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PG AND RESEARCH DEPARTMENT OF BIOCHEMISTRY

E-NOTES

SUBJECT NAME: PLANT BIOCHEMISTRY

SUBJECT CODE: GEBC14B

UNIT-IV: Phytohormones

Phytohormones : Auxins, cytokinins, Gibberellins, ethylene- Structure, Physiological function and metabolism, Plant movement, apical dominance. Stomatal movements and morphogenesis. Photoperiodism and vernalization – flower induction, initiation and development, action of phytohormones.

Auxin Definition

Auxins are a group of naturally occurring and artificially synthesised plant hormones. They play an important role in the regulation of plant growth. Auxins were initially isolated from human urine.

Auxin means to “enlarge” or “increase”. They induce cell division, differentiation and elongation.

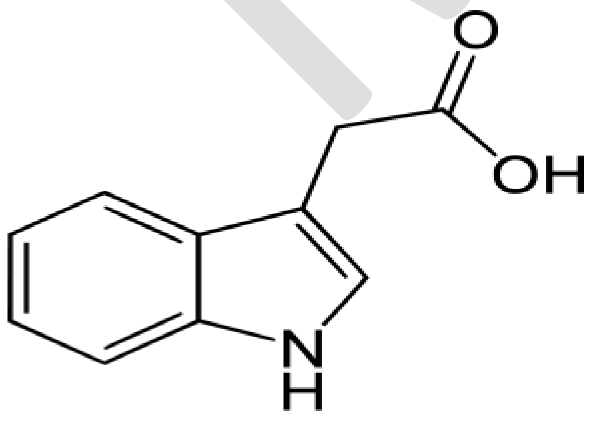
Charles Darwin detected phototropism movement (bending of plants towards light) in the coleoptile of canary grass. He observed that there was some influencer at the tip of the coleoptile, which was responsible for the bending towards the light.

Later, Frits Went isolated and named the substance as “Auxin”, which was responsible for phototropic movement in oat coleoptile.

Kenneth Thimann purified and elucidated the structure of primary auxins, e.g. IAA (Indoleacetic acid).

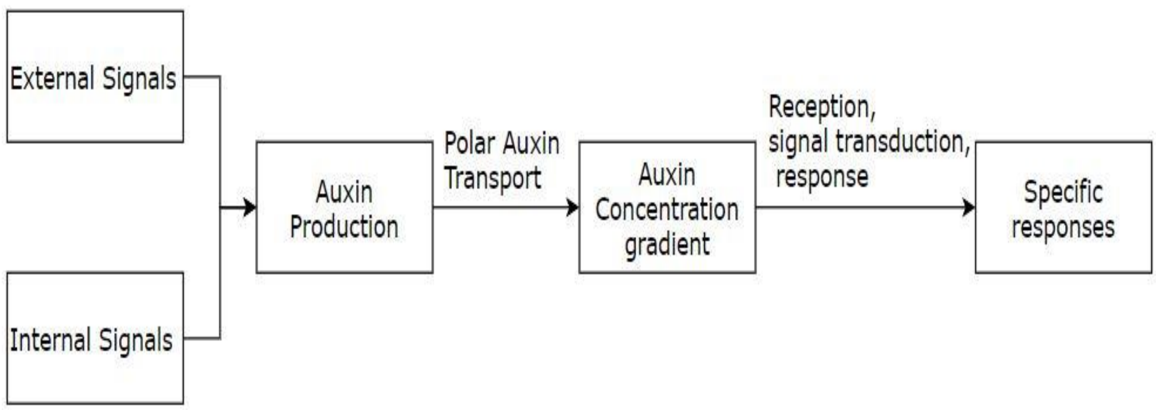
Naturally Occurring Auxins: Indole-3-acetic acid (IAA), Indole butyric acid (IBA)

Artificially synthesized Auxins: 2,4-dichloro phenoxy acetic acid (2,4-D), Naphthalene acetic acid (NAA)



Function of Auxin

- Auxin is mostly produced in the apical meristem of shoots, young leaves and seeds
- Movement of auxin is unidirectional or polar, it moves downwards from its site of production
- Polar transport results in an auxin concentration gradient, which stimulates specific responses
- Auxin specific transport proteins in the plasma membrane control the movement of auxin out of the cell
- Plant hormones act by signal transduction, eliciting more than one cellular responses
- Auxin binds to enzyme-linked receptors, which promotes catalysis of a reaction
- When auxin binds to a receptor, it initiates binding of a repressor protein for certain genes (auxin response gene) to ubiquitin, resulting in degradation of repressor protein and the transcription of auxin response genes progresses leading to cellular growth and development



Auxin Function

1. **Cell Elongation:** Auxin promotes elongation in shoots and coleoptiles. Plasticity of the cell wall is increased by acidification
2. **Cell Division and Differentiation:** Auxin promotes healing. It helps in cell differentiation and regeneration of vascular tissues (phloem, xylem)
3. **Callus Formation and Morphogenesis:** Auxin along with cytokinin induces callus formation in explant and stimulates morphogenesis

4. **Secondary Growth:** Auxin promotes secondary growth and induces cell division in the vascular cambium
5. **Root Initiation on Cuttings:** For asexual propagation, NAA is used to initiate root formation in the stem cuttings
6. **Apical Dominance:** When the growth of apical meristem inhibits the growth of axillary buds, the phenomenon is known as apical dominance. When the shoot tip is removed, it induces the growth of lateral buds. This is used to promote branching, e.g. in hedge-making and tea plantations
7. **Parthenocarpy:** When auxin is applied to some flowers, it induces parthenocarpy, i.e. ovary enlarges and develops into seedless fruit (unfertilized). Seedless tomatoes are widely produced by this method
8. **Fruit development:** Auxin is produced by seeds and it stimulates fruit development with gibberellins and delays senescence
9. **Flowering:** It delays the senescence of flowers. A high concentration of auxin promotes femaleness in some of the plants. It promotes flowering in litchi and pineapples
10. **Herbicides:** Synthetic auxins, e.g. 2,4-D and 2,4,5-T are widely used to kill weeds. It does not affect grasses (monocotyledons)
11. **Promotes Tropism:** Auxin induces phototropism, gravitropism and thigmotropism, i.e. movement in response to light, gravity and touch, respectively.

