PLANT GROWTH AND DEVELOPMENT
PLANT GROWTH REGULATORS

PLANT GROWTH REGULATORS

CHARACTERISTICS

1. The plant growth regulators (PGRs) are small, simple molecules of diverse chemical composition. They could be

Phytohormones		Chemical Name
1.	IAA – Indole-3-acetic acid	Indole compounds
2.	Kinetin – N6-furfurylamino purine	Adenine derivatives
3.	ABA – Abscisic acid	Derivatives of carotenoids
4.	GA_3 – Gibberellic acid	Terpenes
5.	Ethylene, C_2H_4	Gase

2. The PGRs can be broadly divided into two groups based on their functions in a living plant body.

(a) Plant growth promoters	(b) Plant growth inhibitor
One group of PGRs are involved in growth promoting activities, such as cell division, cell enlargement, pattern formation, tropic growth, flowering, fruiting and seed formation. These are also called plant growth promoters, e.g., auxins, gibberellins and cytokinins.	The PGRs of the other group play an important role in plant responses to wounds and stresses of biotic and abiotic origin. They are also involved in various growth inhibiting activities such as dormancy and abscission. The PGR Abscisic acid (ABA) belongs to this group.

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

AUXIN

Auxin term is derived from Greek word 'auxein' which means to grow.

History :

Charles Darwin and his son Francis Darwin :

- They observed that the coleoptiles of canary grass responded to unilateral illumination by growing towards the light source (phototropism).
- After a series of experiments it was concluded that the tip of coleoptile was the site of transmittable influence that caused the bending of the entire coleptile.

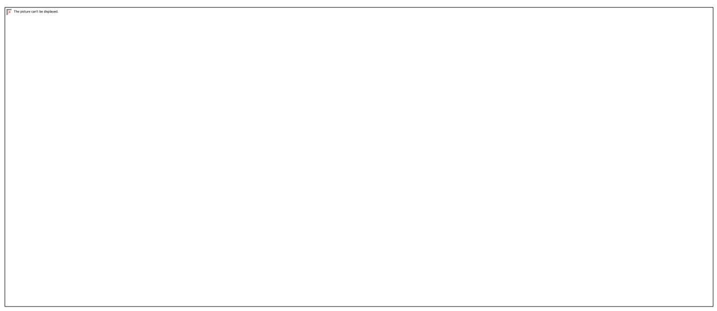


Fig. Experiment used to demonstrate that tip of the coleoptile is the source of auxin. Arrows indicate direction of light

F.W. went :

He is credited for :

- Discovery of auxin.
- Coined the term auxin.
- Isolated auxin from tips of coleoptiles of oat seedlings.
- Bioassay of auxin (Avena curvature test).

KOGL AND HAAGENSMIT :

First time isolated auxin from human urine.

Synthesis : Precursor of auxin is tryptophan. Zinc is also necessary for biosynthesis of auxin.

Auxins are generally produced by the growing apices of the stem and roots.

After synthesis auxins migrate to the' regions of their action. (Transporrt is Polar and basipetal)

Types of auxin : Auxins are of two types. They are :

1. **Natural auxins :** Such auxins have been isolated from plants. e.g. indole 3 acetic acid (IAA). indole 3 butyric acid (IBA).
2. **Synthetic auxins :** Such auxins have been artificially synthesised.

   Examples : NAA (Napthalene acetic acid)

   2.4-D (2. 4-Dichlorophenoxy acetic acid)

   2.4.5-T (2. 4, 5-Trichloro phenoxy acetic acid)

   IPA (Indole Propionic/Pyruvic acid)

Both natural and synthetic auxins have been used extensively in agricultural and horticultural practices.

PHYSIOLOGICAL EFFECTS AND AAPPLICATIONS :

1. **Apical dominance :** "In most higher plants, the growing apical bud inhibits the growth of the lateral (axillary) buds, a phenomenon called apical dominance.

