UNIT 5.1 Plant Growth Regulators

Discovery, Biosynthesis and Physiological roles of Auxins

Plants require light, water, oxygen, minerals and other nutrients for their growth and development. Apart from these external requirements, plants also depend on certain organic compounds to signal, regulate and control the growth of plants. These are collectively called as Plant Growth Regulators or Plant Growth Hormones. Plant growth regulators can be defined as organic substances which are synthesized in minute quantities in one part of the plant body and transported to another part where they influence specific physiological processes. They are signal molecules, produced within plants that occur in extremely low concentrations. Plant hormones control all aspects of plant growth and development, from embryogenesis, the regulation of organ size, pathogen defense, stress and tolerance to reproductive development. They are also referred to as plant growth regulators or phytohormones. Plant growth hormones are organic compounds which are either produced naturally within the plants or are synthesized in laboratories. Generally, there are five types of plant hormones namely, Auxins, Gibberellins (GAs), Cytokinins, Abscisic acid (ABA) and Ethylene. In addition to these, there are more derivative compounds, both natural and synthetic, which also act as plant growth regulators.

Types of Plant Growth Regulators

Plant Growth Regulators can be of a diverse chemical composition such as gases (ethylene), terpenes (gibberellic acid) or carotenoid derivatives (abscisic acid).

Based on their actions, plant growth regulators are broadly classified into two major groups:

1. Plant Growth Promoters
2. Plant Growth Inhibitors

Auxins, Gibberellins and Cytokinins are grouped into Plant growth promoters while Abscisic acid and Ethylene are grouped into Plant growth inhibitors.

Ethylene can be grouped either into the promoters or into the plant inhibitors

Auxins

Auxins were the first class of plant hormones to be identified. The term auxin is derived from the Greek word ‘auxein’ which means ‘to grow’. All those growth regulating organic compounds which are produced at the tips of roots and stem as a result of metabolism and transported to the region of elongation causing elongation of cells are called Auxins. Both natural and synthetic Auxins are known and all have similar effect on plant growth and development. Thimann (1948) defined an auxin as 'an organic substance which promotes growth along the longitudinal axis when applied in low concentrations to shoots of plants freed as far possible from their own inherent growth promoting substances'. Auxins passes from shoot tip to the region of elongation and its movement is basipetal (from apex towards base) in stem but acropetal (from base towards apex) in roots.

Auxin helps in elongation of both shoots and roots. However, optimum for the two is quite different (10 ppm for stem and 0.0001ppm for root)

.Auxin biosynthesis occurs in shoot apices, leaf primordial and developing seeds from amino acid tryptophan in the presence of Zn^{++}ion. The most important member of the auxin family is indole-acetic acid (IAA), which generates the majority of auxin effects in intact plants, and is the most potent native auxin. And as native auxin, its stability is controlled in many ways in plants, from synthesis, through possible conjugation to degradation of its molecules, always according to the requirements of the situation.

Auxins are of two main types:

Naturally occurring (endogenous) auxins in plants include indole-3-acetic acid, 4-chloroindole-3-acetic acid, phenylacetic acid, indole-3-buyyric acid and indole-3-propionic acid.

Synthetic auxins include 1-naphthaleneacetic acid, 2,4- D(2,4- dichlorophenoxyacetic acid) and many others.

Structure of Auxin

Discovery of Auxins

Auxins were the first plant hormones discovered. Charles Darwin was among the first scientists to dabble in plant hormone research. In his book "The Power of Movement in Plants" presented in 1880, he first describes the effects of light on movement of canary grass (*Phalaris canariensis*) coleoptiles.

Darwin's Experiment:

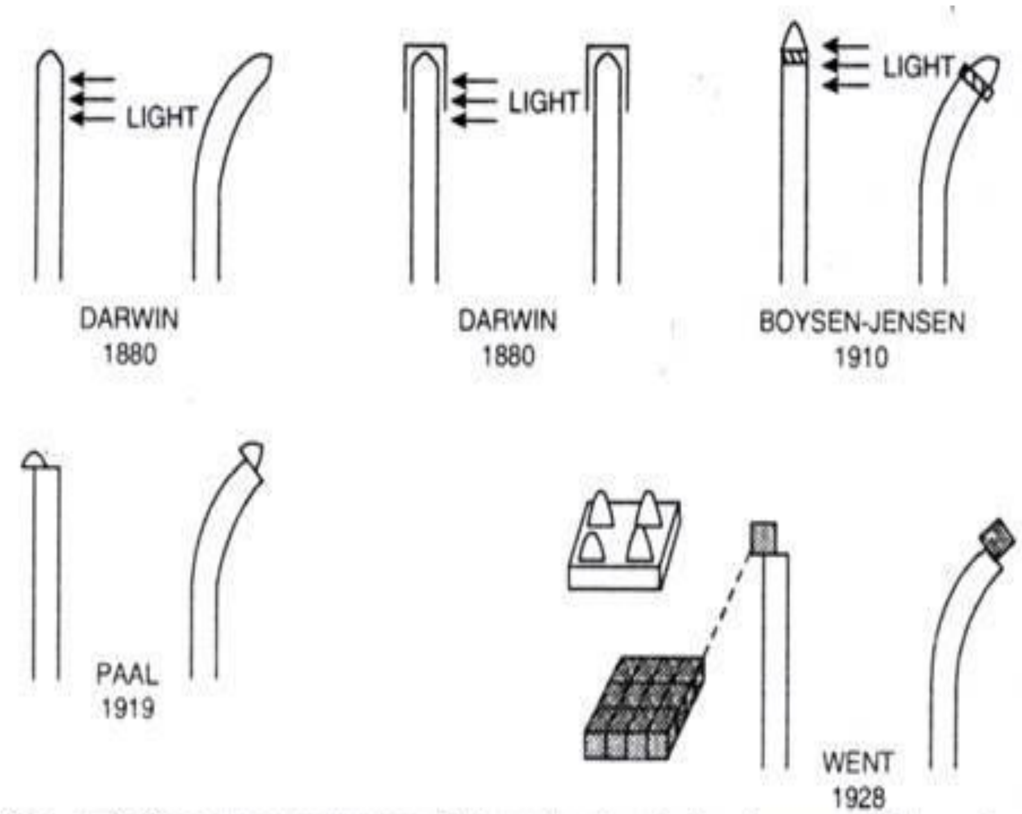
Charles Darwin and his son Francis performed experiments on coleoptiles, the sheaths enclosing young leaves in germinating grass seedlings. They observed the growth of coleoptiles of canary grass towards the light source. Followed by a series of experiments, they concluded the presence of a transmittable substance that influences the growth of canary grass towards the light. That transmittable substance was what we know as auxin which was isolated later by F.W. Went. Their experiment exposed the coleoptile of canary grass (*Phalaris canariensis*) to light from a unidirectional source, and observed that they bend towards the light. By covering various parts of the coleoptiles with a light-impermeable opaque cap, the Darwins discovered that light is detected by the coleoptile tip, but that bending occurs in the hypocotyl. However the seedlings showed no signs of development towards light if the tip was covered with an opaque cap, or if the tip was removed. The Darwins concluded that the tip of the coleoptile was responsible for sensing light, and proposed that a messenger/ substance is transmitted in a downward direction from the tip of the coleoptile, causing it to bend.

Peter Boysen-Jensen Experiment:

In 1913, Danish scientist Peter Boysen- Jensen demonstrated that the signal was not transfixed but mobile. He separated the tip from the remainder of the oat (*Avena*) coleoptile by a cube of gelatin which prevented cellular contact but allowed chemicals to pass through. The seedlings responded normally bending towards the light. However, when the tip was separated by an impermeable substance (a mica plate, there was no curvature of the stem. He concluded that some substance has diffused from the tip through the gelatin to the cut end where it causes growth.

Went Experiment:

In 1928, the Dutch botanist Fritis Warmolt Went showed that a chemical messenger diffuses from coleoptile tips. Went's experiment identified how a growth promoting chemical causes a coleoptile to grow towards the light. He placed several decapitated tips of *Avena* coleoptile over a thin block of agar-agar. The agar block was allowed to stay for sometimes. The block was then cut to small pieces and each piece was placed eccentrically on the cut end of coleoptile. The characteristic bending was observed, though the experiment was performed in darkness. This clearly demonstrated that the substance responsible for growth is synthesized in the apex and translocated downwards. The substance has leached out in the agar block from the coleoptile tips and then migrated downwards where it triggered the longitudinal growth on one side. Went later proposed that the messenger substance is a growth-promoting hormone, which he named auxin, that becomes asymmetrically distributed in the bending region. Went concluded that auxin is at a higher concentration on the shaded side, promoting cell elongation, which results in coleoptiles bending towards the light. Went concluded that "no growth can occur without Auxin"



[redacted] Diagrammatic summary of the major steps in the discovery of the auxins.

