CHAPTER 04

Plant Growth and Development

In this Chapter...

- Plant Growth Regulators (PGRs)
- Discovery of Plant Growth Regulators
- Physiological Effects of Plant Growth Regulators
- Interaction between Growth Regulators

Plant Growth Regulators (PGRs)

It has been suggested from sufficient evidences that the plants have certain chemical substances, which help to control the mechanism of growth.

Plant growth regulators are variously described as plant growth substances or plant hormones or phytohormones. These are the small, simple organic molecules of diverse chemical composition produced naturally in higher plants that control the growth and other physiological functions. These are required in a very small amount by the plant.

Classification of Plant Growth Regulators

The plant growth regulators fall under the following categories of chemical groups

(i) **Indole Compounds,** e.g. Indole-3- Acetic Acid (IAA)

(ii) **Adenine Derivatives**, e.g. N_6 -furfuryl amino purine, kinetin

(iii) **Carotenoid Derivatives,** e.g. Abscisic Acid (ABA)

(iv) **Terpenes,** e.g. Gibberellic Acid (mainly GA_3)

(v) **Gases,** e.g. Ethylene (C_2H_4).

On the basis of functions, they perform in a living plant body in broad terms, PGRs are divided into two groups

1. Plant Growth Promoters

PGRs that exhibit growth promoting activities such as cell division, cell enlargement, tropic growth, pattern formation, flowering, fruiting, seed formation, etc., are called **plant growth promoters**, e.g. auxins, gibberellins and cytokinins.

2. Plant Growth Inhibitors

These primarily function in response to wounds and stresses of biotic and abiotic origin. These are also involved in various growth inhibiting processes like dormancy and abscission, e.g. abscisic acid.

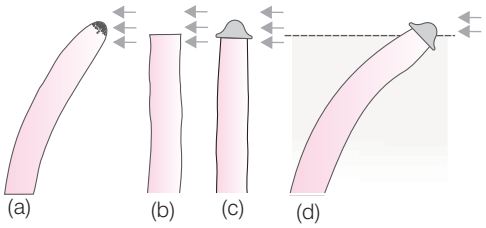
Note *The gaseous form of PGR (like ethylene), can fit in either category and may function both as promoter and inhibitor. But largely, it functions as an inhibitor of growth activities.*

Discovery of Plant Growth Regulators

It is interesting to know that the discovery of all five major groups of plant growth regulators have been done accidentally. All these help in understanding the phenomenon of development and abnormal behaviour in plants.

1. Discovery of Auxin

- This is the **first growth hormone** to be discovered. The knowledge of this hormone came into existence through the observation of **Charles Darwin** and his son **Francis Darwin**.
- They observed that the coleoptiles of canary grass responded to unilateral source of light (phenomenon known as photoperiodism) by growing towards it.
- After performing series of experiments, they came to the conclusion that **coleoptile tip** was the site that has the property of transmittable influence due to which bending of complete coleoptile was caused. The first PGR, i.e. auxin was isolated by **FW Went** in 1928, from the coleoptile tip of oat seedlings.



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

2. Discovery of Gibberellins

- In early part of 20th century, the **bakanae** (foolish seedlings disease of rice), was reported to be caused by a fungal pathogen, *Gibberella fujikuroi*.
- Symptoms shown by the infected plant were elongated stems, little or no production of grains and plant became weak. Thus, it was later identified that the active substance involved here was gibberellic acid.
- The Japanese plant pathologist **E Kurosawa**, reported the appearance of symptoms of the disease in uninfected rice seedlings when they were treated with **sterile filtrate** of the fungus.

3. Discovery of Cytokinins

- **F Skoog** and his coworkers, studied the nutritional requirements of tissue culture. They made nutrient medium derived from the internodal segments of tobacco stems. They observed that from that internodal segments, a **callus** (i.e. a mass of undifferentiated cells) proliferated, only when the nutrient medium containing auxin was supplemented with the extract of vascular tissues or yeast or coconut milk (water of endosperm of coconut).
- It was later found that the active substance present in coconut milk is a modified form of adenine which was crystallised and identified as **kinetin**. Further the compounds that exhibited kinetin like properties were termed as **cytokinins**.

4. Discovery of Abscisic Acid

With the progression in the research on plant growth regulators, three independent researchers reported the purification and chemical characterisation of three different kinds of inhibitors (during mid 1960), i.e. **inhibitor B**, **abscission II** and **dormin**. Later, these were proved to be chemically identical in nature and were named as Abscisic Acid (ABA).

5. Discovery of Ethylene

Cousins (1910), confirmed the release of a volatile substance from ripened oranges that enhance the ripening of stored unripened bananas. This volatile substance was later identified to be a gaseous plant growth regulator, i.e. ethylene.

Physiological Effects of Plant Growth Regulators

All five categories of plant growth regulators discussed above, have the following physiological effects on the growth of the plant

1. Auxins

- Auxin (Gk. *auxein* to grow) was initially isolated from the urine of human, but later on, their presence was also found in plants and was proved to be the first PGR ever known. The real plant auxin is chemically known as **Indole -3-Acetic Acid** (IAA).
- The term is also applied to other natural and synthetic compounds having various growth regulating properties. Production of auxin generally takes place in the region of **growing apices** of the stems and roots from where they migrate to the site of their action.

Note *Auxins can move only through cell to cell by diffusion, i.e. they cannot move through vascular tissues.*

Types of Auxins

There are generally two basic categories in which auxins are divided

i. Natural Auxins

They occur naturally in plants and fungi, e.g. Indole Acetic Acid (IAA) and Indole Butyric Acid (IBA).

ii. Synthetic Auxins

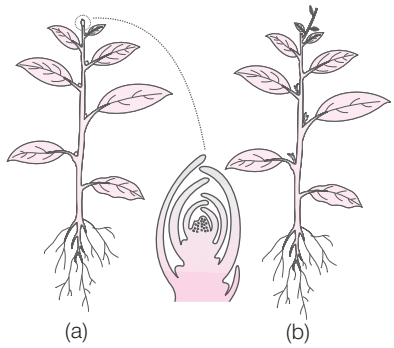
These are prepared from synthetic compounds that cause several responses to IAA. They can easily move in all directions inside the plants, e.g. Naphthalene Acetic Acid (NAA), 2, 4- dichlorophenoxyacetic acid (2, 4-D).
All these types of auxins are extensively been used in agricultural and horticultural practices.

