PLANT GROWTH REGULATORS

- Growth is **complex** and **coordinated** process.
- External factors such as **light, temperature, water, oxygen** and **carbon dioxide** and internal factors such as **nutrients** and **photosynthates** show their influence indirectly on growth.
- Some chemicals show their direct influence on various stages of growth in relatively less concentration at a place away from the place of their synthesis.
- **Julius Von Sachs** first suggested the existence of chemical messengers in plants.
- **Startling** coined the term hormones.
- A phytohormone is defined as any organic substance in less concentration shows its physiological response at place in the plant other than its place of synthesis.
- It is also known as **Plant Growth Regulator.**
- **Auxins, Gibberellins** and **Cytokinins** promote growth and they are known as Growth promoters.
- **Abscissic** acid inhibits growth and it is known as Growth inhibitor.
- **Ethylene** is fruit ripening hormone.

Auxins

- These are first discovered phytohormones.
- The term auxin is derived from a greek word that means to grow
- **Julius von Sachs** showed that some organ forming substances are synthesised in the leaves and translocated downwards.
- **Charles Darwin** and his son **Francis Darwin** in their phototropic experiments on Canary grass confirmed Sachs findings. They wrote their observations in the book entitled '**The Power of Movements in Plants**'. They observed the bending of unilaterally illuminated coleoptiles towards the source of light. Cap covered coleoptiles failed to bend towards the source of light.
- **Boysen Jensen** confirmed the findings of Darwin by keeping gelatin block between the tip and stump of coleoptile.
- Paal observed the curvature of the coleoptile when he asymmetrically placed the cut tip of coleoptile on the stump.
- **F.W.Went** successfully isolated auxin into agar blocks. He observed straight growth of the coleoptile when he placed the treated agar blocks symmetrically over the coleoptile stump. He also observed the curvature of coleoptile when he placed the agar block asymmetrically on the coleoptile stumps. This test for the presence of biologically active substance was called as **Avena Curvature Test**.
- Using biological material to test the activity of a substance is called as **bioassay**.
- Auxins are present in very minute concentrations (**1μg per 10,000** coleoptile tips).
- The most common and abundantly occurring auxin in plants is **Indole-3-Acetic Acid**.
- **4-chloro indole acetic** acid and **phenyl acetic acid** are the other natural auxins.
- Indole butyric acid (**IBA)**, Naphthalene Acetic Acid (**NAA**), 2, 4-dichloro phenoxy acetic acid (**2,4-D**) and 2, 4, 5 – trichloro phenoxy acetic acid (**2, 4, 5 – T**) are some of the synthetic auxins.
- Auxin is mainly synthesised at the apex of stem and its branches and to some extent in root apex.
- Auxins predominantly move in basipetalous manner and some move in acropetalous manner. This movement is in 3:1 ratio.
- Auxin translocation is 10 mm/ hour.
- IAA is synthesised from the aromatic amino acid **Tryptophan**. Zn is essential for auxin synthesis. It has an indole ring with nitrogen and a side chain having carboxylic group.

Physiological effects

1. **Cell elongation**

- Auxins cause growth by promoting cell elongation. They promote cell enlargement in tissue culture. They cause **xylem** differentiation.

2. **Root initiation**

- IAA induces root formation in stem cuttings when applied in low concentrations.
- Synthetic auxins such as **IBA** and **NAA** are effective in inducing root formation in stem cuttings and play a role in vegetative propagation of economically useful plants.

3. **Tropic movements**

- Growth movement of plant or its organ in response to external stimulus is called as **tropic** movement.
- Auxins cause **positive** phototropism in stem and positive geotropism in root. This influence is explained by **Cholodny-went** theory.
- Auxin concentration that promotes growth in the stem inhibits growth in the root. Auxin concentration that promotes growth in the root does not cause growth in the stem.

- When the coleoptiles are illuminated on only one side the coleoptiles bend towards the source of light. This is due to **photo-oxidation** of auxins in the illuminated side or migration of auxins towards the shaded side. There is less cell elongation in the illuminated side than the shaded side and the coleoptile bending is towards the illuminated side.
- Similarly when the seedling is kept horizontally, more auxin is accumulated on the lower side of root and stem. In the stem part there is more cell elongation on the lower side than the upper side hence the stem shows upward bending (negative geotropism). The auxin accumulated on the lower side of root inhibits growth or decreases growth. More growth takes place on the upper side of the root region. Hence the root shows downward bending or positive geotropic growth.

