Plant Growth and Development

1 INTRODUCTION

- All cells of a plant are descendents of the zygote. Development of a mature plant from a zygote follows a precise and highly ordered succession of events.
- Development is the sum of two processes: GROWTH and DIFFERENTIATION.
- During this process a complex body organisation is formed that produce roots, leaves, branches, flowers, fruits, seeds and eventually they die.
- The first step in the process of plant growth is seed germination. The seed germinates when favourable conditions for growth exist in the environment, in absence of favourable conditions they go into a period of suspended growth or rest, and resume metabolic activities on return of favourable conditions and growth takes place.

2 GROWTH

- Growth is irreversible permanent increase in size of an organ or its parts or even an individual cell.
- It is one of the most fundamental and conspicuous characteristic of a living being.
- Growth is accompanied by metabolic processes and occur at the expense of energy.
- Plants retain the capacity of unlimited growth throughout their life due to presence of meristem at certain locations in their body.
- This form of growth wherein new cells are always being added to the plant body by the activity of meristem is called open form of growth. (INDETERMINATE)
- Root apical meristem and shoot apical meristem are responsible for primary growth, i.e., elongation along their axis.
- In dicotyledonous plants and gymnosperms, the lateral meristems like vascular cambium and cork-cambium, which appear later in life and cause increase in girth of the organs called secondary growth.
- **Growth is measurable:** At cellular level, it is principally a consequence of increase in amount of protoplasm. It is measured by a variety of parameters like-increase in fresh weight, dry weight, length, area, volume and cell number.

3 PHASES OF GROWTH

The period of growth is generally divided into three phases MERISTEMATIC, ELONGATION & MATURATION.

(i) The constantly dividing cells at root apex and shoot apex represent meristematic phase of growth.

(ii) Cells proximal to the tip, represent phase of elongation.

(iii) More proximal to the phase of elongation is phase of maturation.

4 GROWTH RATES

Increased growth per unit time is termed as growth rate. it can be arithmetic or geometrical.

(a) Arithmetic growth: Following mitotic cell division, only one daughter cell continues to divide while the other differentiates and matures. So, a linear curve is obtained

e.g., root elongating at a constant rate.

Mathematically, expressed as

$$L_t = L_0 + rt$$

L_t = length at time 't'

L_0 = length at time 'zero'

r = growth rate/elongation per unit time.

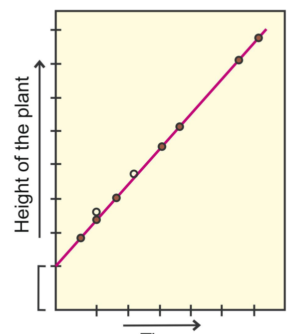

Fig. Linear growth

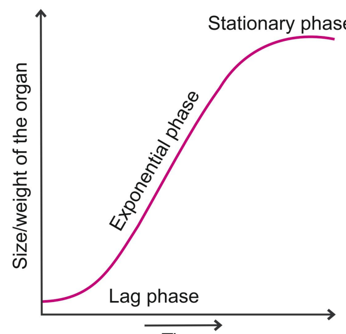

Fig. Sigmoid growth

(b) Geometrical growthŚ: In most systems, initial growth is slow (**lag phase**), it increases rapidly thereafter at an exponential rate (**lag or exponential phase**), as both progeny cells of mitotic cell division retain ability to divide and continue to do so. However with limited nutrient supply, growth slows down leading to **stationary phase**, giving a typical **sigmoid or S-curve**.

- A sigmoid curve is a characteristic of living organism growing in a natural environment. It is typical for all cells, tissues and organs of a plant.

The exponential growth can be expressed as:

$$W_1 = W_0e^{rt}$$

W_1 = final size (weight, height, number etc)

W_0 = initial size at the beginning of period.

r = growth rate; t = time of growth

e = base of natural logarithms.

Here, r = relative growth rate and measure of ability of plant to produce new material called **efficiency index**.

5 QUANTITATIVE COMPARISONS BETWEEN GROWTH OF LIVING SYSTEM CAN BE MADE BY

(i) Measurement and comparison of total growth per unit time called ABSOLUTE GROWTH RATE.

(ii) The growth of given system per unit time expressed on a common basis, e.g., per unit initial parameter is called RELATIVE GROWTH RATE.