- The compounds, which can be converted into auxins, are called **auxin precursors**, e.g. IAA is synthesised from tryptophan amino acid hormone.
- The compounds, which inhibit the actions of auxins, are termed anti-auxins.

Functions of Auxins

Auxins perform several functions, these are as follows

(i) **Apical Dominance** Presence of auxin in higher concentration (in higher plants) in shoot apex, promotes apical dominance. It is seen commonly in many vascular plants, the presence of apical buds does not allow the lateral buds to grow. They only start developing into branches when the apical bud is removed.



Apical dominance in plants, (a) A plant with apical bud intact, (b) A plant with apical bud removed

(ii) **Initiation of Roots** In contrast to stem, higher concentration of auxin inhibits the elongation of shoots, but it initiates more lateral branches of roots.

(iii) **Inhibition of Abscission** Natural auxins delay abscission of young fruits and leaves and also used to control pre-harvest fruit drop.

(iv) **Cell Elongation** Auxin stimulates the elongation of cells of shoots.

(v) **Promotes Flowering** Presence of auxin helps in promoting flowering in some plants, e.g. pineapple, litchi, etc.

(vi) **Parthenocarpy** Auxins are sprayed on to the unpollinated pistil and make them develop into parthenocarpic fruits, which carry a better market values.

(vii) **Metabolism** Application of auxin can enhance metabolism due to mobilisation of nutrients and growth promoting substances.

Applications of Auxins

As stated, use of synthetic auxins is widely accepted now-a-days in various agricultural and horticultural practices.

Following are the applications of auxins

(i) **Eradication of Weeds** Auxins are used as weedicides and herbicides. Application of 2, 4-dichlorophenoxy-acetic acid (2, 4-D) is widely done in order to kill dicotyledonous weeds. It does not affect mature, monocotyledonous plants.

(ii) **Helps in Cell Division** Besides cell elongation, auxin may also play important role in cell division.

(iii) **Controls Xylem and Phloem Differentiation** Auxin controls differentiation of xylem and phloem in stems and roots. There are evidences that low concentration of auxin induces phloem differentiation while higher concentration of auxin is responsible for differentiation of both xylem and phloem tissues.

2. Gibberellins

- These are another group of plant growth regulators, which are known to be weakly acidic growth hormones. There are more than 100 different gibberellins reported from widely different organisms like fungi and higher plants.
- All of them are known to be **acidic** in nature, thus they are termed as **Gibberellic Acids** (i.e. GA, GA_1, GA_2 and so on).
- However, GA_3 is the most important gibberellic acid which was first to be discovered. It is most extensively studied amongst all gibberellins.

Functions of Gibberellins

Gibberellins show various important physiological effects

(i) **Elongation of Internodes** It helps in elongation of the internodes so as to increase the height of the plant. They cause an increase in length of axis and is also used in increasing length of grapes stalks.

(ii) **Elongation of Genetically Dwarf Plants** It has been seen that if gibberellins are administered to a dwarf plant (pea, maize, etc), it may help in overcoming dwarfism. It also causes fruits to elongate and improve their shape, e.g. in apples, etc.

(iii) **Bolting** The gibberellins also help in promoting bolting (internode elongation) just prior to their reproductive phase or flowering. If gibberellin is sprayed on rosette plants like beet, cabbage, etc., these plants will show extensive internodal growth and profuse leaf development.

(iv) **Breaking Dormancy** It also helps in overcoming natural dormancy in buds, tubers, seeds, etc., and helps them to grow.

Note ***Seed Dormancy*** *Seed is said to be in the dormant state when it remains dry and non-germinating even if all conditions for germination are available. Thus, by 'breaking seed dormancy', we simply mean, to make the seed to germinate.*

(v) **Flowering** This can also be induced in long day plants by the action of gibberellins.

Applications of Gibberellins

Gibberellins, apart from showing varied physiological effects, also have numerous applications.

These are as follows

(i) **Delays Senescence** Gibberellins can delay the ripening of fruits such as citrus fruits, apples, etc. This can also be used for safe and prolonged storage of the fruits.

(ii) **Malting Process** The process of malting in brewing industry can be speeded up by the use of GA_3.

(iii) **Sugar Yield** As carbohydrate is stored in the form of sugar in the stems of sugarcane. Thus, if crop of sugarcane is sprayed with gibberellins. It results in increased internodal length of the stem. This enhances the increase in the yield of sugarcane as much as 20 tonnes per acre.

(iv) **Early Seed Production** Plants like *Cycas* and *Pinus* when sprayed $\mathbf{GA_3}$ at juvenille stage, hastens the maturity period of them leading to early seed production.

3. Cytokinins

- These are growth promoters that are **basic** in nature. They have specific effects on cytokinesis (division of cytoplasm) and were discovered as **kinetin** (a modified form of adenine, a purine).
- **Lethometal** (1964), while searching for a substance with cytokinin like activity, isolated **zeatin** from corn kernels and coconut milk. Now presently, several naturally occurring cytokinins and some synthetic compounds having cell division promoting activities have been identified after the discovery of zeatin.

Region of Synthesis of Cytokinins

Natural cytokinins are known to be synthesised in the regions where rapid cell division takes place, e.g. root apex, developing shoot, buds, young fruits, etc., out of these roots are the major source of synthesis of cytokinins, from where, they move upward through xylem.

Naturally Occurring Cytokinins

- **Coconut Milk Factor** The liquid endosperm of coconut is known as coconut milk. This contains some factors that show kinetin like activity that enhance and stimulate the growth in many plant tissues (*in vitro*). All these factors are collectively called as **'coconut milk factor'**. These represent an example of naturally occurring cytokinins.
- **Zeatin** It is also a naturally occurring cytokinin, isolated from maize grains. It is remarkably known to be more active than any other cytokinin.

