Chapter 48

Phytohormones

- A **plant hormone** or **phytohormone** is a chemical substance produced naturally in plants which is translocated to another region for regulating one or more physiological reactions when present in low concentration.
- **All phytohormones are growth regulators** but **all growth regulators are not phytohormones**.
- The **same hormone may produce a different response in different organ** as auxin concentration promotes shoot growth but inhibit root growth.
- A similar response may be produced by different plant growth hormones, eg., both auxins and gibberellins promote cell enlargement.
- Phytohormones can be **broadly divided into two groups based on their functions in a living plant body – growth promoters** and **growth inhibitors**.
- **Auxin**, **gibberellins** and **cytokinin** are **growth promoters** and **ethylene** and **abscisic acid** (**ABA**) are **growth inhibitors**.
- Growth promoters are **involved in growth promoting activities**, **such as cell division**, **cell enlargement**, **pattern formation**; **tropic growth**, **flowering**, **fruiting** and **seed formation**.
- Growth inhibitors are **involved in various growth inhibiting activities such as dormancy and abscission** and also play an important role in plant responses to wounds and stresses of biotic and abiotic origin.
- The **gaseous plant hormone ethylene** could fit either of the groups, but is **largely an inhibitor of growth activities**.

AUXIN

- **F.W. Went** first named the chemical substance 'auxin' (means to grow) **derived from Greek word auxein**.
- Auxin is **weakly acidic growth hormone** having an unsaturated ring structure and **promotes cell elongation especially in shoots**.
- **Auxins obtained from plant** are called **natural auxin**.
- **IAA** (Indole acetic acid) is a **natural auxin** obtained from *Rhizopus scinus* and *Avena* coleoptile.
- **Tryptophan** is the **precursor of IAA** and **zinc is required for its synthesis**.
- Many auxins have been synthesized and some examples of **synthetic auxins** are **indole-3-butyric acid (IBA), naphthalene acetic acid (NAA), 2,4-dichlorophenoxy acetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2, 4, 5 -T)**.

Agent Orange

Mixture of two phenoxy herbicides in ester form, 2, 4-D and 2, 4, 5–T (dioxin) is given the name agent orange which was used by USA in Vietnam war for defoliation of forests (*i.e.* in chemical warfare). Phenoxy agents work by mimicking a plant growth hormone, 1AA. When sprayed on broad leaf plants they induce rapid uncontrolled growth eventually killing them.

- **Free auxins** are those which **are easily diffusible** *i.e.*, they move out of tissues easily, e.g., IAA, indole-3 ethanol etc.
- **Bound auxins** are those which **are not diffusible** and **they can be removed from the plant tissues by the application of some special techniques like enzymolysis** etc., e.g. auxin glycosyl esters.
- **Active sites of auxin synthesis** are shoot tip region and **its synthesis occurs rapidly in green leaves in the presence of light than in dark**.
- Indole acetic acid is **destroyed by enzymatic oxidation** and **photo-oxidation**.
- **IAA oxidase**, an enzyme, which oxidises IAA was isolated in 1947 by **Yang and Bonner**.
- **F. Skoog** had reported that auxin is inactivated under

the influence of X-rays and gamma radiations and ultraviolet light brings about inactivation of IAA.
- Translocation of auxins is **polar.**
- **Auxin transport** is **basipetal in stem** and **acropetal in roots**.
- Transport of auxin is **energy consuming** and is **drastically reduced in the absence of oxygen**.
- Compounds that inhibit the polar auxin transport are called **antiauxins**. Eg. 2,3,5-triiodobenzoic acid (TIBA), α-naphthylphthalamic acid (NPA).
- **Ethylene** (a gaseous hormone) **also inhibits auxin polar transport**.
- The use of living material for testing the effect of biologically active substances is called **bioassays**.
- **Avena curvature test** (given by F. W. Went) and **split pea stem curvature test** are the bioassays that are generally used for auxins.