Phototropic movement (bending towards light) can be explained by cell elongation due to auxins. Auxin concentration increases towards the shaded side due to auxin migration. It results in more cell elongation at the shaded side than the side exposed to light.

Gibberellins Definition

"Gibberellins are any group of plant hormones that stimulate elongation of the stem, flowering and germination."

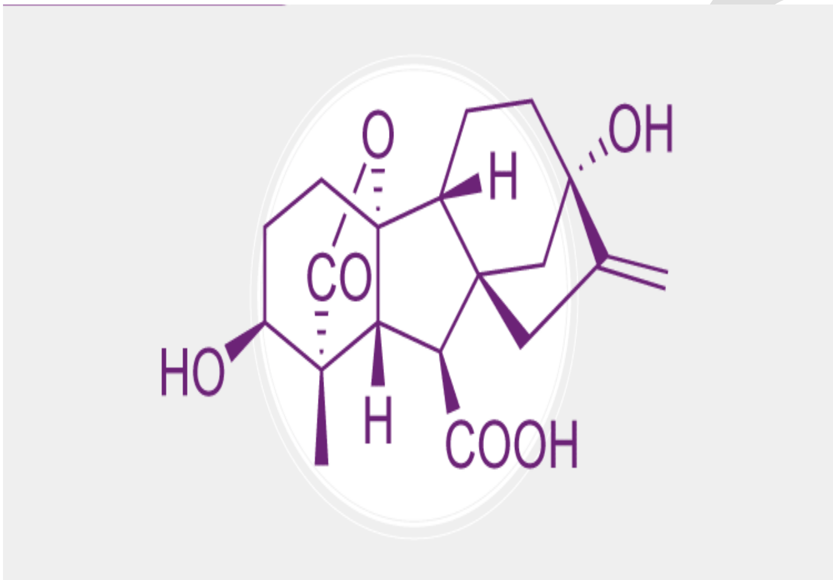
What are Gibberellins

Gibberellins are the plant growth regulators involved in regulating the growth and influencing different developmental processes which include stem elongation, germination, flowering, enzyme induction, etc.

Gibberellins have different effects on plant growth and the stem elongation is the most dramatic amongst all. The stem starts to grow when it is applied in low concentration to a bush. The internodes grow so long that the plants become indistinguishable from climbing. The Gibberellins overcome the genetic limitations in different dwarf varieties.

There are more than 70 gibberellins isolated. They are GA1, GA2, GA3 and so on.
GA3 Gibberellic acid is the most widely studied plant growth regulators.

Gibberellin Structure



Gibberellin Structure

Gibberellin is a diterpenoid. It forms the basis of molecules such as vitamins A and E. The figure above shows the structure of the Gibberellin A1, the first identified gibberellin.

The structure of all the gibberellins is the same with several side groups attached. These groups determine the unique functions of gibberellins in different tissues.

Function of Gibberellins

Seed Germination

Some seeds that are sensitive to light such as tobacco and lettuce exhibit poor germination in the absence of sunlight. Germination begins rapidly if the seeds are exposed to the sunlight. If the seeds are treated with gibberellic acid, the light requirement can be overcome.

Dormancy of Buds

The buds that are formed in autumn stay dormant until next spring. This dormancy can be overcome by treating them with gibberellin.

Root Growth

Gibberellins have almost no effect on the growth of roots. However, some inhibition of growth can occur at a higher concentration in a few plants.

Elongation of the Internodes

Internodes elongation is the most pronounced effects of gibberellins on plant growth. In many plants such as dwarf pea and maize, the genetic dwarfism can be overcome.

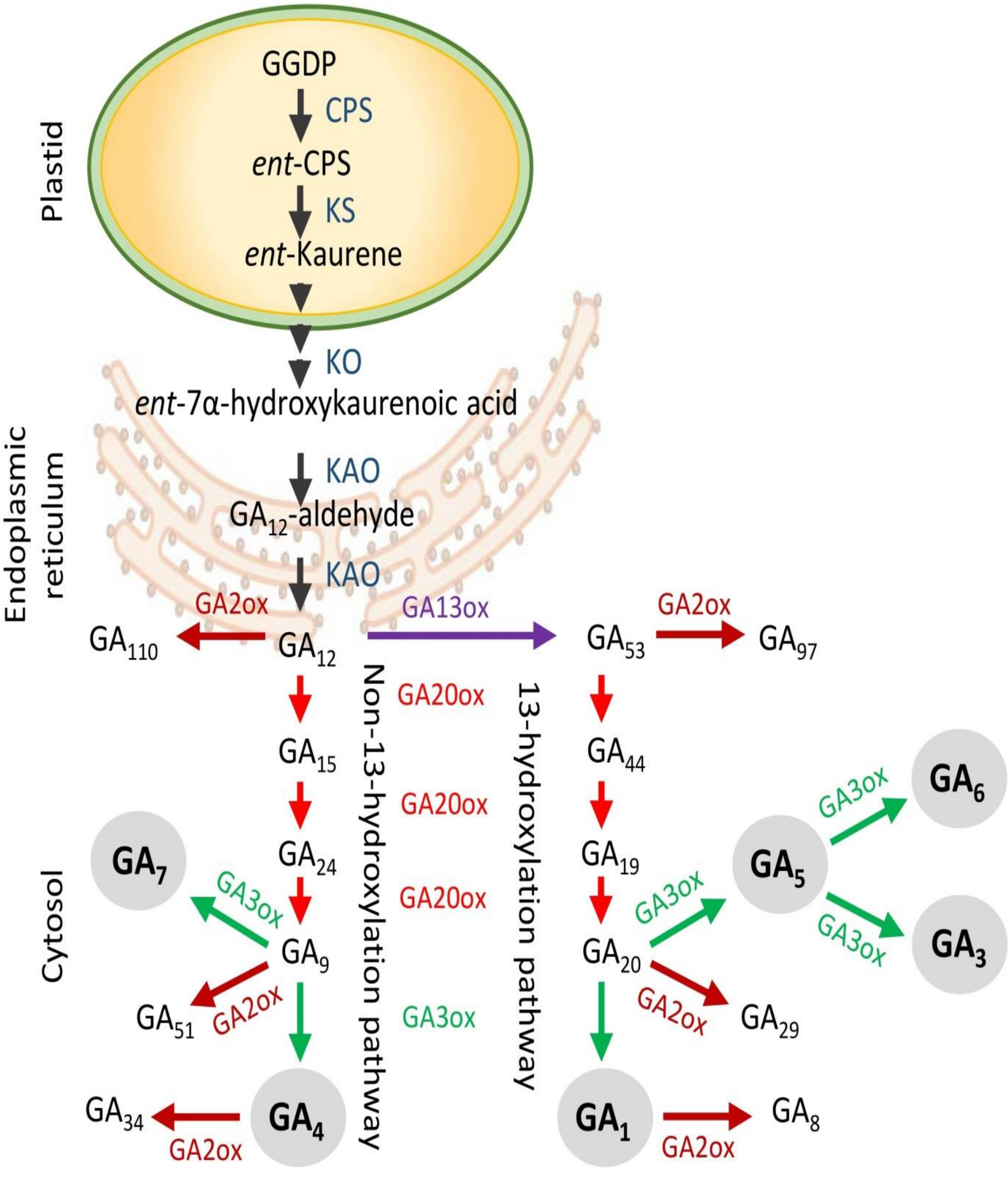
For example, the dwarf pea plants have expanded leaves and short internodes. But the internodes expand and look like tall plants when treated with gibberellin.