Functions of Cytokinins

Cytokinins have following remarkable physiological effects

(i) **Promotes Cell Division** This is one of the most common and important biological effect of kinetin on plants, i.e. to induce cell division in the presence of sufficient amount of auxin (IAA).

(ii) **Reduces Apical Dominance** They promote the growth of lateral buds by breaking apical dominance.

(iii) **Morphogenesis** Differentiation or morphogenesis of plant tissues/organs is seen to be in control, if ratio of cytokinins and auxins is proportionate.

(iv) **Resistance** They also increase resistance of plants to high or low temperature and diseases.

(v) **Delays Senescence** These also help in delaying senescence (ageing) of leaves and other organs by controlling synthesis of protein and mobilisation of resources or nutrients.

Applications of Cytokinins

Applications of cytokinins are as follows

(i) **Tissue Culture** Cytokinins are essential for tissue culture, apart from cell division, they are also involved in **morphogenesis**.

(ii) **Shelf Life** Administration of cytokinins to harvest fruits and vegetables keeps them fresh for several days and **increase their shelf life**.

Note *Shelf life of flowers and cut shoots can also be increased by dipping them in cytokinin solutions.*

4. Ethylene

- It is a simple gaseous plant growth regulator, which is synthesised from the amino acid, **methionine**. In plants, synthesis of ethylene takes place in almost every part of the plant, i.e. roots, leaves, flowers, seeds, fruits, etc.
- Most important effect of ethylene is the promotion of **senescent changes** in the plant. Thus, it is synthesised by tissues in large amounts that undergo senescence and also by ripening fruits, due to this property, it is also known as **fruit ripening hormone**.

Functions of Ethylene

Ethylene shows various important physiological effects

(i) In dicot seedlings, ethylene influences the horizontal growth of seedling, swelling of the axis and formation of apical hook.

(ii) It is highly effective in fruit ripening. It also increases the rate of respiration. This rise in the respiration rate is called **respiratory climacteric**.

(iii) It helps in breaking seed and bud dormancy.

(iv) Initiation of germination in peanut seeds and sprouting of potato tubers is also due to the production of ethylene in plants.

(v) In deep water rice plants, ethylene promotes rapid **internode** and **petiole elongation**.

(vi) It proves to be helpful in increasing absorption surface of plants by promoting growth of root and formation of root hairs.

(vii) It also stimulates flowering in fruits like pineapple, mango and other related plants.

Applications of Ethylene

As ethylene helps in regulating these many physiological processes in plants. It is known to be the most widely used PGR in agricultural field.

Ethephon It is the most widely used compound as a source of ethylene. This tends to absorb readily in an aqueous solution and transported within the plant. This slowly releases ethylene. Functions of ethephon are as follows

(i) Ethephon is known to control fruit ripening (in tomatoes and apples).

(ii) It also helps in **accelerating abscission** in flowers and fruits (causes thinning of fruits like cotton, cherry, walnut, etc).

(iii) Helps in **promoting formation of female flowers,** thus, enhancing the yield of the fruits, e.g. cucumber.

5. Abscisic Acid (ABA)

- It is slightly acidic growth hormone that functions as a **growth inhibitor** by counteracting with other mentioned growth hormones, i.e. auxins, gibberellins and cytokinins.
  Thus, like other PGR, abscisic acid also has a wide range of effects on growth and development of plants.
- As its production is stimulated under stress (unfavourable conditions such as drought, water lodging, excessive temperature, etc), it is known as **stress hormone**. It acts antagonistically to gibberellic acid.

Note *This hormone is transported to all parts of the plants through the process of diffusion by* ***conductive channels****.*

Functions of Abscisic Acid

Abscisic acid shows various important physiological effects

(i) It has a primary role in regulating abscission and dormancy of buds and seeds. By inducing dormancy, it helps the seeds to withstand the desiccation and other factors related to unfavourable growth.

(ii) It acts as a general plant growth inhibitor and also inhibits metabolism of plants.

(iii) It has its role in inhibition of seed germination.

(iv) Also plays an important role in seed development and maturation.

(v) Abscisic acid stimulates the closure of stomata.

The Mechanism of Stomatal Closing by ABA

ABA binds to receptors of the plasma membrane at the surface of the guard cells.

The receptors in turn activate several **interconnecting pathways**, which cause a rise in pH in the cytosol promoting the transfer of Ca^{2+} from the vacuole to the cytosol.

All this causes stomata to close and opening of stomata occurs when conditions are just reverse to it.

Interaction between Growth Regulators

For the regulation of every phase of growth, i.e. for differentiation and developmental processes in plants two or more phytohormones are intimately related to each other. These can either act **synergistically** or **antagonistically**.

Thus, every PGR has one or the other role to play. Likewise, there are also number of events in the life of a plant where more than one PGR is also involved to affect that particular event to take place. For example,

(i) Dormancy of seeds and buds is mostly due to abscisic acid, while it is broken down by gibberellins.

(ii) Auxins and cytokinins act antagonistically in controlling apical dominance, i.e. auxins cause apical dominance, while cytokinins help to overcome them.

(iii) Senescence is prevented by both auxins and cytokinins, while its stimulation is done by abscisic acid.

(iv) Auxins and cytokinins act synergistically in promoting cell division.

Chapter Practice

PART 1
Objective Questions

• Multiple Choice Questions

1. Which one includes growth promoters?
(a) Auxin, cytokinin, ABA
(b) GA, cytokinin, C_2H_4
(c) C_2H_2, ABA
(d) Auxin, cytokinin, GA_3

Ans. (***d***) Auxin, cytokinin and GA_3 are growth promoters.

2. 'Bakanae' (foolish seedling) disease of rice seedlings, was caused by *Gibberella fujikuroi*, which is a
(a) fungi (b) protozoan
(c) bacteria (d) virus

Ans. (***a***) Bakanae disease is caused by a fungus, *Gibberella fujikuroi*.