- Removal of shoot tips (decapitation) usually results in the growth of lateral buds. It is widely applied in tea plantations and in hedge-making.

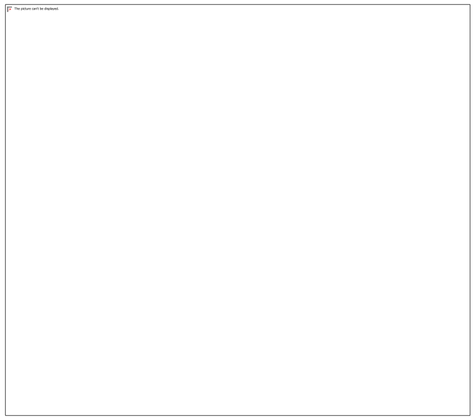


Fig : Apical dominance in plants (1) A plant with apical bud intact (2) A plant with apical bud removed note the growth of lateral buds into branches after decapitation.

2. **Root initiation :** Auxins help to initiate rooting in stem cuttings. This application is widely used for plant propagation.
3. **Flowering :** Auxins promote flowering in pineapple.
4. **Abscission :** Auxins help to prevent fruit and leaf drop at early stages but promote the abscission of older mature leaves and fruits.
5. **Parthenocarpy :** Auxin induce parthenocarpy in tomatoes.
6. **Herbicide/weedicide :** Auxins used as herbicides. 2, 4 D widely used to kill dicotyledonous weeds. 2, 4 D does not affect mature monocotyledonous plants. It is used to prepare weed free lawns by gardeners.
7. **Xylem differentiation :** Auxin controls xylem differentiation.
8. **Cell division :** Auxins helps in cell division.
9. **Potato dormancy :** MH (maleic hydrazide) and NAA keep lateral buds of potato tubers dormant. Thus, potato tubers can be stored for longer durations.

BIOASSAY OF AUXIN :

Bioassay is a biological testing of a substance (PGR) on a plant or its parts.

(a) Avena curvature test

(b) Root growth inhibition

GIBBERELLINS:

- **The 'bakanae' (foolish seedling) disease of rice seedlings, was caused by a fungal pathogen Gibberella fujikuroi. E. Kurosawa (1926) reported the appearance of symptoms of the disease in rice seedlings when they were treated with sterile filtrates of the fungus.**
- **Yabuta and Sumiki (1938)** isolated this substance in crystalline form and named it as Gibberellin.

  There are more than 100 gibberellins reported from widely different organism such as fungi and higher plants. They are denoted as GA_1, GA_2, GA_3 and so on. All GAs are **acidic.**

  The higher concentration of gibberellins is found in leaves, young seeds and embryo. The most common Gibberellin is **GA_3 ($C_{19}H_{22}O_6$).**
- Biosynthesis of Gibberellin takes place through **mevalonic acid pathway** & **kaurene** is its precursor.

PHYSIOLOGICAL EFFECTS AND PRACTICAL APPLICATION OF GIBBERELLINS:

1. **Internodal growth:** Gibberellin stimulates the elongation of Internodes in stem. Therefore the length of stem increases.

- **This ability is used to increase the length of grapes stalks.**
- **Sugarcane stores carbohydrate as sugar in their stems. Spraying sugarcane crop with gibberellins increases the length of the stem, thus increasing the yield by as much as 20 tonnes per acre.**
- **Elongation of genetically dwarf plants:** GA induces the elongation in genetically dwarf plants therefore they grow as normal tall plant. **e.g. dwarf pea and maize plants.**