Biosynthesis of Auxin

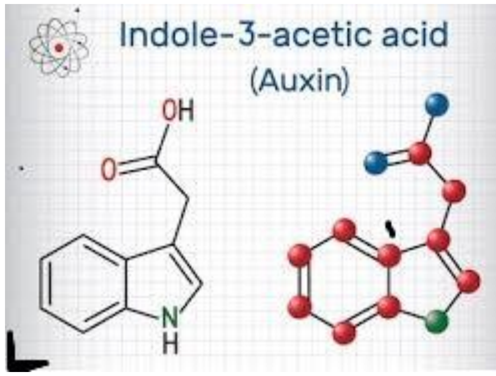
Indole-3-acetic acid (IAA), the most important natural **auxin** in plants, is mainly synthesized from the amino acid tryptophan (Trp). Tthe amino acid tryptophan (Trp) is a pre cursor of IAA as it has a close similarity with it and is presumably present in all cells. The progress in **auxin biosynthesis** also lays a foundation for understanding polar **auxin** transport and for dissecting **auxin** signaling mechanisms during plant development.

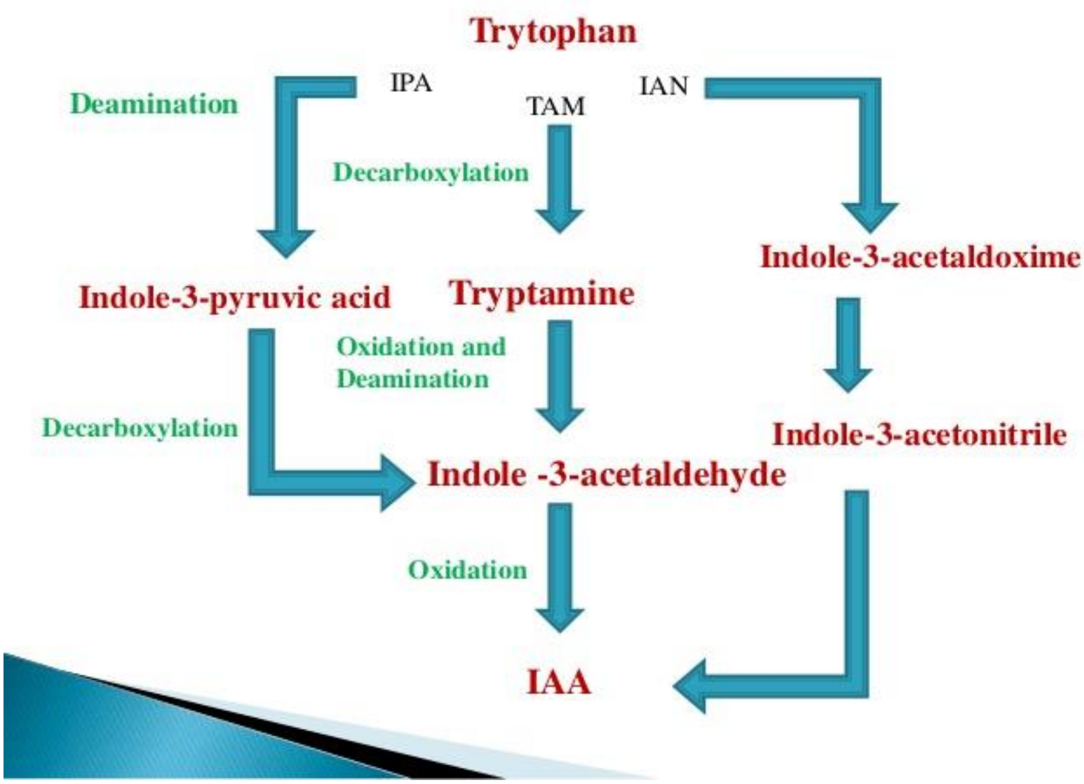
IAA biosynthesis pathways in plants:

(i) The Indole-3-pyruvic acid (IPA) pathway: In this pathway, first of all the amino acid tryptophan donates its amino group to another α- keto acid by transamination reaction to become indole pyruvic acid. The reaction is catalyzed by enzyme indole tryptophan transaminase. Then indole pyruvic acid undergoes decarboxylation in the presence of enzyme indole pyruvate decarboxylase to become indole acetaldehyde. Finally indole acetaldehyde oxidizes to become indole-3-acetic acid. This reaction is catalyzed by enzyme indole acetaldehyde dehydrogenase. Examples- sterile pea shoots, in cucumber seedlings, etc.

(ii) The Tryptamine (TAM) pathway: Tryptamine occurs sporadically in higher plants. It was first isolated from *Acacia* and since been found in several other species. In this pathway Tryptophan is decarboxylated to form Tryptamine in the presence of enzyme tryptophan decarboxylase, followed by deamination to form indoleacetaldehyde in the presence of enzyme tryptamine oxidase. Indoleacetaldehyde is then oxidized to form Indole-3-acetic acid in the presence of enzyme indoleacetaldehyde dehydrogenase.