3. Match the following columns.

	Column I		Column II
A.	Darwin and Darwin	1.	Kinetin
B.	E Kurosawa	2.	Gibberellic acid
C.	Skoog and Miller	3.	Auxin
D.	Cousin	4.	Ethylene

Codes

	A	B	C	D
(a)	1	2	3	4
(b)	3	2	1	4
(c)	4	3	2	1
(d)	3	2	4	1

Ans. (***b***) A–3, B–2, C–1, D–4

4. The first hormone to be isolated from human urine was
(a) auxin (b) ABA
(c) ethylene (d) gibberellic acid

Ans. (***a***) Auxin was first isolated from human urine. Kogl and Haagen Smith (1931) isolated three chemicals from human urine and named them as auxin.

5. Which of the following effects of auxins on plants is the basis for their commercial application?
(a) Callus formation
(b) Curvature of stem
(c) Induction of root formation in stem cuttings
(d) Induction of shoot formation

Ans. (***c***) Auxins stimulate root formation on the stem cuttings, e.g. IAA, IBA, NAA, etc. This application of auxin is widely used for plant propagation on a commercial basis.

6. Parthenocarpy in tomatoes is induced by
(a) cytokinin (b) auxin
(c) gibberellin (d) CH_2— CH_2

Ans. (***b***) Parthenocarpy is induced by auxin in tomato. Applications of auxins (e.g. IAA, IBA) and conjugate auxins (e.g. IBA, alanine) to unpollinated pistils induce their development into seedless or parthenocarpic fruit.

7. To get a carpet-like grass, lawns are mowed regularly this is done to
(a) remove the shoot apical meristem
(b) remove the axillary buds
(c) accelerate the growth of lateral bud
(d) Both (b) and (c)

Ans. (***c***) Removal of shoot tips results in the growth of axillary/lateral buds. Thus, to accelerate the growth of the lateral buds and get carpet-like grass, lawns are mowed regularly.

8. Auxin promotes flowering and controls xylem differentiation.
(a) True (b) False
(c) Cannot say (d) Partially true or false

Ans. (***a***)

9. Apple's elongation and improvement of its shape is brought about by
(a) auxin (b) ethylene (c) C_2H_4 (d) GAs

Ans. (***d***) Gibberellins (GAs) cause fruit like apple to elongate and improve its shape. They also delay senescence.

10. Which of the following statement regarding gibberellins is incorrect?

(a) GA_3 was one of the first gibberellins to be discovered
(b) All GAs are acidic
(c) Spraying GA on conifers causes late seed production
(d) Dwarfness can be controlled by treating the plant with GA_3

Ans. (***c***) Statement in option (c) is incorrect and can be corrected as
Spraying juvenile conifers with GA_3 brings about early maturity period and thus leads to early seed production.
Rest of the statements are correct regarding gibberellins.

11. Difference between the kinetin and zeatin is that

(a) kinetin is active, zeatin is non-active
(b) zeatin is synthetic, kinetin is natural
(c) zeatin is active, kinetin is non-active
(d) zeatin is natural, kinetin is synthetic

Ans. (***d***) Kinetin does not occur naturally in plants. Search for natural substances with cytokinin like activity led to the isolation of zeatin from corn kernels and coconut milk. Thus, zeatin is natural and kinetin is synthetic.

12. Which hormone helps in increase the surface area of roots by promoting root growth and root hair formation?

(a) Cytokinin (b) Kinetin
(c) Ethylene (d) ABA

Ans. (***c***) Ethylene helps plants to increase their absorption surface area by promoting root growth and root hair formation.

13. Identify the effects of ethylene and choose the correct option accordingly.

I. More female flowers in cucumber.
II. Alpha-amylase production in barley grain.
III. Acceleration of fruit ripening in tomato.
IV. Delayed sprouting in potato tubers.

Codes

(a) I and II (b) I and III
(c) III and IV (d) II and IV

Ans. (***b***) Statements I and III are the effects of ethylene.

14. Which plant growth regulator induces triple response?

(a) C_2H_4 (b) IAA
(c) IBA (d) ABA

Ans. (***a***) Ethylene (C_2H_4) induces triple response. These triple responses are

(i) inhibited stem elongation
(ii) increased stem thickening
(iii) horizontal growth habit

15. Match the following columns and choose the correct option from the codes given below.

	Column I		**Column II**
A.	IAA	1.	Gases
B.	N_6-furfuryl amino purine	2.	Terpenes
C.	ABA	3.	Derivatives of carotenoids
D.	GA_3	4.	Adenine derivatives
E.	C_2H_4	5.	Indole compounds

Codes

	A	B	C	D	E
(a)	1	2	3	4	5
(b)	5	4	3	2	1
(c)	5	4	1	2	3
(d)	4	5	1	2	3

Ans. (***b***) A–5, B–4, C–3, D–2, E–1

• Assertion-Reasoning MCQs

Direction (Q. Nos. 1-5) *Each of these questions contains two statements, Assertion (A) and Reason (R). Each of these questions also has four alternative choices, any one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.*

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true, but R is not the correct explanation of A
(c) A is true, but R is false
(d) A is false, but R is true

1. **Assertion** (A) Hormones are also called growth regulators.

Reason (R) These promote or inhibit plant growth.

Ans. (***a***) Both A and R are true and R is the correct explanation of A.

2. **Assertion** (A) Plants have hormones called phytohormones.

Reason (R) These increase the rate of reactions, thus always accelerate growth and other related changes.

Ans. (***c***) A is true, but R is false because
In plants, growth regulators or plant hormones known as phytohormones can promote or inhibit various activities in plant growth and thus are categorised as plant growth promoters, e.g. auxin, etc., and plant growth inhibitors, e.g. ethylene.

3. **Assertion** (A) Plant Growth Regulators (PGRs) are very important for plant growth and development.

Reason (R) Auxins do not induce flowering in gymnosperms.

Ans. (***b***) Both A and R are true, but R is not the correct explanation of A.

Plant Growth Regulators (PGRs) are small, simple molecules of diverse chemical composition, which in low concentration regulate growth, differentiation and development by promoting or inhibiting the same.