Gibberellins exhibit their impact by altering gene transcription.

The steps of gibberellin functions are mentioned below:

- The GA enters the cell and binds to a soluble protein receptor.
- This binds to a protein complex (SCF) that attaches ubiquitin to one or the other DELLA proteins.
- This activates the destruction of DELLA proteins through proteasomes.
- The destruction of DELLA proteins releases the inhibition and gene transcription starts.

This procedure is amongst different cases in biology where the pathway is turned on by inhibiting the pathway. However, most of the proteins that are involved differ according to circumstances, both auxin and gibberellins influence gene expression by a common mechanism of repression relief.

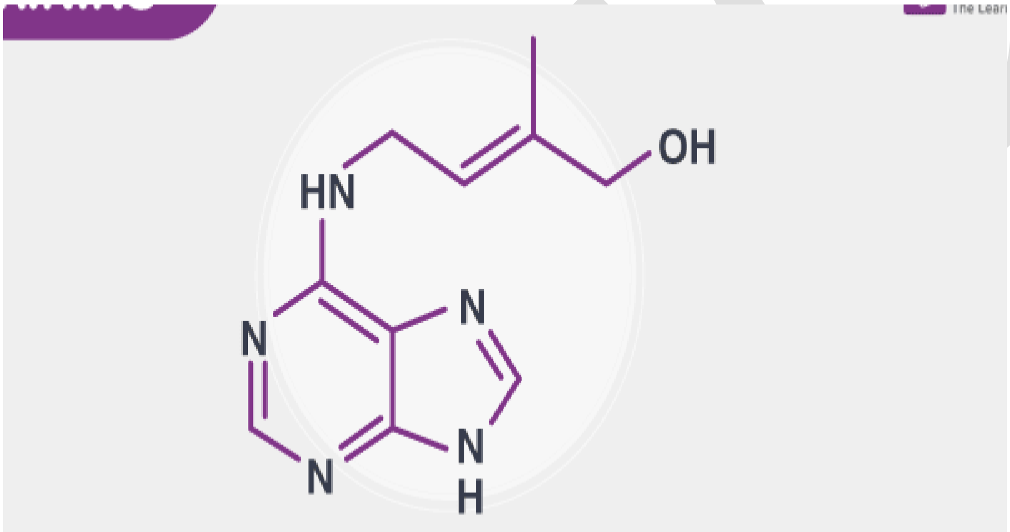


Plastid
GGDP
CPS
ent-CPS
KS
ent-Kaurene
KO
ent-7α-hydroxykaurenoic acid
Endoplasmic reticulum
KAO
GA12-aldehyde
KAO
GA2ox
GA110
GA12
GA13ox
GA53
GA2ox
GA97
GA20ox
GA15
GA20ox
GA24
GA20ox
GA9
GA3ox
GA44
GA19
GA20
Non-13-hydroxylation pathway
13-hydroxylation pathway
Cytosol
GA7
GA3ox
GA51
GA2ox
GA4
GA34
GA2ox
GA3ox
GA5
GA3ox
GA6
GA3ox
GA3
GA2ox
GA29
GA1
GA2ox
GA8

Cytokinin Definition

Cytokinin, along with auxin, is counted as a vital growth factor. A plant requires both of these PGRs for the very survival of the embryo. Hence, the essence that cytokinin gathers is irreplaceable. We can define cytokinin as the plant growth factor that promotes cell division. Cytokinins are known to promote the process of cytokinesis in conjunction with auxins. There are several properties credited to this hormone, such as wound healing, abscission in plants, cell enlargement, feminizing effect, promotion of shoot growth over root growth, and many more.

Cytokinins



Cytokinins Functions

There are several functions assigned to this plant hormone. So, when asked what is the role of cytokinin hormone in plants, you can list any of these.

1. **Role in cell division**
   - Cytokinins regulate both G1 to S phase transition and G2 to M phase transition in the cell cycle.
   - Cytokinins are responsible for the positive regulation of SAM (shoot apical meristem) and the negative regulation of RAM (root apical meristem).
2. **Morphogenesis**

- Cytokinins are capable of mediating callus differentiation into shoots and roots.
- This differentiation isn't the sole capability of auxins. Only auxins acting in presence of cytokinins can mediate this process.
- Auxin/Cytokinin Ratio=HIGH (leads to root initiation)
- Auxin/Cytokinin Ratio=LOW (leads to shoot initiation)
- Auxin/Cytokinin Ratio=1 (leads to proliferation of undifferentiated cells, as in crown gall formation)

3. Inhibition of Apical Dominance

- Auxins via strigolactones lead to BRC1 protein production. BRC1 is responsible for lateral growth suppression.
- It is at this intracellular level that cytokinin acts and inhibits BRC1.
- Since no lateral growth is suppressed now, it can express itself effectively. This, in turn, paves way for inhibition of apical dominance.