Physiological effects of auxin

- The cell enlargement is induced by auxin by
  - increase in **osmotic content** of the cell.
  - increase in **cell membrane permeability** to water.
  - reduction in wall pressure.
  - synthesis of wall material.
  - increase in respiration.
  - synthesis of specific RNA and proteins which result in increase in cell wall plasticity.
- Auxin **initiates** and **enhances cell division** by inducing **meristematic activity** and **cambial cells activity**.
- Auxin **induce early differentiation of xylem and phloem in tissue culture experiments**.
  Auxin + 2% sucrose – **Xylem–differentiation**
  Auxin + 3% sucrose – **Xylem and phloem differentiation**
  Auxin + 4% sucrose – **Phloem differentiation**
- In tissue culture growth of callus requires the presence of auxin, e.g., 2, 4-D.
- It has been suggested that **traumatic acid** (wound hormone) is produced which **increases cell division resulting in callus formation**.
- Auxin **causes root initiation but high concentration of auxin inhibits the root growth and the number of branches of roots are also decreased**.
- **IBA**, a synthetic auxin is a **potent root initiator**. Other auxins used as rooting agent are NAA, IAA etc.
- **Apical dominance or bud inhibition** is the phenomenon of suppression of growth of lateral buds by apical buds. When apical buds are removed, lateral buds develop into branches.
- Apical dominance is **due to the presence of high concentration of auxins in apical buds**.
- Auxin **enhances the size of carpel** and **hence earlier fruit formation**.
- **Hitchock and Zimmerman** for the first time showed that flowering in *Nicotiana* can be stimulated by auxin.
- Auxin **increases the number of spikelets in wheat and flowering in pineapple**.
- **NAA** induces the formation of more fertile branches in cotton plants.
- IAA promotes **formation of female flowers** (feminization).
- Flowers are borne only on dwarf shoot in apple tree but NAA increases the number of dwarf shoot and therefore more flower and fruits are borne.
- The development of fruit without pollination and fertilization is called **parthenocarpy**, and such fruits are obtained by spraying with dilute solution of IAA & IBA.
- Auxins like **IAA**, **IPA**, **NAA** and **IBA** are commerically **used to induce parthenocarpy in banana, orange, citrus, grapes, guava etc**.
- Auxin **delays abscission of leaves and fruits**.
- 2,4-D, NAA, 2,4,5-T (2,4,5 trichlorophenoxy acetic acid), MCPA (2, methyl-4 chlorophenoxy acetic acid) are **used as effective weedicides or herbicides**.
- **2,4-D** is a **selective weed killer** as it is **toxic to broad leaved plants** and in low concentration it is useful in preventing preharvest fruit drop of orange and apple.
- According to **Cholodny-Went theory auxins are responsible for phototropism and geotropism**.
- IAA is known to **stimulate nodule formation**.
- Few auxins are used to **prolonging the life of storage products** like corm, tuber, rhizomes etc., e.g. NAAM (**Naphthalene acetamide**).

GIBBERELLINS

- Gibberellins are **weakly acidic plant growth hormone** that **possess a gibbane ring structure** and are **able to promote cell elongation** of the stem, leaves and also internodal length of genetically dwarf plant.

- They are named after fungus *Gibberella fujikuroi* which produces **foolish seedling disease of rice** or **bakanae disease**.
- **Yabuta**, **Hayashi** and **Kahnbe** first isolated the active principle toxin secreted by the fungus which was called **gibberellin** by them.
- Chemical nature of Gibberellins was established in 1954 and till now more than 100 different types of gibberellins have been isolated.
- Chemical gibberellins are related to **terpenoids** and its precursor is **kaurene.**
- Gibberellins are found in **angiosperms, gymnosperms, ferns, algae** but **rarely in fungi** and **bacteria.**
- **Sites of gibberellin synthesis** are young leaves (**major site**), root tips and immature seeds.
- Gibberellins **move readily in all directions and in all tissues including phloem and xylem**.
- **Translocation of gibberellins** is **passive**, **non polar** and **diffuse type**.
- Techniques used for the **bioassay of gibberellins** are – **dwarf pea elongation technique**, **barley endosperm digestion technique**.
- Compounds that inhibit the action of gibberellins are **antigibberellins or gibberellins retardants**. Examples are phosphon D, Amo 1618, paclobutrazol, cycocel (CCC), maleic hydrazide etc.