One type of plant growth regulators are plant hormones or phytohormones. Auxins are phytohormones. They do not induce flowering in gymnosperms.

4. **Assertion** (A) Removal of shoot tip increases apical dominance.

Reason (R) Due to the accumulation of auxin in lateral parts, growth is enhanced.

Ans. (***d***) A is false, but R is true. A can be corrected as

Removal of shoot tip increases the lateral dominance. Further, accumulation of auxin in lateral parts elongate cells and increases growth.

5. **Assertion** (A) ABA acts as antitranspirant.

Reason (R) It promotes senescence of leaf.

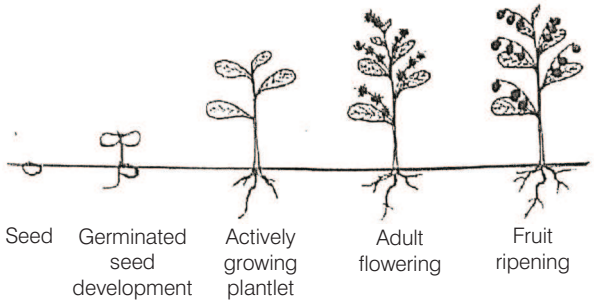
Ans. (***b***) Both A and R are true, but R is not the correct explanation of A.

ABA acts as antitranspirant as it induces partial closure of stomata during drought. It also promotes leaf senescence.

• Case Based MCQ

1. Given below are diagrammatic representation of different stages of plant life and different phytohormones synthesised in them at that stage.

GAs ABA	GAs *A*	*B* GAs Cytokinin	*C* Cytokinin	Ethylene ABA



(i) Identify *A* and *C* in the above figure.

	A	*C*
(a)	Ethylene	IAA
(b)	ABA	**GAs**
(c)	**GAs**	IAA
(d)	IAA	Ethylene

Ans. (***b***) *A*–Abscisic acid and *C*–GAs. Abscisic acid (ABA) inhibits seed germination and also plays an important role in seed development and maturation, while $\mathbf{GA_3}$ induces flowering.

(ii) Which of the following is not a plant growth inhibitor?

(a) Dormin (b) IAA
(c) Ethylene (d) ABA

Ans. (***b***) IAA is a plant growth promoter, while dormin, abscisic acid and ethylene are plant growth inhibitors. IAA (Indole 3-Acetic Acid) is an auxin. Auxins are synthesised in shoot apices, leaf primordia and developing seeds from the amino acid, tryptophan. So, IAA is not a plant growth inhibitor.

(iii) Fruits can be left on the tree longer, so as to increase the market period. This is due to the function of

(a) delayed senescence by auxin
(b) delayed senescence by $\mathbf{CH_2{=}CH_2}$
(c) delayed senescence by cytokinin
(d) delayed senescence by GA

Ans. (***d***) Gibberellin delays senescence. Thus, the fruits can be left on tree longer so as to extend the market period by exposing them to GA.

(iv) Cytokinins help to produce

(a) new leaves and chloroplast in leaves
(b) lateral shoot
(c) adventitious shoot
(d) All of the above

Ans. (***d***) Cytokinins help to produce new leaves and chloroplast in leaves, lateral shoot and adventitious shoot.

Thus, option (d) is correct.

(v) Respiratory climacteric is related with

(a) ABA (b) ethylene
(c) auxin (d) GA

Ans. (***b***) Respiratory climacteric is related with ethylene. Climacteric is the sudden rise in respiration that normally takes place without external influences.

It is the stage of fruit ripening associated with increased ethylene production and a rise in cellular respiration.

PART 2

Subjective Questions

• Short Answer (SA) Type Questions

1. What are plant growth regulators? Name any four different chemical nature of them with one example of each.

Ans. Plant growth regulators are small, simple molecules secreted in minute quantities that influence various physiological functions in plants. They are of diverse chemical composition.

(i) Indole compounds [such as- Indole-3- Acetic Acid (IAA)]

(ii) Adenine derivatives [such as kinetin, N_6-furfuryl amino purine]

(iii) Derivatives of carotenoids [such as Abscisic Acid (ABA)]

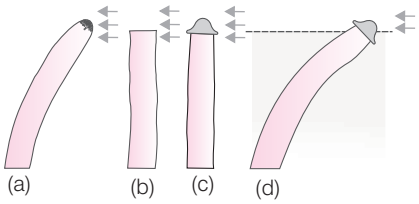
(iv) Terpenes (such as gibberellic acids)

2. Write short note on discovery of auxin.

Ans. • This is the **first growth hormone** to be discovered. The knowledge of this hormone came into existence through the observation of **Charles Darwin** and his son **Francis Darwin**.

• They observed that the coleoptiles of canary grass responded to unilateral source of light (phenomenon known as photoperiodism) by growing towards it.

• After performing series of experiments, they came to the conclusion that **coleoptile tip** was the site that has the property of transmittable influence due to which bending of complete coleoptile was caused. The first PGR, i.e. auxin was isolated by **FW Went** in 1928, from the coleoptile tip of oat seedlings.



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

3. Write about the types of auxins.

Ans. There are generally two basic categories in which auxins are divided

(i) **Natural Auxins** They occur naturally in plants and fungi, e.g. Indole Acetic Acid (IAA) and Indole Butyric Acid (IBA).

(ii) **Synthetic Auxins** These are prepared from synthetic compounds that cause several responses to IAA. They can easily move in all directions inside the plants, e.g. Naphthalene Acetic Acid (NAA), 2, 4-dichlorophenoxyacetic acid (2, 4-D).

All these types of auxins are extensively been used in agricultural and horticultural practices.

4. Explain inhibitory effect of auxins with the help of one example.

Ans. Higher concentration of auxins inhibits growth of the plants. In normal course in nature, self produced auxin in plants inhibits the growth and development of lateral buds and as a result lateral bud remains dormant.