4. Chloroplast maturation

- Cytokinins are responsible for the maturation of etioplasts (protochlorophyll) to chloroplasts (chlorophyll).
- Cytokinins trigger the enzymes and structural proteins responsible for the formation of thylakoid structures and systems and photosynthesis machinery required for chloroplast maturation.

5. Delaying senescence

- Cytokinins are responsible for delaying senescence in plants.
- The mechanisms for this process haven't been elucidated yet.
- This is the reason cytokinins are also called 'anti-aging hormones".

6. Promotes feminizing effect

7. Promotes root initiation in plant cuttings (like in callus)

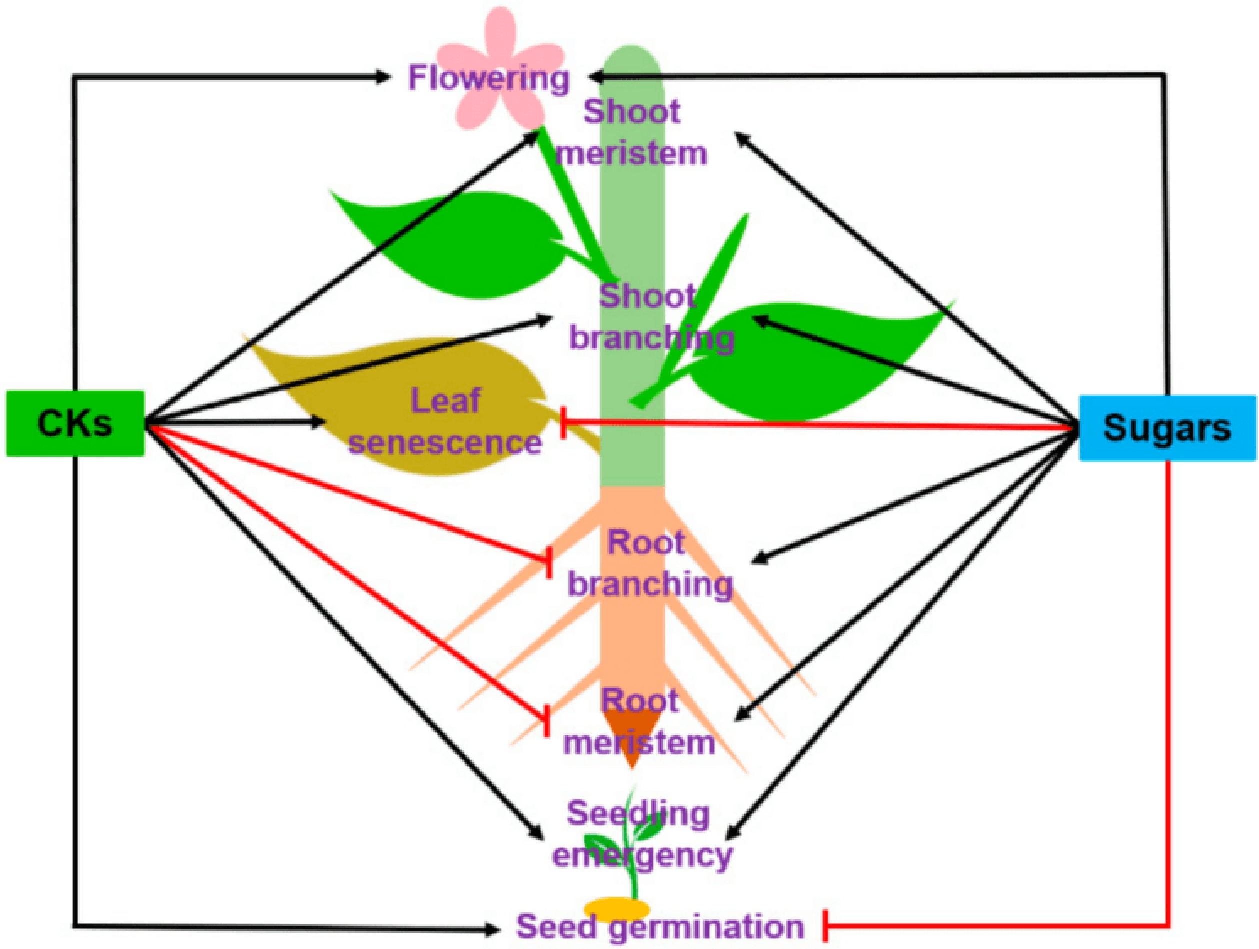
8. Promotes flowering in plants

9. Promotes phloem transport

10. Promotes shelf life of vegetables and cut flowers

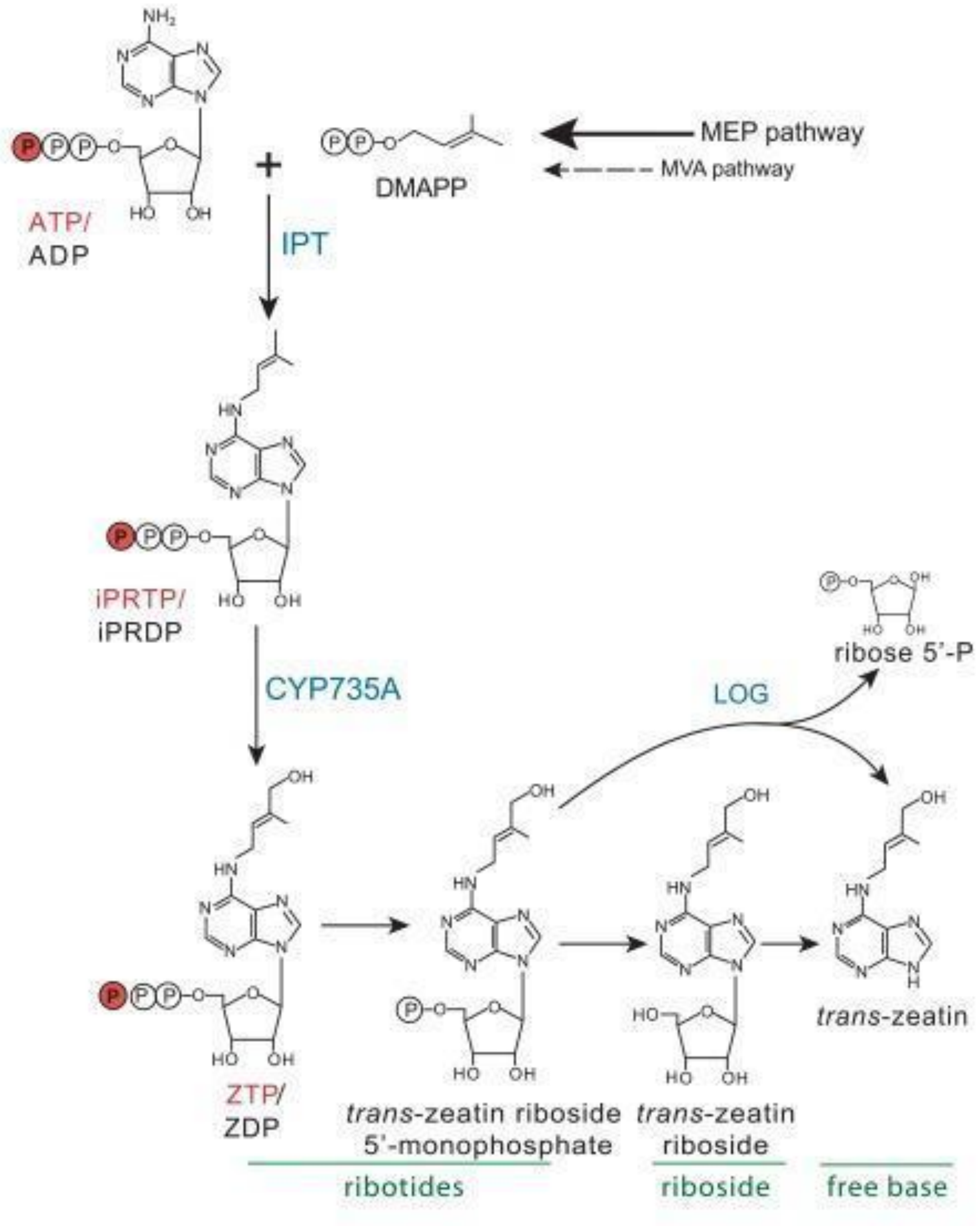
11. Inhibits dormancy in plants

Note: Cytokinin does not help in the promotion of leaf senescence. Rather it suppresses leaf senescence.