4. Apical dominance

- Dominance of apical bud over axillary or lateral bud in terms of growth due to high amount of auxin in the axillary buds is called as **apical dominance.** High auxin concentration that promotes growth in the terminal bud inhibits growth in the axillary buds. It is evident in plants like *Casuarina, Polyalthia* and *Eucalyptus.*
- When apical bud is removed, lateral growth is acitivated.
- *Thimann* and *Skoog* experimentally proved the movement and accumulation of auxin from the apical bud towards axillary buds.
- Decapitation of apical buds prevents the supply of auxins to the axillary buds and results in the elimination of apical dominance.

5. Parthenocarpy

- Formation of fruits with out the act of fertilisation is called as Parthenocarpy. Such fruits are seedless.
- Auxin induced parthenocarpic fruit development was first noticed in **orchids**.

6. Sex determination

- In high concentrations, auxins promote the formation of female flowers in plants like **Cucumber**.

Gibberellins

- These are discovered in Japan in connection with *bakanae disease of rice* caused by *Gibberella fujikuroi*. The asexual stage of the fungus is *Fusarium moniliformae.*
- The symptoms of bakanae disease or foolish seedling disease are
  1. excessive tallness, 2. thin and pale stem,
  3. less tillering, and 4. little grain production.
- **Sawada** discovered that some substance secreted by the fungus is responsible for the disease.
- **Kurasawa** induced bakanae symptoms in healthy rice seedlings by applying the extracts of the fungus.
- **Yabuta** and **Sumuki** isolated and crystallised the substance and gave the name Gibberellic acid.
- Gibberellins are large group of Phytohormones. So far about **110** different types of gibberellins have been discovered from different plant groups. They are named in abbreviated form as **GA_1, GA_2, GA_3** ….. etc.
- GA_3 ($C_{19}H_{22}O_5$) is also known as **Gibberellic acid**. It is the most commonly present **gibberellin** in plants.
- These are **diterpenoid** compounds and usually consist of **20** carbon atoms. e.g. GA_{20}. A few of them have **19** carbon atoms. e.g. GA_1,GA_3, GA_4 and GA_7, .
- These are synthesised from **acetyl coenzyme A molecules**.
- These mainly promote **cell elongation** like auxins.

Physiological effects

1. Removable of Genetical dwarfism

- In genetically dwarf plants the gene for gibberellin synthesis is blocked due to gene mutation. Due to this cell elongation in the internodes is blocked resulting in **shorter internodes** and dwarfness in plant.
- When gibberellins are applied in dwarf plants like **pea, maize etc**. cell elongation is promoted in the cells of internodes and internodal length is increased.

2. Seed germination

- **Paleg** demonstrates the role of gibberellins in inducing seed germination.
- In cereal grains like barley, during germination, the embryo synthesises gibberellins and these are transported to the aleuron layer of endosperm.
- In the aleurone layer, gibberellins promote the synthesis **of α - amylase**, which hydrolyses the starch of endosperm into sugars.
- The energy liberated during the oxidation of sugars in respiration is utilised for seed germination.

3. Bolting and Flowering

- During the vegetative growth of plants like Cabbage and Cauliflower, the plants show bush like growth (Rosette formation) due to less elongation of internodes, which in return is due to less concentration of Gibberellins.
- Sudden elongation of the stem just before flowering due to excessive synthesis of Gibberellins in such plants is called as **Bolting.**
- **Flowering** follows bolting.

- In several plants Gibberellins promote flowering.

4. Formation of Parthenocarpic fruits

- When gibberellins are applied on flowers prior to their opening, they promote the formation of seedless fruits in plants like grapes and tomato.