5. In botanical gardens and tea gardens, gardeners trim the plants regularly, so that they remain bushy. Does this practice have any scientific explanation? **(NCERT Exemplar)**

Ans. The apical buds present in tea and other plants prevent the growth of lateral buds in them by releasing auxin hormone. This phenomenon is called apical dominance. Trimming removes the apical bud and allowing the lateral buds to grow laterally and give plants a dense bushy appearance.

The scientific explanation for this trimming method is that apical bud is removed and thus it results in the removal of auxin and phenomenon of apical dominance is overcomed.

6. Auxins are growth hormones capable of promoting cell elongation. They have been used in horticulture to promote growth, flowering and rooting. Write a line to explain the meaning of the following terms related to auxins.

(i) Auxin precursors (ii) Anti-auxins

(iii) Synthetic auxins **(NCERT Exemplar)**

Ans. Auxin is an important phytohormone required for the growth and development of every plant in its life cycle.

(i) **Auxin precursors** are raw materials required to initial synthesis of auxins. IAA is synthesised from tryptophan, adenine compounds and derivatives of carotenoids.

(ii) **Anti-auxins** are compounds that inhibit action of auxins, e.g. p-chlorophenoxy isobutyric acid (PCIB), Tridobenzoic Acid (TIBA), etc.

(iii) **Synthetic auxins** are synthesised not by plants, but artificially by man, e.g. 2-4 D (weedicide), NAA, dicamba and IBA (Indole Butyric Acid), which are natural as well as synthetic auxin.

7. What are the different applications of auxins in the field of agriculture and horticulture?

Ans. Use of synthetic auxins is widely accepted now-a-days in various agricultural and horticultural practices.

Following are the applications of auxins

(i) **Eradication of Weeds** Auxins are used as weedicides and herbicides. Application of 2, 4-dichlorophenoxyacetic acid (2, 4-D) is widely done in order to kill dicotyledonous weeds. It does not affect mature, monocotyledonous plants.

(ii) **Helps in Cell Division** Besides cell elongation, auxin may also play important role in cell division.

(iii) **Controls Xylem and Phloem Differentiation** Auxin controls differentiation of xylem and phloem in stems and roots. There are evidences that low concentration of auxin induces phloem differentiation while higher concentration of auxin is responsible for differentiation of both xylem and phloem tissues.

8. Write about the action of auxin on vascular tissue in plant.

Ans. Xylem and phloem are vascular tissue found in plants. Auxin controls differentiation of xylem and phloem in stems and roots. There is evidenes that low concentration of auxin induces phloem differentiation while higher concentration of auxin is responsible for differntiation of both xylem and phloem tissues.

9. Gibberellins were first discovered in Japan when rice plants were suffering from bakanae (foolish seedling disease) caused by a fungus *Gibberella fujikuroi*.

(i) Give two functions of this phytohormone.

(ii) Which property of gibberellin caused foolish seedling disease in rice? **(NCERT Exemplar)**

Ans. (i) The functions of hormone, gibberellin

(a) Produce the phenomenon of bolting, i.e. the growth of the internodal region of stem in rosette plants.

(b) Induces seed germination and break bud and seed dormancy.

(ii) The rice seedling/plant shows excessive growth in their internodal region when gets infected with fungus, *Gibberella fujikuroi*. This fungus produces excessive amount of plant hormone GA which makes plants taller than the normal plant foolishly and many results into death of the plant.

10. How does spraying of sugarcane plants with gibberellins increase the yield of sugar?

Ans. Spraying of sugar plants with gibberellin can increase the yield of sugar. Spraying increases the length of internodes and increased or lengthy internodes will produce more sugar.

11. Which plant hormone can transform genetically dwarf plants into tall plants? State the mechanism involved with suitable example.

Ans. Cabbage and sugarbeet plants have rosette habit of leaves. The leaves in these plants are condensed because of shortening of internodal area of the stem. It is a genetic character. When we spray $\mathbf{GA_3}$ solution on these plants, these became abnormally tall. It happens because of increase in internodal area. Thus, such genetically dwarf plant is made tall by $\mathbf{GA_3}$.

12. How are gibberellins useful in agriculture to improve productivity. Give any three points in support of your answer.

Ans. Gibberellins are useful in agriculture in the following ways

(i) Application of gibberellins increases the length of the stem and increases the yield of sugar in sugarcane.

(ii) Gibberellins delay senescence and prevent the premature fruits drop.

(iii) They can cause fruits like apple to elongate and improve in shape.

13. What are the physiological effects of cytokinins?

Ans. Cytokinins have following remarkable physiological effects

(i) **Promotes Cell Division** This is one of the most common and important biological effect of kinetin on plants, i.e. to induce cell division in the presence of sufficient amount of auxin (IAA).

(ii) **Reduces Apical Dominance** They promote the growth of lateral buds by breaking apical dominance.

(iii) **Morphogenesis** Differentiation or morphogenesis of plant tissues/organs is seen to be in control, if ratio of cytokinins and auxins is proportionate.

(iv) **Resistance** They also increase resistance of plants to high or low temperature and diseases.

(v) **Delays Senescence** These also help in delaying senescence (ageing) of leaves and other organs by controlling synthesis of protein and mobilisation of resources or nutrients.

14. In an experiment, the callus produced from internodal segments did not proliferate until coconut water was added. Give reason.

Ans. Callus (i.e. undifferentiated mass of cells) proliferates only when nutrient medium containing auxin was supplemented with coconut milk because it contains kinetin (a cytokinin) which stimulates growth of plant tissues.

15. Why do cut leaves dipped in cytokinins stay green for a longer duration?

Ans. Cytokinins are plant growth stimulator, which play a major role in cell growth and differentiation. They retard ageing of plant organ by promoting protein synthesis and mobilisation of nutrient resources so, the chlorophyll will be retained and leaves will remain green for longer time.

16. A farmer grows cucumber plants in his field. He wants to increase the number of female flowers in them. Which plant growth regulator can be applied to achieve this? **(NCERT Exemplar)**

Ans. Ethylene is also responsible to play a major role in determining the sex of monoecious flowers and is associated with the promotions of femaleness in plants thus the farmer must spray ethylene hormone on this cucumber crop to produce female flowers and to increase the yield (number of fruits produced).