(iii) The Indoleacetaldoxime (IAN) pathway: This pathway is characteristic of the family Cruciferae. In this, tryptophan is converted into Indole-3-acetaldoxime which in the presence of Indole-3-acetaldoxime hydrolase converts it into indole-3- acetonitrile (IAN). The enzyme nitrilase coverts





Biosynthesis of IAA from Tryptophan

Physiological Role of Auxins

1. Cell Elongation and longitudinal growth: The growth of cells in length is called cell elongation. The primary and chief function of auxin in plants is to stimulate the cell elongation in shoot. Extensive studies on the mechanism of auxin action in cellular elongation shows that auxins promote cell elongation by; causing increased wall plasticity with decreased elasticity, enhancing the water and solute uptake and interacting at gene level by synthesizing enzymes that are required for the synthesis of cell wall and cytoplasmic components. Auxins induce enzymatic or non-enzymatic deformation or loosening of cell wall by breaking the cross links between the cell wall components. This results in increased plasticity with decreased elasticity of the cell wall. The bonds are reformed after the cellular elongation.

2. Apical Dominance: The influence of apical bud in suppressing the growth of lateral buds is called apical dominance. If the terminal bud is intact and growing, the lateral buds remain suppressed, particularly in long and sparsely branched vascular plants. Removal of apical bud results in the fast growth of the lateral buds. The reason of this was explained by Thimann and Skoog (1934) and Thimann (1937). According to them, the auxin is synthesized in the apical meristem from where it is translocated downwards causing inhibition of growth of lateral buds. During downward movement of auxin some correlative inhibitors are synthesized which inhibit the growth of lateral buds. Recent investigations support the view that auxins induce the formation of ethylene which acts as inhibitor for lateral buds.

3. Cell division: Auxins initiate as well as promote cell division in tissues like cambium. This effect of auxin is particularly important in secondary growth of stem and differentiation of xylem and phloem.

4. Root growth and root initiation: The same concentration of auxin does not show the same effect on the different parts of plant. Sometimes the conc. of auxin which increases growth of one organ, reduces or inhibits the growth of other organ, e.g. the conc. of auxin which accelerates the growth of stem, reduces the growth of roots but the number of lateral branches in roots is increased. Auxins always inhibit root growth at higher concentrations. At low concentrations, they promote root growth. The conc. of auxin which is inhibitory to root growth causes initiation of adventitious roots from the nodes or basal regions of stem. The localized accumulation of auxin in epidermal cells of the root initiates the formation of lateral or secondary roots.

5. Prevention of abscission: Natural auxins control the falling of fruits, flowers and leaves from the plants. The leaves and fruits fall down from the plants only when abscission layer is formed between petiole or pedicel or fruit stalk and stem at the point of attachment. This region is called abscission zone. It has been shown that abscission zone does not occur when the conc. of auxin is high, it always occurs when auxin gradient becomes less or neutral. It is also believed that the hormone ethylene promotes the abscission (due to auxin induced synthesis of ethylene).

6. Parthenocarpy: The formation of seedless fruits without fertilization is called Parthenocarpy. Although it is common in nature but parthenocarpic fruits can be obtained treating the flowers with low conc. of auxins. Parthenocarpy has been induced successfully by synthetic auxins in fruits like orange, banana, apple, tomato, pineapple, cucumber, etc.

7. Respiration: Auxins stimulates respiration in many plants and there is a close correlation between auxin induced growth and an increased rate of respiration. It is believed that auxin increases the supply of ADP from ATP by utilizing the latter in the expanding cell. The increase in the availability of ADP increases the rate of ATP formation and thus stimulates respiration.

8. Flower initiation: Auxins normally inhibit the flowering. However in litchi and pineapple auxins like 2,4-D and NAA have been found to promote flowering. When auxins in dilute concentrations are sprayed on pineapple plants, uniform flowering occurs. Low conc. of auxins as NAA or IAA are also effective in inducing flowering in barley.

9. Shortening of internodes: Auxin helps in the reduction of size of branches. It is generally observed in plants like apple and pear where two types of branches, small and big, are found and fruits are born only on small branches.

10. Plant growth movements: Auxin regulates phototropism, geotropism and other developmental changes. The uneven distribution of auxin, due to environmental cues, such as unidirectional light or gravity force, results in uneven growth of plant tissue. Generally, auxin governs the form and shape of the plant body, direction and strength of growth of all organs and their mutual interaction.

Some other effects of auxins includes: wound response, in improving size and quality of fruit, as weed killer, etc.

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