5. Sex determination

- Gibberellins promote the formation of more male flowers in plants like **Cucurbita** and **Cannabis.**

Cytokinins

- **Haberlandt** induced cell divisions in cut potato tubers by using substance obtained from vascular tissues of different plants.
- **Overbeek** used liquid endosperm of coconut known as Coconut milk to induce cell division in tissue culture studies.
- **Skoog** and **Miller** isolated a cell division inducing substance from yeast DNA that stimulated cell divisions in tobacco pith cultures.
- They also isolated and characterised a cell division inducing substance from partially degraded DNA of herring sperm. They named the substance as **Kinetin** because it induced cytokinesis of cell division.
- Kinetin is chemically **6 – furfuryl amino purine.** Since it is degraded product of DNA, it cannot be considered as natural cytokinin.
- Independently, **Letham** of Australia and **Miller** of USA isolated a cell division inducing substance from the milky stage grains of Maize and named it as **Zeatin**.
- **Benzyl adenine** (BA) and Benzyl **amino purine** (BAP) are synthetic cytokinins.
- **Young embryos** are rich in cytokinins.
- These are mostly synthesised in the root and later transported to shoot system.

Physiological effects

1. Cell Division

- Inducing cell division is the main influence of cytokinins.

2. Cell expansion

- Cytokinin treated soybean leaf discs and Radish cotyledons showed phenomenol increase in size due to more cell elongation.

3. Morphogenesis (Organ formation)

- Cytokinins promote **organogenesis** when used along with auxins.
- **Skoog** and his associates showed the formation of roots in callus in **high auxin to low cytokinin** concentrations. They also demonstrated the formation of stem, leaves and buds in **high cytokinin to low auxin** concentration.

4. Delay in Senescence

- Aging or yellowing of leaves is called as **Senescence**. It is due to break down or poor synthesis of chlorophyll, RNA and proteins. Senescence is followed by death of organ or plant.
- Delay in senescence by cytokinins is called as **Richmond – Lang effect**.
- Leaves with proper concentrations of cytokinins remain green and healthy.

5. Stomatal Opening

- Cytokinins promote stomatal opening and there by transpiration by inducing the **accumulation of more K^+** concentration in the guard cells.

Abscissic acid

- It is growth-inhibiting substance that promotes the senescence of leaves and induction of dormancy in buds and seeds.
- **Addicott** isolated abscission-inducing substances from the immature cotton fruits and named them as **Abscissin I** and **Abscissin II**. Abscissin II is biologically more active.
- **Wareing** isolated dormancy inducing substance from the senescent leaves of Acer and named the substance as Dormin.
- Abscissin II and Dormin are structurally similar and these are named together as Abscissic acid.
- ABA is a terpenoid compound (Sesquiterpene) with **15** carbon atoms synthesised catabolically from carotenoids or anabolically from **Acetyl Co**. A.
- It is synthesised in stress conditions to protect the plant from water stress. Hence it is called as **Stress hormone**.
- In is abundantly present in dormant **buds, seeds** and **senescent leaves.**
- It is not yet reported from roots.
- It is reported in all tracheophytes, several mosses, green algae and some fungi.
- It is not reported from bacteria.
- Earlier it was thought to induce abscission. Hence the name abscissic acid was given. Now it is disproved. Ethylene is considered as a hormone with regulatory role on senescence.

Physiological effects

1. Dormancy

- It is inactive state of bud or embryo of seed in which the growth is suspended for specific length of time due even in favourable conditions.
- **ABA** induces seed and bud dormancy.

2. Stomatal closure

- In water stress conditions, more abscissic acid is synthesised in the plant. This abscissic acid promotes the closing of stomata and thereby decreases transpiration.

3. Formation of Perennating buds

- When the water level decreases in the ponds, ABA promotes the formation of these buds in plants like **Lemna**. These buds survive in unfavourable conditions at the bottom of the pond. With the monsoon showers, they become active and develop into plants.

4. Senescence of Leaves

- It promotes senescence or yellowing of leaves prior to leaf fall.

Ethylene

- **Gane** suggested to consider ethylene as phytohormone.
- **Ethylene** was considered as Phytohormone mainly due to the extensive works of **Burg** and **Thimann.**
- It has simple structure and is gaseous hormone.
- It is produced in all parts of the plant.
- It is synthesised from the amino acid **Methionine.**

Physiological effects :

1. Fruit ripening

- Ethylene enhances fruit ripening in plants like Apple, Banana, Tomato etc. Hence it is referred has Fruit ripening hormone.
- Unripe fruits can be made ripened by exogenous application of ethylene.