2. **Seed germination:** Gibberellins stimulate the production of hydrolytic enzymes **-amylase, lipases, ribonucleases and proteases**. The enzymes solubilise the reserve food of the seed. The same is transferred to embryo axis for its growth. Some of the light sensitive seeds germinate with the treatment of GA even in complete darkness. **e.g. Lactuca sativa and Nicotiana**
3. **Breaking of seed dormancy:** It initiates breaking seed dormancy.
4. **Parthenocarpy:** Gibberellins have been found to be 500 times more effective than auxins in inducing parthenocarpy **e.g. Tomato, Pear, apple, etc.**
5. **Flowering in LDP:** Gibberellins induce flowering in long day plants in the presence of dim light. By the application of GA biennial plants can makes flower in first year of growth, so behave as annuals. **e.g. Henbane.**

6. **Maleness:** Gibberellins initiate the development of male reproductive organs in some plants like Cucumis, Cannabis.
7. **Bolting: Gibberellins also promotes bolting (internode elongation just prior to flowering) in Beet, cabbages and many plants with rosette habit.**
8. **Substitution of cold treatment:** Low temperature requirement or vernalization in some plants can be replaced by gibberellins.
9. **GA_3 is used to speed up the malting process in brewing industry.**
10. **Spraying juvenile conifers with GAs hastens the maturity period, thus leading to early seed production**.
11. **Gibberellins causes fruits like apple to elongate and improve its shape. They also delay the senesence. Thus, the fruits can**

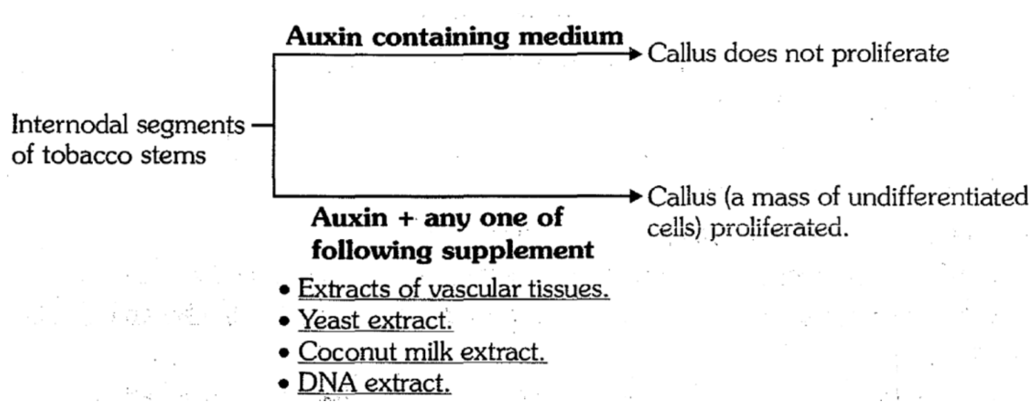
Bioassay of Gibberellins:

(1) Dwarf Pea test. (2) Barley Endosperm test

CYTOKININS

History :

F. Skoog and his Co workers :



Skoog and Miller : They identified and crystallised the cytokinesis promoting active substance that they termed kinetin. (a modified form of adenine, a purine).

Miller : He isolated an active substance from the autoclaved DNA of sperm cells of herring fish.

Kinetin does not occur naturally in plants.

- Search for natural substances with cytokinin like activities led to the isolation of zeatin from corn kernels and coconut milk.

  Synthesis : Natural cytokinins are synthesisedin regions where rapid cell division occurs, for example : root apices, developing shoot buds, young fruits etc. Root tips are major site of synthesis of cytokinins.

PHYSIOLOGICAL EFFECTS AND APPLICATIONS :

1. **Cell division :** Cytokinins have specific effects on cytokinesis (cytoplasmic division). It is considered as most important biological effect of cytokhlins.
2. **Overcome apical dominance :** Cytokiniris promote the growth of lateral buds. This role of cytokinin is antagonist to auxin.
3. **Senescence :** Cytokinins promote nutrient mobilisation towards young parts which helps in the delay of leaf senescence.
4. Help to proguce new leaves.
5. Help to produce chloroplast in leaves.
6. Promote lateral shoot growth and adventitious shoot formation.
7. Induce opening of stomata.