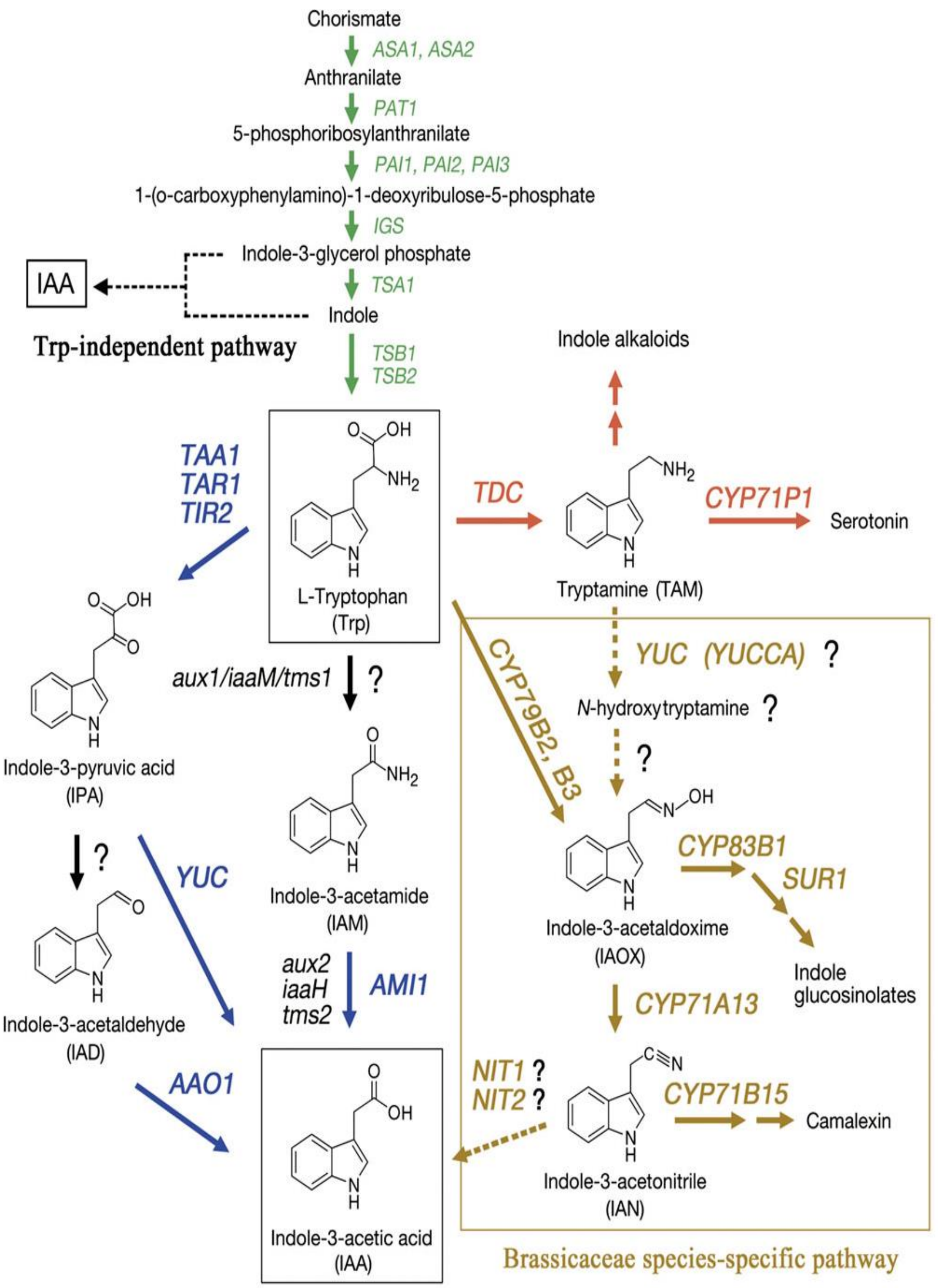


Biosynthesis

1. The cytokinin biosynthesis is maximum in the meristematic regions (actively dividing and growing regions).
2. Pathway for biosynthesis: ISOPRENOID pathway.
3. The enzyme involved in the very 1st reaction in cytokinin synthesis: Adenosine phosphate-isopentenyltransferase (IPT)
4. Precursor of cytokinin= Purine (adenine or guanine)
5. Various substrates for the biosynthesis of isoprene cytokinins= ATP, ADP, AMP, DMAPP, HMBPP
6. Rate-limiting step in the biosynthesis of cytokinins = Biosynthesis of isoprene cytokinins
7. Only plant hormone that plays role in the regulation of biosynthesis of cytokinin= Auxin



MEP pathway
MVA pathway
DMAPP
ATP/
ADP
IPT
iPRTP/
iPRDP
CYP735A
LOG
ribose 5'-P
ZTP/
ZDP
trans-zeatin riboside
5'-monophosphate
trans-zeatin
riboside
trans-zeatin
ribotides
riboside
free base



...e pathways for IAA biosynthesis in plants. Green arrows indicate the tryptophan synthetic pathway

Ethylene

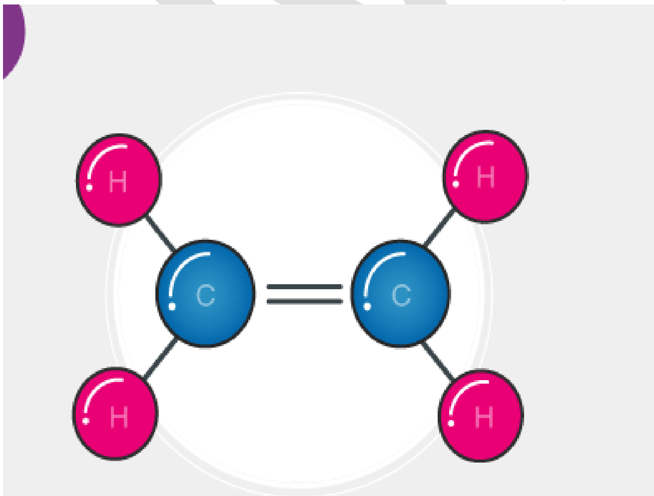
Ethylene is a group of plant growth regulators which are widely used for ripening fruits and for the production of more flowers and fruits.

Ethylene is a small hydrocarbon, the colourless flammable gas which is denoted by a formula C_2H_4 or $H_2C=CH_2$. Ethene is the IUPAC name for ethylene. It has a "sweet and musky" odour when it is pure. It is the simplest alkene and also the second simplest unsaturated hydrocarbon C_2H_2.

Ethylene is abundantly used in the chemical industry, and the polyethene is extremely produced using ethylene. Further, ethylene is also used in agricultural practices to ripen fruits, germination of the seed, etc.

Ethylene Structure

Ethylene is a hydrocarbon. As the name suggests it has four atoms of hydrogen bonds that are paired with carbon atoms with a double bond. All these six atoms H-C-H form an angle of 117.4°, close to the 120° to form a hybridized carbon sp^2. Further, the bond is rigid about the C-C bond with high energy process by breaking the π-bond.



Ethylene Formula

The ethylene formula is written as:

C_2H_4

or

$H_2C{=}CH_2$

Ethylene as a Plant Hormone

The ethylene in a plant growth regulator that acts as a trace level of entire plant life by regulating and stimulating the opening of flowers, fruit ripening and shedding of leaves.

During the ancient days, Egyptians used this technique with gash figs to stimulate ripening. While the Chinese burn incense in a closed room to fasten the ripening of pears. This plant hormone is essentially produced in all parts of grown plants including roots, stems, tubers, leaves, flower, fruits and seeds.