Physiological effects of gibberellins

- Gibberellins **enhances seed germination** by enhancing amylase synthesis and thus overcomes dormancy.
- **In the aleurone layer of barley** the gibberellins **increase the transcription of genes that code for protease and amylase enzyme**.
- Gibberellins **stimulate conversion of storage polymers into sucrose or mobile amino acids** during germination to facilitate their translocation *via* phloem into and through out the young root and shoots.
- The **cold treatment** which breaks the natural bud dormancy **increases the endogenous level of gibberellins**.
- Gibberellins **play important role in elongation of internodes in rosette plants** (e.g. Henbane, cabbage) which is called **bolting**. Flowering takes place after bolting.
- Gibberellins **causes etiolation** (elongation) **in plants when kept in dark**, as flavonoids which are inhibitors of GA are not formed in dark.
- Gibberellins **induces cell division and cell elongation** when bolting take place.
- Genetic dwarfism is caused by mutation of a single gene. If gibberellins is sprayed on these single gene dwarf plants, **genetic dwarfism is overcome** and plants become long, eg. in maize, pea etc.
- Gibberellins play an important role in the **initiation of flowering in vernalised and long day plants during short day condition**, eg. cabbage.
- **Synthesis of florigen** which is a flowering hormone is mediated through gibberellins.
- Gibberellins promotes **male flowers production** *i.e.*, on female plant, male flowers are produced by application of gibberellins, e.g., *Cannabis.*
- Exogenous application of gibberellins also **induces the production of parthenocarpic fruits**. Examples are plants belonging to family rosaceae, as stone fruits and pome.
- When gibberellins are sprayed on the plants their leaves become expanded. It **results in an increase in the total photosynthetic area and biomass**.
- Commercially gibberellins are employed to
  - **increase the size of seedless grape fruits**,
  - **increase the height of sugar cane plant** and **thus enhances the yield of sugar**.
  - **used in storage of orange as it prevents rind disorder by delaying senescence**.

CYTOKININS

- Cytokinins are **mildly basic growth hormones** which are usually **amino purine derivatives** and **promote cell division in plants**.
- **Miller** in 1955 isolated an active substance from autoclaved DNA from Herring sperms which stimulated cell division. He named this substance as **kinetin**.
- Chemically kinetin was identified as **6-furfurylamino purine.**
- **Zeatin** is a **naturally occurring cytokinin**. **Letham obtained zeatin** in pure crystalline form in unripe maize grains.
- Zeatin **occurs in the roots, stem and leaves** but it is **present in abundance in its milk kernels**.
- **Synthetic cytokinins** are substances that show cytokinins like activities. The examples are **6 aminopurine** (adenine), **benzimadazole**,

6-benzyladenine, 2 ip (isopentanyl adenine).

- **Beauchene** and **Bontarel** in 1963 prepared a compound **N^6-isopentanyl adenine** which **is ten times more active than cytokinins**.
- Precursors of cytokinin is either **adenine** or **adenosine**.
- Cytokinins are **found in abundance in young roots, leaves** and **young fruits** and are **synthesised in the meristematic regions of the plants**.
- **Translocation of cytokinin takes place through xylem**. Mobility is **polar** and **basipetal**.
- **Zeatin**, **dihydrozeatin** and **isopentanyl adenine** are **physiologically active cytokinin**.
- Some of the **bioassays for cytokinins** are
  - **excised radish cotyledon enlargement test**
  - **chlorophyll preservation test** or **delay in senescence test**
  - **tobacco pith culture**.

