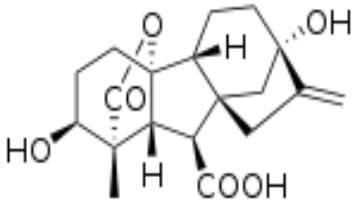
Unit 5.1

Gibberellins: Discovery, Biosynthesis and Physiological role

Gibberellins (GAs) are plant growth regulators that regulate various developmental processes, including stem elongation, germination, dormancy, flowering and fruit senescence. GAs strongly promotes cell elongation of intact plants commonly. They are concentrated in the regions like shoot apex, young leaves, embryos, flower buds, fruits and immature seeds. It means that rapidly growing and developing regions of the plant possess higher concentrations of gibberellins. These include a large range of chemicals that are produced naturally within plants and by fungi. They have also been found in algae, mosses, ferns and gymnosperms.

All the gibberellins are almost similar in structure. They contain a gibbane ring made up of cyclohexane ring and 4-lactone ring. They differ in minute details viz., the number and position of –OH and sometimes $–CH_3$ and –COOH groups at different carbon atoms of the gibbane ring. GA_3 is the most thoroughly studied gibberellin.



Chemical structure of Gibberellin (GA_3)

Gibberellins are transported in the entire conducting system- both in phloem and xylem. It moves from one part to the other in the phloem similar to the transport of carbohydrates and other substances. GA is translocated in the xylem due to the lateral movement between the two vascular bundles. In general GA movement is non-polar in contrast to polar transport of auxin.

Discovery of Gibberellins

The discovery of gibberellins is very interesting. Japanese farmers first observed that in the rice fields a few plants were distinctly taller, seedless and pale in colour. They called it as “Bakanae or foolish seedling” diseases because it made the young rice plants grow ridiculously tall. Hori (1898)

worked on and suggested that the agent of this disease was a fungal pathogen *Fusarium*. Sawada (1912) hinted that the disease might be caused by something secreted by the fungus. Kurosawa (1926) discovered that the disease was caused by a substance secreted by the fungal species *Gibberella fujikuroi* resulting to controversy over the true pathogen.

Wollenweber (1931) stated that the fungus *Fusarium moniliforme* is the asexual or imperfect stage of the ascomycete *Gibbrerlla fujikuroi*. Yabuta and Sumiki (1938) finally succeeded in isolating a pure crystalline growth promoting substance which they named 'Gibberellin-A'. Japanese chemists then discovered that Gibberellin-A was actually a mixture of several different growth promoters which they named GA_1, GA_2 and GA_3. Takahashi (1957) isolated another compound from this fungus and named it GA_4.MacMillian and Suter (1958) were the first to isolate and identify GA_1 from plants. Cross et.al. (1961) isolated 6 gibberellins from the fungus *Fusarium moniliforme* and named them as GA, GA_1, GA_2, GA_3, GA_4, GA_7 and GA_9. MacMillian and Takahashi (1968) proposed that gibberellins may be assigned numbers in order to reduce confusion between compounds. MacMillan et.al.(1961) also isolated three gibberellins from bean seeds and named them as GA_5, GA_6 and GA_8. Mulholland (1963) discovered GA_{10} and GA_{13}. Till date more than 125 gibberellins have been isolated from plants.

Foolish Seedling disease of Rice

Biosynthesis

Gibberellins are synthesized inside the plastids of immature seeds, young leaves and even the roots. They are synthesized from acetate units of acetyl coenzyme A by the mevalonic pathway. The following steps are involved in the biosynthesis of gibberellins:

1. Synthesis of gibberellins begins with **acetate molecule**. Acetate is esterified with coenzyme (CoA) to form three **acetyl coenzyme A** (acetyl Co A) molecules which undergoes a series of condensing reactions to **β-hydroxyl-β-methyl glutaryl CoA** (BOG-CoA). Then BOG-Co A is reduced in two successive NADPH-requiring steps to form **mevalonic acid**.

2. **Mevalonic acid** is then phosphorylated by mevalonic acid kinase (mevalonate kinase) in the presence of 2ATP molecules to form **mevalonic acid pyrophosphate**.

3. Then decarboxylation of **mevalonic acid pyrophosphate** in the presence of ATP which yields Isopentenyl **pyrophosphate** (IpPP)

4. **IpPP** is converted into **dimethylallyl pyrophosphate** (DMAPP) which is an isomer of IpPP, by enzyme IpPP isomerase.

5. One molecule of **dimethylallyl pyrophosphate** then serve as an acceptor of one IpPP molecule with elimation of pyrophosphate and formation of one molecule of di-isoprenoid alcohol pyrophosphate or **gereniol pyrophosphate**(GPP).

6. **GPP** accepts a molecule of IpPP to form **farnesol pyrophosphate** which also accepts another IpPP molecule to form **geranyl geraniol pyrophosphate** (GGPP).

7. Then **geranyl gereniol pyrophosphate** (GGPP) is folded on various ways and then converted into a partially cyclized compound, **copalyl pyrophosphate** (CPP in the presence of ent- copalyl diphosphate synthase. Then it is finally transformed into a fully cyclic compound, **ent-kaurene** by ent- kaurene synthase.

8. **ent-kaurene** is oxidized step-wise at C-19 to form **ent-Kaurenol**, **ent-kaurenal** and **ent-Kaurenoic acid**. The latter is hydroxylated to **ent-7α-hydroxy Kaurenoic acid.**

9. Now the contraction of β-ring and β-hydroxylation occurs. The conversion of **ent-7α-hydroxy Kaurenoic acid** to a 20 carbon **GA_{12} -aldehyde** involves loss of 6β-hydrogen, a shift of 7, 8 bond to 6, 8-positionand loss of a proton from the extruded C-7.