Ethylene is the most widely used plant growth regulator as it plays a vital role in:

- Stimulating fruit ripening.
- Helps in determining the sex of a flower.
- It is involved in the production of female flowers in a male plant.
- Promotes Apo-geotropism in roots.
- Helps in the root initiation and pollination.
- Ethylene increases the speed of leaf and flower senescence.
- Induces seed germination.
- Induces root growth to increase the capability of water and mineral absorption.
- Stimulates epinasty.
- Induces a climacteric rise in respiration in some fruits.
- Effects gravitropism.
- Stimulates nutational bending.
- Inhibits stem growth.
- Interference with auxin transport.
- Induces flowering in pineapples.

Ethylene Function

Following are the important function of ethylene:

Growth

Ethylene stimulates horizontal growth and the swelling of the axis. It inhibits the growth in the longitudinal direction.

Gravity

It reduces the sensitivity to gravity. The stems become positively geotropic and the leaves and flowers undergo drooping.

Senescence

It speeds up the senescence of flowers and leaves.

Abscission

Ethylene stimulates the abscission of flowers, leaves, fruits and other parts of the plant. It helps in the formation of hydrolases.

Apical Dominance

It prolongs dormancy of lateral buds and promotes apical dominance.

Breaking Dormancy

It breaks the dormancy of seeds, buds and storage organs.

Ripening of Fruit

Ethylene induces artificial ripening of climacteric fruits such as banana, mango, apple, etc.

Flowering

Ethylene induces flowering in plants like pineapple and mango. In some plants, it also causes fading of flowers.

Photoperiodism: Learn Definition, Types, Mechanism

Photoperiodism: What is photoperiodism? This is one question which usually comes to students' minds when studying the concept. The concept is not a hard one but it is one which needs proper focus to understand properly. Photoperiodism occurs in plants and animals and it is a periodic phenomenon. Students will get a proper understanding of the concept wehn dwelling into the chapter deep.

This article has provided all the important topics and details that are associated with photoperiodism. After reading this article, students will be able to confidently define photoperiodism, types of photoperiodism and so on. Keep reading this article to master the concept of photoperiodism.