Physiological effects of cytokinin

- **Cell division activity** and **cell enlargement** is enhanced by cytokinins.
- Cytokinins are **essential for cytokinesis** though chromosome doubling can occur in their absence.
- **In the presence of auxin**, cytokinins **bring about division even in permanent cells**.
- Cytokinins control morphogenesis *i.e.*, **control initiation of plant organs**.
  - **High cytokinins to auxin ratio** causes differentiation of shoot.
  - **Low cytokinins to auxin ratio** causes differentiation of root.
  - **Intermediate cytokinins to auxin ratio** causes differentiation of both root and shoot.
  - **Intermediate cytokinins to low auxin ratio** leads to callus formation.
- Cytokinins are quite effective in **breaking the dormancy of seeds and some other plant organs**. For e.g., seeds of *Lectuca sativa.*
- Cytokinins **counteract the phenomenon of apical domimance** and it **induces lateral bud formation even in presence of apex**.
- Cytokinins **induces plastid differentiation, lignification of tracheary elements** and **differentiation of interfasicular cambium**.
- Cytokinins **delay the senescence of leaves and other organs**. It is called **Richmond Lang effect** after its discover who worked with detached leaves of *Xanthium.*
- Cytokinins, like auxins, **promote femaleness in male flowers**.
- Cytokinins **enhance chloroplast development** and **chlorophyll synthesis**. There is **increase in rate of protein synthesis** on kinetin treatment.
- When detached leaves are treated with cytokinins it leads to **delay of degradation of proteins and chlorophyll**.
- Cytokinins **induce flowering in short day plants** like *Lemna, Wolffia.*
- Cytokinins **influence the physiological properties** of **RNA** and **DNA**.
- Cytokinins **help in phloem transport**.
- Cytokinins **mobilise solutes and other nutrients**.
- **Commericial use of cytokinins** (CK) are–
  - CK **increases shelf life of vegetables and cut flowers**.
  - CK **improves yield and quality of fruits**.
  - A combination of cytokinin (6-benzyl-adenine) and gibberellins (GA_4GA_7) called **pomalin** is particularly effective in **increasing apple size**.

ETHYLENE

- Ethylene is a **naturally occurring volatile hormone.**
- **Crocker** (1930) **reported presence of ethylene from plant organs** and named it as **gaseous hormone**.
- **Burg** (1962) established that **ethylene** is the **only gaseous growth regulator.**
- **Production of ethylene** by various organisms can be detected by **gas chromatography.**
- **Algae do not** produce ethylene.
- **A small number of bacteria** and a large number of **fungi** produce ethylene.
- **All parts of seed plants produce ethylene**. The **shoot apex** produces **maximum amount of ethylene**.
- Flowers and leaves **before withering produce considerable amount of ethylene**.
- **Maximum ethylene is formed** in ripening fruits and senescing tissues.
- Molecular weight of ethylene is **28.06** and freezing point is **–186°C**.
- **Biosynthesis of ethylene** occurs from **methionine** which is a sulphur containing amino acid.
- **Inhibitors of ethylene synthesis** are – **amino-ethoxyvinylglycine** and **amino-oxyacetic acid.**

- An increased concentration of CO_2 inhibits many effects of ethylene. Besides CO_2, a more effective **inhibitor** of **ethylene action** is **silver ion (Ag^+)**.
- **Bioassays** for ethylene are **triple pea test** and pea **stem swelling test**.

Physiological effects of ethylene

- Ethylene **enhances abscission** and **senescence.**
- Ethylene **induces cellulase activity leading to promotion of leaf abscission**.
- Ethylene **induces femaleness in monoecious flowers** as in cucurbits like cucumber, *Cannabis* etc.
- Ethylene **inhibits phenomenon of geotropism (graviperception)**, **growth of lateral buds** and **expansion of leaves**.
- **In low concentration** ethylene **induces root initiation**.
- Ethylene **breaks bud** and **seed dormancy** in some species.
- Ethylene **promotes elongation of stem and petiole in submerged and partially submerged aquatic plants**, eg., *Ranunculus*.
- Ethylene **enhances activity of chlorophyllase** which causes degreening phenomenon.
- **Maximum rate of ethylene production** occurs during the period of **maximum respiration** just **before senescence** in many fleshy fruits. This is **climacteric rise and it acts as trigger for the conversion of unripe fruits to ripened fruits**.
- Term climacteric was given by **Kidd and Went** (1930).
- **Examples of climacteric fruits** are – apple, banana, mango, pear, peach, plum, tomato and **nonclimacteric fruits** are – citrus, grape, pineapple, strawberry, watermelon, cherry.
- Ethylene is a **fruit ripening hormone** and it stimulates all the biochemical changes which take place upto fruit ripening.
- Ethylene as **ethaphone** (2 chloroethyl phosphonic acid) is used in artificial ripening and colour changes in climacteric fruits.
- Ethylene **induces flowering** in mangoes, pineapple etc.
- **Excess of auxin causes ethylene synthesis** whereas **ethylene lowers synthesis and transport of auxin**.
- Ethylene **causes petal discolouration**. Highest rate of release of ethylene has been reported from fading flowers of *Vanda*.
- Ethylene **induces epinasty** or downward bending of leaves. In rose the effect appears even at concentration of 1 ppm.
- Ethylene **inhibits root and stem elongation** but **induces root hair formation**.
- Ethylene **induces seismonasty**, synthesis of β-1, 3 glucan.