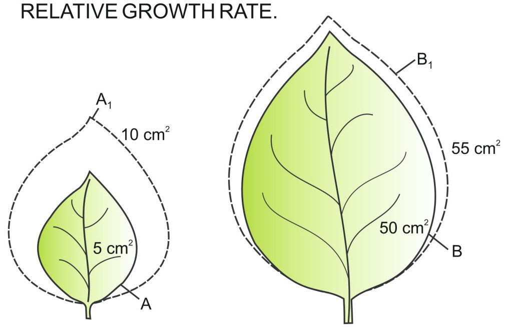

Fig. Absolute and relative growth rates

6 CONDITIONS FOR GROWTH

- **Water:** For cell enlargement, i.e., extension growth by turgidity. Water also provides medium for enzymatic activities.
- **Oxygen:** For aerobic respiration to get metabolic energy.
- **Macro and Micro nutrients:** for synthesis of protoplasm.
- **Temperature:** Optimum range for best growth.
- **Light and Gravity:** also affect certain phases/stages of growth.

9 PLASTICITY

- Plants follow different pathways in response to environment or phases of life to form different kinds of structures. This ability is called **Plasticity**.
- Heterophylly in cotton, coriander and larkspur-leaves of the juvenile plant are different in shape from those in mature plants.
- Environmental heterophylly in buttercup is also an example of plasticity, which shows difference in shape of leaves produced in air and water.

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DIFFERENTIATION

- The cells derived from root apical and shoot apical meristems and cambium differentiate and mature to perform specific functions, this act leading to maturation in termed differentiation.
  eg. tracheary element

DE-DIFFERENTIATION

- Living differentiated cells, that have lost the capacity to divide can regain capacity of division under certain conditions; this phenomenon is de-differentiation, e.g., formation of interfascicular and cork-cambium from parenchyma cells.

RE-DIFFERENTIATION

- De-differentiated meristems are able to divide and produce cells that once again lose capacity to divide but mature to perform specific functions, i.e., get redifferentiated.
  e.g., secondary xylem, secondary cortex, cork, etc.

8 DEVELOPMENT

- Development includes all changes that an organism goes through during its life cycle from germination of seed to senescence.

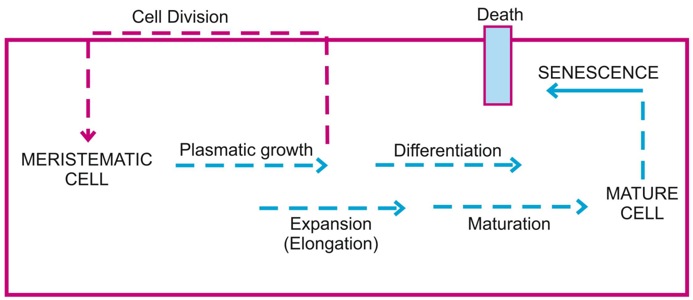

Fig. Sequence of developmental process in a plant cell

10 PLANT GROWTH REGULATORS

- Broadly divided into two groups based on their functions in a living plant body.

Involved in Growth promoting activities

(Like-cell division, cell enlargement, pattern formation, tropic growth, flowering, fruiting and seed formation)

1. Auxin (indole compounds) IAA.
2. Gibberellins (GA_3, terpenes)
3. Cytokinin (adenine derivatives) (N^6-furfurylamino purine, kinetin)

Involved in Growth inhibiting activities

(Like-Response to wounds and stresses of biotic and abiotic origin; dormancy and abscission)

E.g.: Abscisic acid (derivatives of carotenoids)

* The gaseous PGR, ETHYLENE, could fit either of the groups, but it is largely an inhibitor of growth activities.

11 PLANT GROWTH REGULATORS

1. AUXIN

- Charles Darwin and his son Francis Darwin studied phototropism in canary grass.
- F.W. Went isolated auxin from tips of coleoptiles of oat seedlings.
- First isolated from human urine.
- Produced by growing apices of stems and roots.
- IAA and IBA isolated from plants.
- NAA, 2,4-D are synthetic.

Physiological effects:

- Initiate rooting in stem cultings.
- Promote flowering in pineapples.
- Help prevent fruit and leaf drop at early stages but promote abscission of older mature leaves and fruits.
- Apical dominance
- Induce parthenocarpy in tomatoes.
- 2, 4-D kill dicot weeds. Used to prepare weed-free lawns.
- Auxin controls xylem differentiation and helps in cell-division.