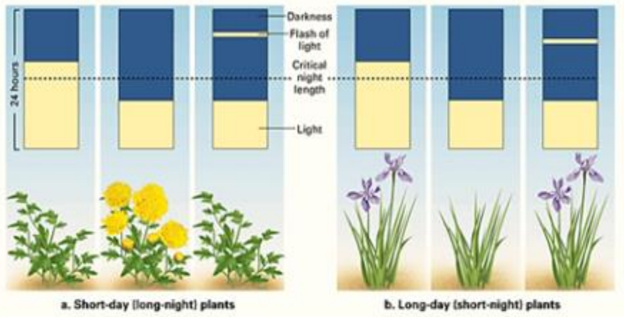
What Is Photoperiodism?

"Effect or requirement of the relative length of day and night on flowering is called Photoperiodism." (Source: Arihant Biology Handbook)

The term Photoperiod has been derived from the word 'Photo' means 'light' and 'period' means 'length of time'. Photoperiodism is the typical movement in plants under the influence of the availability of light to induce flowering. Plants respond to light, both intensity and quality, to convert from vegetative to flowering.

Discovery of Photoperiodism

Garner and Allard first studied Photoperiodism. They took a tobacco mutant, i.e., 'Maryland mammoth', for their experiment. They observed that this tobacco mutant flowered at different times at different places. After controlling other factors like temperature, nutrition, etc., they concluded that it was the length of the day which affected flowering. Most of the plants would initiate flowering only when subjected to light for lesser or more than a certain period called 'critical photoperiod.'



Photoperiodism Plant Types

Depending on the light requirement, plants can be divided into the following categories:

1. Short Day Plants
2. Long Day Plants
3. Day Neutral Plants
4. Intermediate Plants
5. Short – Long Day Plants
6. Long – Short Day Plants

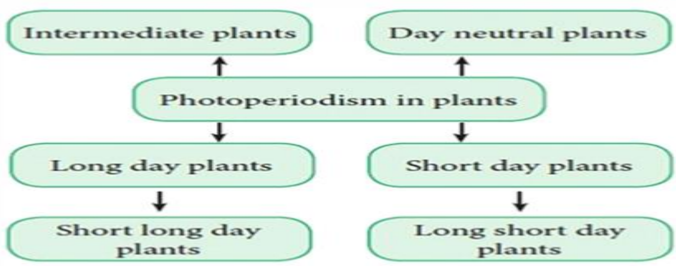


Fig: Classification of Plants based on Photoperiodism

1. Short Day Plants (SDP)

(a) These plants flower only under day lengths shorter than the critical period.

(b) They require a short daylight period of 8–10

hours and a continuous dark period of about 14–16

hours to flower.

(c) They do not flower when the day is long and the night is short.

(d) They do not flower if the dark period is briefly interrupted by red light.

(e) They are also known as long night plants.

(f) Examples: *Xanthium strumarium* (Cocklebur), *Nicotiana tabacum*, *Glycine max* (Soyabean), *Coffea arabica* (Coffee), Chrysanthemum, etc.

2. Long Day Plants (LDP)

(a) These plants flower only under day length more than the critical period.

(b) They require longer daylight, usually 14–16

hours, for subsequent flowering.

(c) They require a relatively short period of darkness.

(d) The light period is critical in LDP plants.

(e) They require prolongation of the light period for a brief exposure to light during the dark periods that bring about flowering.

(f) They are also known as short night plants.

(g) Examples: *Beta vulgaris* (Beet), *Raphanus sativas* (Reddish), *Spinacia oleracea* (Spinach), *Daucus carota* (Carrot), *Allium cepa* (Onion), *Triticum aestivum* (Wheat), *Avena sativa* (Oat), *Zea mays* (Maize), *Saccharum officinarum* (Sugarcane).

3. Day Neutral Plants (DNP)

(a) These plants do not require any specific day or night period for flowering.

(b) They can blossom throughout the year.

(c) Examples: *Helianthus annuus* (Sunflower), *Lycopersicon esculentum* (Tomato), *Cucumis sativus* (Cucumber), *Gossypium hirsutum* (Cotton), *Pisum sativum* (Pea), *Capsicum annuum* (Chilli).

4. Intermediate Plants (IP)

(a) These plants flower within a definite range of light hours.

(b) They cannot flower above and below this range.

(c) Example: Wild Kidney Bean.

5. Short–Long Day Plants (S-LDP)

(a) They are generally long-day plants.

(b) They require short photoperiods for floral initiation and long photoperiods for blossoming.

(c) They usually flower between spring and summer.

(d) Examples: *Triticum vulgare*, *Secale cereale* (Rye), *Trifolium repens*, etc.

6. Long-Short Day Plants (L-SDP)

(a) They are generally short-day plants.

(b) They require long days for floral initiation and short days for blossoming.

(c) They usually flower between summer and autumn.

(d) Examples: *Cestrum nocturnum*, Bryophyllum, Kalanchoe.