17. Which PGSs is known as stress hormone and why?

Ans. Abscisic Acid (ABA) is known as stress hormone as it reduces rate of transpiration by forceably closing stomata under the condition of water stress to prevent the plant from wilting and thus it is called a stress hormone.
For example, in deciduous trees, leaves fall down during autumn when the moisture level in soil reduces and plants face water stress. ABA thus saves the life of trees from wilting during drought and desiccation.

18. 'The role of ethylene and abscisic acid is both positive and negative'. Justify the statement.

Ans. The role of ethylene and abscisic acid is both positive and negative. Ethylene is a simple gaseous PGR. It is synthesised in large amount by tissues undergoing senescence and ripening. It also promotes senescence and abscission of plant organs especially of leaves and flowers. This is its negative effect. As its positive effect, ethylene breaks seed and bud dormancy, initiates germination in peanut seeds, sprouting of potato tubers. It promotes internode/petiole elongation in deep water rice plants. It helps leaves/inner parts of the shoot to remain above water.

Abscisic acid's positive effect is that it plays an important role in seed development and maturation. Its negative effect is that it acts as a genaral plant growth inhibitor and an inhibitor of plant metabolised. ABA inhibits seed germination. ABA stimulates the closure of stomata in the epidermis and increases the tolerance of plants to various kinds of stresses.

19. What would be expected to happen if

(i) GA_3 is applied to rice seedlings.
(ii) dividing cells stop differentiating.
(iii) a rotten fruit gets mixed with unripe fruits.
(iv) you forget to add cytokinin to the culture medium.
(NCERT)

Ans. (i) Rice seedlings will grow extremely tall.
(ii) An undifferentiated mass of cells is formed.
(iii) The unripe fruits will ripe quickly.
(iv) The callus will not develop shoot buds.

20. Plant Growth Substances (PGSs) have innumerable practical applications. Name the PGR you should use to

(i) increase yield of sugarcane
(ii) promote lateral shoot growth
(iii) cause sprouting of potato tuber
(iv) inhibit seed germination **(NCERT Exemplar)**

Ans. (i) Gibberellin increases yield of sugarcane.
(ii) Cytokinins promote lateral shoot growth.
(iii) Gibberellin causes sprouting of potato tuber.
(iv) Abscisic acid inhibits seed germination.

21. Suggest some ways in which inhibitors are important to plant survival in natural adverse conditions.

Ans. Inhibitors are important to the survival of higher plants in temperate zones where there are extreme variation in weather conditions prevails.
Here, plants become dormant during harsh winter period and become active plant on coming favourable conditions. Seeds often will not begin to germinate until they have been exposed to cold. The breaking of dormancy and the beginning of growth depend on the release from inhibition of metabolic activities.

22. On germination, a seed first produces shoots with leaves and flowers appear later.

(i) Why do you think this happen?
(ii) How is this advantageous to the plant?
(NCERT Exemplar)

Ans. (i) On germination, a seed first produces shoots with leaves, flowers appear later, because the flower hormone florigen is synthesised in the leaves and is transmitted to the growing points where flowering occurs.
(ii) It is advantageous to plants as the vegetative phase prepares the plants for the reproductive phase so that it can bear structures like fruits and seeds.

• Long Answer (LA) Type Questions

1. Explain how the cytokinins, ABA and ethylene hormones are discovered.

Ans. **Discovery of Cytokinins**

- **F Skoog** and his coworkers, studied the nutritional requirements of tissue culture. They made nutrient medium derived from the internodal segments of tobacco stems. They observed that from that internodal segments, a **callus** (i.e. a mass of undifferentiated cells) proliferated, only when the nutrient medium containing auxin was supplemented with the extract of vascular tissues or yeast or coconut milk (water of endosperm of coconut).
- It was later found that the active substance present in coconut milk is a modified form of adenine which was crystallised and identified as **kinetin**. Further the compounds that exhibited kinetin like properties were termed as **cytokinins**.

Discovery of Abscisic Acid

With the progression in the research on plant growth regulators, three independent researchers reported the purification and chemical characterisation of three different kinds of inhibitors (during mid 1960), i.e. **inhibitor B**, **abscission II** and **dormin**. Later, these were proved to be chemically identical in nature and were named as Abscisic Acid (ABA).

Discovery of Ethylene

Cousins (1910), confirmed the release of a volatile substance from ripened oranges that enhance the ripening of stored unripened bananas. This volatile substance was later identified to be a gaseous plant growth regulator, i.e. ethylene.

2. Write in detail about abscisic acid.

Ans. It is slightly acidic phytohormone that functions as a growth inhibitor by counteracting with other mentioned growth hormones, i.e. auxins, gibberellins and cytokinins.

Thus, like other PGR, abscisic acid also has a wide range of effects on growth and development of plants.

As its production is stimulated under stress (unfavourable conditions such as drought, water lodging, excessive temperature, etc). So, it is known as stress hormone. It acts antagonistically to gibberellic acid.

Abscisic acid shows various important physiological effects

(i) It has a primary role in regulating abscission and dormancy of buds and seeds. By inducing dormancy, it helps the seeds to withstand the desiccation and other factors related to unfavourable growth.

(ii) It acts as a general plant growth inhibitor and also inhibits metabolism of plants.

(iii) It has its role in inhibition of seed germination.

(iv) It also plays an important role in seed development and maturation.

(v) Abscisic acid stimulates the closure of stomata.

(vi) It promotes senescence by decomposing chlorophylls, protein and nucleic acid, thus the leaves turn yellow before falling.

3. Explain functions and applications of ethylene.

Ans. **Functions of Ethylene**

Ethylene shows various important physiological effects

(i) In dicot seedlings, ethylene influences the horizontal growth of seedling, swelling of the axis and formation of apical hook.

(ii) It is highly effective in fruit ripening. It also increases the rate of respiration. This rise in the respiration rate is called **respiratory climacteric**.

(iii) It helps in breaking seed and bud dormancy.

(iv) Initiation of germination in peanut seeds and sprouting of potato tubers is also due to the production of ethylene in plants.