10. **GA_{12}-aldehyde** is converted into **GA_{12}** by ent- kaurene acid oxidase (KAO)

10. Loss of one carbon must occur to give rise to C-19 GAs such as GA_3.

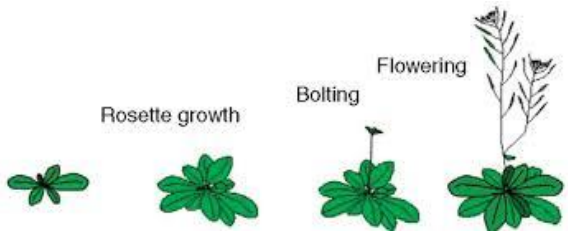
Physiological Role

Gibberellins play important role in the following processes:

1. Stem elongation: The most important effect of gibberellins is elongation of stem and leaf sheaths in intact plants. Lack of gibberellins causes shortening of internodes and reduced height. It has been observed in several plants like, Pea, bean cucumber, lettuce, pepper, cabbage, etc. The elongation of stem results due to cell division and cell elongation induced by gibberellins.

2. Reversal of dwarfism: One of the most prominent effects of gibberellins is the elongation of genetically dwarf (mutant) varieties of plants like corn and pea. It is believed that dwarfism (shortening of internodes and reduced height) in mutant a variety of plants is due to the absence of endogenous gibberellins or presence of natural inhibitors. When the gibberellins are applied exogenously, the dwarf plants show rapid elongation of internodes and normal growth.

3. Bolting and flowering: Certain plants show profuse leaf development but reduced/retarded growth. This form of growth is called rosette-habit, where a large number of leaves remain attached to a very short axis. The rosette habit is due to the deficiency of gibberellins which inhibit cell division at sub-apical meristem and stem remains very short at internodes. It has been observed that plants with rosette habit exhibit extensive internode growth just before reproduction. The axis elongates 5-6 times the original height of the plants and starts flowering. This type of rapid internode growth just before reproduction is called bolting. Usually such plants require specific long day photoperiods or specific cold requirements to bolt and flower. If such plants are treated with gibberellins during condition of rosette growth, the plants bolt and flower



4. Parthenocarpy: The formation of seedless fruits without pollination and fertilization is called Parthenocarpy which may be natural or induced. Gibberellins like auxins are also capable of inducing Parthenocarpy, which has been reported in many plants such as cucumber, brinjal, etc. Gibberellins are more effective than the auxins in inducing parthenocarpy. Seedless fleshy tomatoes and large sized grapes are also produced by gibberellin treatment on commercial scale.

5. Breaking of dormancy: Gibberellins are known to break seed dormancy. They induce germination of light sensitive (positive photoblastic) seeds of Tobacco and Lettuce in complete darkness. The seeds of some temperate species like apple and peach need low temperature (1-7^{o} C) for a few days and gibberellins can replace the need of low temperature for seed germination. Gibberellins also promote seed germination in several species, which otherwise fail to germinate unless subjected to low temperature, long days or red light. The dormancy in buds of evergreen and deciduous trees and shrubs can also be overcome by exogenous supply of gibberellins. The potato also has a dormant period after harvest, but the application of gibberellins sprouts the eyes vigorously.

6. Prevention of senescence: It has been demonstrated that the exogenous application of GA prevent the senescence of leaves of *Taraxanum Rumex* and *Tropaeolum*. Gibberellins are often sprayed on the fruits and leaves of orange to prevent rind disorder during storage. GA delays senescence and maintains firmer rinds.

7. *De- novo* synthesis of hydrolytic enzymes: During germination of seeds, the organic food and minerals stored in the form of macromolecules in endosperm and cotyledons are released and transported in the growing root and shoot axis, until the seedling is established in the soil. Thereafter, the seedling starts abstracting nourishment from the soil and atmosphere. Gibberellins are known to stimulate the hydrolysis of stored macromolecules (starch) and their transport to the embryonic axis. In cereals, the starchy endosperm is surrounded by a thin aleurone layer. The cells of this layer provide hydrolytic enzymes that hydrolyze and digest the starch, and other materials present in the endosperm cells. The exogenous application of gibberellins in the aleurone layer promotes the production of hydrolytic enzymes like amylases, proteases (through de novo synthesis). These enzymes participate in the breakdown of the stored starch to simple sugars. These sugars are then translocated to the growing embryo to provide energy for growth.

8. Sex Expression: Gibberellins are also capable of changing the sex of the flowers towards maleness. Its application promotes the formation of mala flowers on genetically female plants of Cannabis and can also replace female flowers with male flowers on monoecious plants of cucurbits.

What is the difference between auxin and gibberellin?

The main difference between auxin and gibberellin is that the auxin promotes the growth of the shoot system whereas gibberellin promotes stem elongation, germination, and flowering. Furthermore, auxin plays a role in apical dominance whereas gibberellin has no role in apical dominance.

Reference /Syllabus Books (For material & diagrams)

1.A Text Book of Plant Physiology by H. S. Srivastava(Rastogi Publication)

2. A Text Book of Plant Physiology by S. K. Verma (S. Chand & Company Ltd.)

3. Plant Physiology and Metabolism by Dr. H.N. Srivastava (Pradeep Publications)

4. Plant Physiology and Metabolism by Dr. Kamaljit & co-workers (S. Vinesh & Co.)

5. Plant Physiology and Metabolism by Dr. B.B. Arora (Modern Publishers)