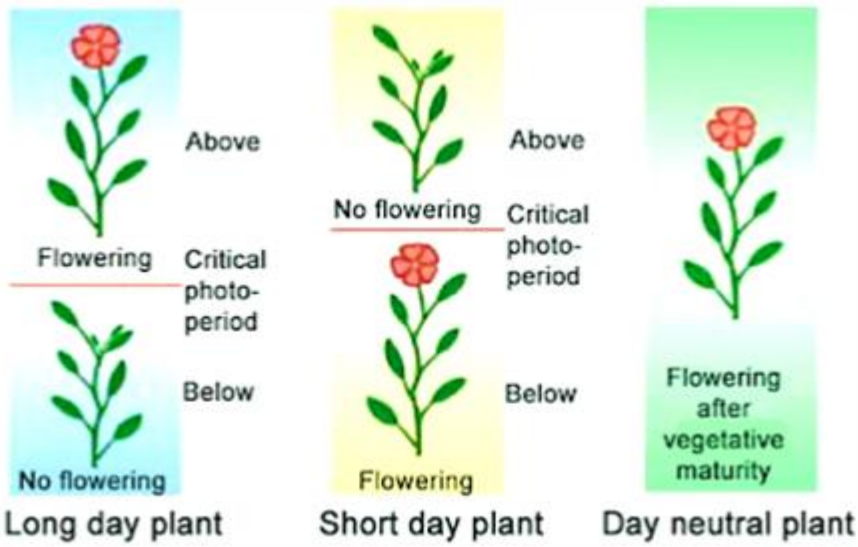


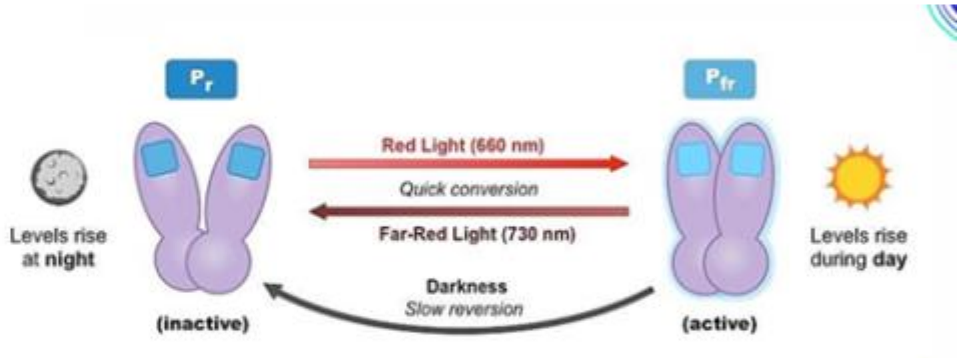
Fig: Photoperiodism Plant Types

Role of Phytochrome in Photoperiodism

Phytochrome is a blue-green pigment that acts as a photoreceptor and helps in photoperiodic induction. Phytochromes exist in two forms: active form (Pfr)

and inactive form (Pr). The Pr absorbs red light (660nm), and Pfr absorbs far-red light (730nm). During the daytime, two forms Pr and Pfr interchange till they reach an equilibrium. The Pfr is the biologically active form. It is predominant during the day as more red light is present. The Pfr acts as the switch that turns on flowering or seed germination. The Pfr breaks down into the Pr by absorbing far-red light. The response is determined by the length of the night period. In the absence of light, the Pr will gradually convert to Pr. So during the night, the Pr form is predominant. The inactive Pr is converted into active Pfr

by absorbing red light.



Vernalization

Vernalization is derived from a Latin word "vernus" which means "of spring". It means to make "spring-like". It is the induction of the flowering process of the plant by exposure to the long periods of cold winter or such conditions. Once this process takes place, plants develop the capability of flowering. However, they may necessitate extra seasonal weeks of growing before they flower.

In the process of vernalization, flowering is facilitated by a cold treatment provided to a completely hydrated seed or to a growing plant. As a result of the process of vernalization, the vegetative phase of the plant is restricted, which leads to early flowering. In the absence of cold treatment, those plants which need vernalization exhibit delayed flowering or stay vegetative.

Types of Vernalization

Vernalization can be of the following types –

- Obligate vernalization

Plants must be exposed to lower temperatures for a specified period of time. Example – Biennial plants (cabbage)

- Facultative vernalization

Upon being exposed to lower temperatures, flowering in plants appears earlier. Example – winter annual triticale.

Mechanism of Vernalization

Through vernalization, there is an advancement in the process of blooming as a result of the delayed period of low temperatures, for instance, that which is attained in winter. To describe the mechanism of vernalization, there are two main hypotheses –

- Phasic development theory
- Hormonal theories

Phasic Development Theory

As per this hypothesis, there is organization of stages in the plant's improvement. Each stage is under the impact of environmental elements such as light, temperature etc. Here, in turn, there are two main stages –

- Thermostage – depends on temperature, wherein vernalization accelerates thermostat. Thermostage is the vegetative phase requiring low heat, aeration and enough dampness
- Photostage – necessitates high temperature. Here, vernalin assists in producing florigen.

Hormonal theories

As per this hypothesis, the freezing treatment propels the development of a floral hormone referred to as vernalin. Such a hormone is imparted to various parts of the plant. The vernalin hormone diffuses from the vernalized plants to the unvernalized plants, prompting blooming.

Vernalization in Plants – Site of vernalization

The metabolically active apical meristems are the sites of perception of temperature to initiate flowering. The younger leaves are more susceptible to the process of vernalization. The shoot apex of mature stems or embryo of seeds receives low temperature stimulus. Consequently, the stimulus of this process is perceived by meristematic cells only such as the shoot tips, root apex, developing leaves, embryo tips, etc.

Vernalization examples

Some food plants have a spring or winter variety, wherein the spring variety is typically planted in the spring. Hence, flowers produce grains towards the end of this season. However, the winter variety is planted in autumn wherein it germinates in winter, grows in the spring and is harvested the following summer. Biennial plants require two years for flowering as they grow stem, leaves and roots in the first year and for the cold months enter into dormancy. In the subsequent months, it requires a period of cold or vernalization for the process of flowering. Gradually, biennial plants flower producing fruits and in the following summer/spring, they die. Some examples are cabbages, carrots, and sugarbeets.

Predominantly, garlic is planted through winter, as it necessitates cold temperature (vernalization). In the event where the temperature is not low enough for a particular duration of time, garlic does not shape the bulbs, winter wheat does not blossom and frame grain in the following season.

Devernalization

Devernalization is the reversion of the process of vernalization as a result of being exposed to higher temperatures. This process is affected by treating vernalized buds or seeds with a high range of temperature. It was in 1957 that Lang et al demonstrated that applying gibberellins coils substitute the cold treatment for vernalization in some biennial plants.

Factors affecting vernalization

The process of vernalization is affected by the following factors –

- Age of the plants
- Site of vernalization
- Provision of suitable low temperature
- Oxygen
- Duration of being exposed
- Water

Significance of Vernalization

- This process can aid in shortening the vegetative phase of a plant and bring about early flowering, which is applicable to temperate plants and some tropical plants
- Through vernalization, Kernel wrinkles of Triticale can be eliminated
- It elevates the yield, resistance of plants to fungal diseases
- It increases the cold resistance of plants
- Aids in improvement of crop
- Vernalization in biennials can induce early flowering and early fruit setting
- The process of flowering could be induced by grafting which is used in the process of horticulture