TISSUE CULTURE :

- Cytokinin and auxin together cause dedifferentiation in differentiated parenchymatous cells in tissue culture.

Morphogenesis :

- High concentration of cytokinins to low concentration of auxin = shoot differentiation
- High concentration of auxin to low concentration of cytokinin = root differentiation

Bioassay of cytokinin :

1. Tobacco pith cell division test.
2. Chlorophyll preservation (retention) test.

Ethylene:

- It is a gaseous plant hormone that is effective in concentration of **0.01-10.00 ppm.**
- **Cousins confirmed the release of a volatile substance from ripened oranges that hastened the ripening of stored unripened bananas. Later this volatile substance was identified as ethylene, a gaseous PGR.**
- **Crocker** et al (1935) recognised ethylene as a plant hormone.
- **Bery & Theman** (1962) established that ethylene is a endogenous hormone which controls the fruit ripening.
- Ethylene regulates so many physiological processes, so it is one of the most widely used PGR in agriculture. The most widely used compound as source of ethylene is ethephon.

Practical application and physiological effects of Ethylene:

1. **Ripening of fruit: Ethylene play an improtant role in the ripening of various fruits. Example- Banana, Apple, Watermelon etc. Those fruits which produce ethylene during ripening are called climacteric fruits.**
2. **Influences of ethylene on plants include horizontal growth of seedlings, swelling of the axis and apical hook formation in dicot seedlings.**
3. **Ethylene promotes senescence and abscission of plant organs especially of leaves and flowers.**
4. **Ethylene breaks seed and bud dormancy, initiates germination in peanut seeds, sprouting of potato tubers.**
5. **Ethylene promotes rapid internode/petiole elongation in deep water rice plants. It helps leaves/upper parts of the shoot to remain above water.**
6. **Ethylene is used to initiate flowering and for synchronising fruit-set in pineapples. It also induces flowering in mango.**
7. **Ethephon hastens fruit ripening in tomatoes and apples and accelerates abscission in flowers and fruits (thinning of cotton, cherry, walnut).**
8. **It promotes female flowers in cucumbers thereby increasing the yield**

9. **Isodiametric growth:** It promotes transverse growth but inhibits longitudinal growth in plants.
10. **Sex modification:** Exogenous application of ethylene can change the sex in plants. i.e. induction of female flowers in male plants of cucumber and hence increases the yield.
11. **Root growth: Ethylene also promotes root growth and root hair formation, thus helping the plants to increase their absorption surface.**
12. **Graviperception:** It reduces senstivity to gravity.
13. **Epinasty:** It promotes downward bending of leaves.

Abscisic acid:

- In plants, certain substances inhibit their growth. These chemical substances are called growth inhibitor.
  Carns & Adicott (1965) isolated a substance from **cotton fruits** and named it **abscisin II**.
- **Wayering (1964)** and **Robinson (1964)** seperated a substance from **leaves of Acer** which inhibited seed germination and growth of buds. It was called **Dormin**. **Inhibitor B** was also identied by a independent researcher. But later it was found that Dormin, Inhibitor B and Abscisin II are a similar chemical. Later on it was named **Abscisic acid (ABA).**
- It counteracts the influence of growth promoting hormones (auxin, gibberellins and cytokinins) **mainly antagonistic to gibberellins**

Role of Abscisic acid:

1. **It acts as a general plant growth inhibitor and an inhibitor of plant metabolism**
2. **It inhibits seed germination**.
3. **By inducing dormancy, ABA helps seeds to withstand desiccation and other factors unfavourable for growth.**
4. It inhibits synthesis of RNA.
5. **It promotes stomatal closure and increases as the tolerance of plants to various kinds of stresses. Therefore, it is also called the stress hormone.**

- Other growth inhibitors includes-**Malic hydrazide, Morphactins, Para- ascorbic acid, Coumaric acid or Cinemic acid.**