2. GIBBERELLINS

- Bakanae (foolish seedling) disease in rice was caused by fungal pathogen *G. fujikuroi.* Kurosawa helped understand it. Later the chemical Giberellic acid was identified.
- GA_3 discovered first and remains intensively studied form.
- All GAs are acidic.
- Increase length of grapes stalk.
- Cause fruits like apples to elongate and improve shape.

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- They delay SENESCENCE.
- Used to speed up malting process in brewing industry.
- Increases length of stem and yield by 20 tonnes per hectare in sugarcane.
- Spraying juvenile conifers with GAs hastens maturity period.
- Promotes BOLTING in beet, cabbages and many plants with rosette habit.

3. CYTOKININ

- Skoog and Miller crystalised cytokinesis promoting active substance and termed it KINETIN a modified form of adenine from autoclaved herring sperm DNA. Kinetin does not occur naturally in plants.
- ZEATIN the naturally occurring cytokinin was isolated from corn-kernels and coconut milk.
- Synthesised in regions of rapid cell-division like root apices, developing shoot buds, young fruits etc.
- Helps produce new leaves, chloroplasts in leaves, lateral shoot growth and adventitious shoot formation. Overcomes apical dominance.
- Promote nutrient mobilisation.
- Helps delay LEAF SENESCENCE.

4. ETHYLENE

- COUSINS helped to identify Ethylene.
- Synthesised in large amounts by tissues undergoing sencescence and ripening fruits.
- Horizontal growth of seedlings, swelling of axis and apical hook formation in dicot seedlings is influenced by ethylene.
- Promotes SENESCENCE and ABSCISSION in leaves and flowers.
- Effective in fruit ripening, by increasing rate of respiration called CLIMACTIC.
- Breaks seed and bud dormancy.
- Initiates germination in peanut seeds, sprouting of potato tubers.
- Promotes rapid internode/petiole elongation in deep water rice plants
- Promotes root growth and root hair formation
- Initiates flowering and helps in synchronising fruit-set in pineapples.
- Induces flowering in MANGO.
- ETHEPHON is source of ethylene. It hastens fruit ripening in tomatoes and apples and accelerates abscission in flowers and fruits. (thinning of cotton, cherry, walnut)
- Promotes female flowers in cucumbers, increasing yield.

5. ABSCISIC ACID

- Regulates abscission and dormancy
- A general plant growth inhibitor and inhibitor of plant metabolism.
- Inhibits seed germination.
- Stimulates closure of stomata
- Plays important role in seed development, maturation and dormancy.
- By inducing dormancy, ABA helps seeds to withstand desiccation and other factors unfavourable for growth.
- In most situations, ABA acts as an antagonist to GAs.

14 SEED DORMANCY

- Controlled by ENDOGENOUS factors, i.e., conditions within the seed itself.
- Impermeable and hard seed coat; presence of chemical inhibitors-ABA, phenolic acids, para-ascorbic acid and immature embryos cause seed dormancy.
- Man made measures like mechanical abrasions, using knives, sand paper or vigorous shaking can break dormancy.
- In nature microbial action, passage through digestive tract of animals can break dormancy.
- Chilling condition, use of gibberellic acid and nitrates can remove effect of inhibitory substances.
- Light and temperature can also break dormancy.

- Development in plants can be under intrinsic and extrinsic control. Intrinsic can be intra cellular (GENETIC) or inter cellular (PGR).
- In plants growth and even differentiation is also open, as cells and tissues of same meristem have different structure at maturity
- PGRs can be having complimentary or antagonistic role, which can be individualistic or synergistic.

13 PHOTOPERIODISM

Some plants require a periodic exposure to light to induce flowering.

Such plants are able to measure duration of exposure to light.

(a) Long-day plants: require light period exceeding well-defined critical period.

(b) Short-day plants: require light less than critical period

(c) Day-neutral plants: No such co-relation between exposure to light duration and induction of flowering response.

- Flowering in certain plants depends on combination of light and dark exposures and also their relative durations.
- This response of plants to periods of day/night is termed PHOTOPERIODISM.
- The site of perception of light/dark duration are the leaves. A hypothesised hormonal substance is responsible for flowering.

15 VERNALISATION

- Vernalisation is either QUALITATIVE or QUANTITATIVE exposure to low temperature for flowering in some plants.
- It prevents PRECOCIOUS reproductive development late in the growing season, and enables the plant to have sufficient time to reach maturity.
- Wheat, barley, rye have winter and spring varieties.
- Subjecting biennials like sugarbeet, cabbages, carrots to cold treatment stimulates a subsequent photoperiodic flowering response.