ABSCISIC ACID

- **Carns** and **Addicott** had identified abscisic acid in 1963 while working on cotton balls and called the compounds as **abscisin I (from old cotton balls)** and **II (from young cotton balls)**.
- **Wareing and coworkers** discovered **dormin** from buds and leaves of *Acer* (Birch) plants which induces dormancy in buds, underground stems etc.
- **Abscisin I, II and dormin** are all the same compounds and term **abscisic acid (ABA)** was used for these compounds.
- Abscisic acid is mildly 15-C sesquiterpene multi role plant hormone which **act as an inhibitor because it opposes the growth promoting effect of auxin, gibberellins, and cytokinin** thus keep their activity under control.
- Abscisic acid is **found in vascular plants, some mosses, some fungi and some green algae**.
- **Site of synthesis of abscisic acid** is many parts of the plant but **more inside the chloroplasts of green cells**.
- ABA is a **naturally occurring growth inhibitor** in plants.
- **Biosynthesis** of abscisic acid **takes place through mevalonic acid or xanthophylls** (violaxanthin).
- **Translocation of abscisic acid takes place in xylem** and **phloem** and also parenchyma cells outside vascular bundles.
- **Bioassays** for **abscisic acid** are – **rice seedling growth inhibition test** and **inhibition of α amylase synthesis in barley endosperm**.

Physiological effects of abscisic acid

- Abscisic acid **induces dormancy** in buds.
- Abscisic acid **enhances the process of abscission** and **senescence**.
- Abscisic acid **induces flowering in some short day plants** like *Ribes, Fragaria* etc., during long days and inhibits flowering in long day plants.
- Abscisic acid **stimulates the release of ethylene**.
- Abscisic acid **counteracts many effects of gibberellins like induction of hydrolases and α-amylases in barley seedlings**.

- The **buds** and **seeds sprout only** when **abscisic acid is overcomed by gibberellins**.
- Abscisic acid (ABA) is called **antigibberellin**.
- ABA **promotes ageing** of leaves by stimulating breakdown of proteins and nucleic acid through promoting activity of their hydrolases.
- ABA **promotes cold hardiness** and **inhibits growth** of **pathogens**.
- ABA has been found to **induce parthenocarpic development in rose**.
- Use of abscisic acid **promotes roots** in many stem cuttings.
- Excessive production of abscisic acid **stops the synthesis of RNA and proteins which causes senescence**.
- Abscisic acid **stops mitosis in vascular cambium** towards the approach of winter.
- Abscisic acid is also known as **stress hormone** as it is produced under conditions of stress and causes **partial closure of stomata** under drought and thus **acts as antitranspirant**.
- **Leaves makes** large amount of **abscisic acid during drought and it functions as messenger that enables plant to conserve water during drought**.

Morphactins

- These are a group of artificially synthesized substances, which affect morphology and hence called **morphactins** (by **Schneider**).
- These contains '**fluorene ring**' in their structure.
- Generally these are **growth inhibitors**.
- **Physiological effects of morphactin** are –
  - Formation of **cornets** (fusion of leaf with stem) and **ochria** (fusion of calyx with other floral parts).
  - Induction of gamopetalous condition.
  - Induction of parthenocarpy.
  - Root growth and shoot growth is inhibited by morphactines, *i.e.*, leads to shortening of plants.
  - **Depot effect :** First morphactins are accumulated in plants and after sometime show their effect.
  - Seed germination is inhibited.

Wound hormone or Traumatic acid

- **Haberlandt** (1913) reported that injured plants cells release a chemical substance (wound hormone), which stimulate the adjacent cells to divide rapidly in order to heal up the wound.
- **English** *et. al.* (1939) finally isolated and crystallized this wound hormone and named it as **traumatic acid**.

End of the Chapter