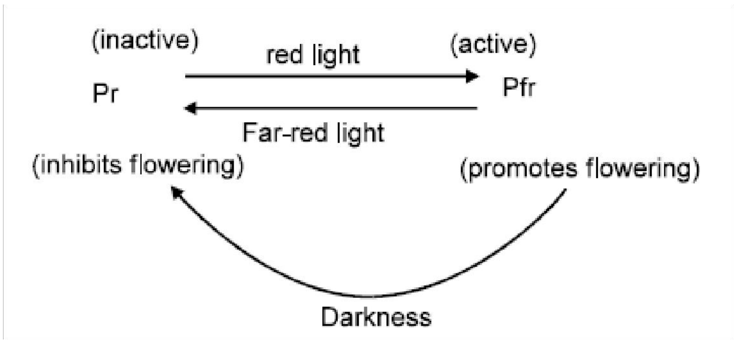
1. **Photoperiodism**

- It is a response of plants to periods of day or night
- The duration of day is called photoperiod
- There is a specific photoperiod described for a specific region. This photoperiod is called critical photoperiod Garner and Allad (1920) in Maryland Mammoth variety of Tobacco
- The duration of light and exposures are perceived by leaves
- There is a pigment protein called phytochrome seen in the leaves
- It is photosensitive and this pigment protein receives the photo period
- It has been hypothesized that there is a hormonal substance that is responsible for flowering and is called florigen
- It migrates from leaves to shoot apexes for inducing flowering only when the plants are exposed to necessary inductive photoperiod
- Along with the duration of light period, duration of dark period is also of equal importance
- It can be said that flowering in certain plants depends not only on a combination of light and dark exposures but also their relative directions

Phytochromes are of 2 types

They are type I - Pfr (P fr 725)

Type II Pr (P_{665})



- Pr and Pfr are interconvertible forms

  Pr takes red light and converts to Pfr

  Pfr takes far red light and converts to Pr

  Pft promotes flowering and Pr inhibits flowering

  In darkness Pfr converts to Pr

  Based on the flowering response to various photoperiods flowering plants can be classified into 3 types

- Long day plants
- Short day plants
- Day neutral plants

Long day plants or short night plants

- These are the plants which flower only they get photoperiod exceeding a critical photoperiod

  Eg: Spinach, Radish, Lettuce, wheat, oats, hentane

Short day plants

- These are the plants which flower when they get photoperiod less than the critical photoperiod

  Eg: Xanthium, Chrysanthimum, Cosmos, Aster, Rice, Strawberry, Potato, tobacco, soyabeans

Day neutral plants

In these plants there is no correlation between exposure to light and flowering

Vernalisation

Also called chilling treatment, yarovisation

It was first identified by klippart and term was coined by lysenko

It is the phenomenon in which certain plants need exposure to low temperature quantitatively or qualitatively

The seeds should be vernalised

When seeds are vernalised a hypothetical hormone called vernalin to produced.

In order to convert vernalin into florigen the seeds germinate and show enhanced vegetative growth and reach sexual maturity

There the response of vernalisation is flowering

Examples for plants in which vernalisation is seen are biennials plants which are monocarpic that they flower and dies in the 2nd season

Some common biennials are sugar beet, cabbages, carrot etc subjecting the seeds of a biennial plant to a cold treatment stimulates a subsequent photoperiodic flowering response

Another example is 2 types of varieties of wheat, barley and dye (winter and spring varieties)

The spring variety are normally planted in spring and it flowers and produce grains before the end of growing season

But seeds of the winter varieties as they need low temperature they are planted in late autumn

They germinate and produce seedlings in winter season and grow in the spring and are harvested usually around mid summer

Instead we can vernalise the seeds of winter variety and can sow in the starting of spring season

We can harvest them in the end of growing season

Seed Dormancy

It is an evolutionary adaptation that prevents seeds from germinating during unfavourable ecological conditions. That would typically lead to a low probability of seedling survival.

This is controlled by endogeneous or internal conditions within the seed itself conditions like impermeable and hard seed coat

Presence of chemical inhibitions such as abscisic acid, phenolic acids, parascorbic acid etc, and immature embryos are some of the reasons which causes seed dormancy

Methods for overcoming seed dormancy

There are natural means and man made methods

The man made measures are

1. Scarification

It means softening seed coats and other coverings

It is all of different types

Like mechanical sacrification in which knives, sand papers, hammers etc can be used or can be vigorously shaken

Hot water sacrification, acid sacrification etc are the other methods of sacrification

2. Stratification

It is a process of treating seeds to stimulate natural conditions that the seeds must experience before germination can occur.

For example: Effect of inhibitory substances can be removed by subjecting the seeds to chilling conditions on application of certain chemicals like gibberellic acids and nitrates changing the environmental conditions such as light and temperature