2. Triple Response Growth

- Inhibition of **Stem elongation**, Inducing **stem thickening** and causing **transverse geotropism** in stem together known as Triple response growth. It is induced by Ethylene.

3. Flowering

- It delays or inhibits flowering in many plants.
- It promotes flowering in Pineapple. Hence it is used in Pineapple plantations for uniform flowering.

4. Other effects

- It promotes leaf abscission.
- It induces flower senescence.
- It promotes female flower formation in cucurbits.
- It removes or inhibits apical dominance.
- It promotes growth or divisions at wounded regions and plays a role in **wound healing.**

Role of Phytohormones in Agriculture and Horticulture

I. Auxins

- Several developmental responses of plants are under the control of auxins.
- Synthetic auxins are more effective than natural auxins because are not destroyed by enzymes and can persist in the plant body for several days after application.

1. Root formation in stem cuttings

- Synthetic auxins such as **NAA, IBA** and natural auxin **IAA** when applied at low concentrations promote the induction of roots in stem cuttings.
- Due to this property, auxins are used for rapid multiplication of useful plants in horticulture.
- **IBA** is the most effective auxin to induce root formation in stem cuttings.

2. Fruit fall

Auxins like **IBA** and **NAA** when used as foliar spray prevent premature falling of fruits. Hence increase the yield.

Herbicidal activity

- Synthetic auxins such as **2,4 - D** and **2,4,5 – T** are used as weed killers to eradicate dicot weeds in monocot crops, pastures and lawns.

4. Female flower formation

- Auxins increase the yield in cucurbits by increasing the formation of female flowers.

II. Gibberellins

1. Grape gardens

- Gibberellins are extensively used in grape gardens to increase grape production.

- They induce the formation of seedless fruits.
- They increase the size of fruits; fruits per bunch and number of bunches in each plant.
- It increases the sugar content of grapes.
- They promote more elongation of peduncle. Hence proper distance is maintained between the fruits of a bunch. Such fruits are not susceptible to fungal and insect attack. Less tight packing increases fruit size.

2. Orange orchards

- Preharvest foliar spray of gibberellins on citrus plants delays fruit ripening. It delays pigment formation in rind, softening of flesh. Such fruits are not damaged during storage and transportation.

3. Flowering

- It increases the production of flowers in **Roses, Rhododendrons** and **Poinsettias.**

4. Sugarcane

- Gibberellin application on sugarcane crop increases size and sugar content in the canes.

5. Seed production

- A mixture of $\mathbf{GA_4}$ and $\mathbf{GA_7}$ application increases seed production in conifers.

6. Malt production

- High and superior quality malt is obtained from gibberellin treated germinating seeds. It is used in making beverages.

III. Cytokinins

- These have little application in agriculture and horticulture when compared with auxins and gibberellins.

1. Shelf life (Freshness period of fruits or leaves)

- Preharvest spray of cytokinins on leafy vegetables such as Asparagus, Spinach and Lettuce make them remain fresh for several days after harvest.

2. Vase life (Freshness period of cut flowers in vases)

- Flowers like Dianthus and Poinsettia having their cut ends dipped in **BAP** solution remain fresh in flower vases for several days.

4. Abscissic acid

- Pre – harvest spray of **ABA** on **potato crop** prevents the sprouting in potatoes during storage.
- It also helps in crop survival during dry spell by acting as antitranspirant.

5. Ethylene

- Since there are practical difficulties in the application of ethylene in field conditions, it is used in the form of **Ethephon** (2 – chloroethyl phosphonic acid). Ethephon is ethylene releasing substance.

1. Fruit Ripening

- It accelerates fruit ripening in apple, banana, water-melon etc.

2. Flowering

- It promotes synchronous flowering and fruit ripening in Pineapple. So the cost of harvest can be minimised.

3. Rubber plantations

- It enhances the exudation of latex from cut regions of rubber plants.

4. Coffee plantations

- It improves the colour and quality of coffee berries.

5. Tobacco crop

- It promotes uniform senescence of leaves. So the number of picking of tobacco leaves can be minimised.
- It decreases nicotine content.