(v) In deep water rice plants, ethylene promotes rapid **internode** and **petiole elongation**.

(vi) It proves to be helpful in increasing absorption surface of plants by promoting growth of root and formation of root hairs.

(vii) It also stimulates flowering in fruits like pineapple, mango and other related plants.

Applications of Ethylene

As ethylene helps in regulating these many physiological processes in plants. It is known to be the most widely used PGR in agricultural field.

Ethephon It is the most widely used compound as a source of ethylene. This tends to absorb readily in an aqueous solution and transported within the plant. This slowly releases ethylene.

Functions of ethephon are as follows

(i) Ethephon is known to control fruit ripening (in tomatoes and apples).

(ii) It also helps in **accelerating abscission** in flowers and fruits (causes thinning of fruits like cotton, cherry, walnut, etc).

(iii) Helps in **promoting formation of female flowers,** thus, enhancing the yield of the fruits, e.g. cucumber.

4. Explain why?

(i) Exogenous application of auxin fails to enhance the growth of intact plants.

(ii) Vitamins are not considered as plant growth hormones.

(iii) Some plants, belonging to halophytes and growing in marshy lands, face great difficulty in seed germination.

(iv) Gibberellins do not enhance the growth of isolated plant parts.

Ans. (i) Auxin fails to cause growth of intact plants because the required amount of auxin is already present in the apical region of such plants and only these parts grow.

(ii) Vitamins have no specific influence on growth of plants. They are essential dietary factors needed by an organism in small amounts. They influence on growth and metabolism through their indirect effect on metabolism because some vitamins are cofactors of many enzymes.

(iii) Plants belonging to halophytes and growing in marshy lands, face a great difficulty in seed germination due to the presence of high concentration of salt in water. These plants solve this problem by vivipary.

(iv) Gibberellins require the presence of meristematic cells to cause elongation growth. Therefore, they do not enhance growth of isolated plant parts if meristematic cells are absent.

5. While experimentation, why do you think it is difficult to assign any effect seen to any single hormone? **(NCERT Exemplar)**

Ans. Most of the hormones are synergistic to each other in their mode of functions. Thus, during experimentation, we cannot judge whether, a particular effect is produced by a single hormone or is an additive effect of many hormones.

For example,

(i) Auxins help to initiate rooting in stem cuttings (an application widely used for plant propagation). Cytokinins also show the similar function of root formation. Auxins promote flowering, e.g. in pineapples. They also induce parthenocarpy, e.g. in tomatoes.

(ii) Both gibberellins and ethylene are synergistic to auxin in initiating flowering and for synchronising fruit set in pineapples.

(iii) Cytokinins and gibberellins help overcome the apical dominance and delay the process of leaf senescence.

(iv) On the other hand, ethylene promotes senescence and abscission of plant organs especially of leaves and flowers. This shows that all hormones are synergistic to each other in their mode of action in plants.

6. Mention the factors which prove that phytohormones act synergistically or antagonistically.

Ans. The factors which prove the phytohormones act synergistically or antagonistically are

(i) Cell division is promoted by both auxins and cytokinins acting synergistically.

(ii) Auxins and cytokinins interact to control morphogenetic differentiation of shoot and root. When auxin is in excess, roots differentiate on the callus, while excess of cytokinins promotes shoot bud formation.

(iii) Auxins and cytokinins act antagonistically in controlling apical dominance. Auxins cause apical dominance, while cytokinins overcome same.

(iv) Senescence is prevented by auxin and cytokinin, while it is stimulated by abscisic acid.

(v) The activity of cambium and fruit growth seems to be promoted by auxins, gibberellins and cytokinins, the same is inhibited by abscisic acid.

(vi) The dormancy of seeds and buds is mostly due to abscisic acid and the same is broken by gibberellins.

(vii) Cytokinins cause opening of stomata, while abscisic acid results in their closure.

• Case Based Questions

1. **Direction** *Read the following passage and answer the questions that follows.*

Raju's father is a businessman, they have many orchards. On one fine sunday, he went to a mango orchard, where he saw that some workers were placing carbide powder in between the raw mangoes before covering them. He asked one of the worker, why do they do so and what will be its effect on mangoes. Then, the worker showed him another carten in which he placed the same powder. Few days ago, Raju was surprised to see that all mangoes are riped and their skin colour is also changed due to this, worker explained that this powder helps the fruits in ripening.

(i) How does the carbide powder help in ripening of mangoes?

Ans. The carbide powder contains ethylene hormone which helps in ripening of mangoes.

(ii) What is respiratory climacteric?

Ans. The rise of the rate of respiration in ripening of fruits is called respiratory climacteric.

(iii) Which is the most widely used PGR in agriculture and why?

Ans. Ethylene is the most widely used PGR in agriculture as it regulates many physiological processes like inducing flowering, synchronise fruit set, etc.

(iv) Name the most widely used source of ethylene.

Ans. Ethephon is the most widely used compound as a source of ethylene.

(v) Where does the plant hormone ethylene is synthesised in plants?

Ans. Ethylene is synthesised in the tissues undergoing senescence and ripening fruits.

2. **Direction** *Read the following passage and answer the questions that follows.*

Phytohormones play vital roles in the growth and development of plants as well as in interactions of plants with microbes. These are naturally occurring small organic substances which are generally active at very low concentration and often, impose inhibitory effects if applied or present at higher concentration. The five classical phytohormones are auxins, cytokinins, gibberellins, abscisic acid and ethylene. These hormones produce various effects in plants like phototropism, bolting, dormancy, abscission, etc. They also have synergistic and antagonistic functions in various processes.

(i) Which hormone induces phototropism and geotropism in plants?

Ans. Auxins are responsible for phototropism and geotropism in plants.

(ii) What is precursor of gibberellins?

Ans. Acetyl Co-A is the precursor of gibberellins. These are synthesised *via* the mevalonic acid pathway.

(iii) In which part of plant, high concentration of auxin is present?

Ans. High concentration of auxin is present in the growing apices of the stem, from where auxin migrates to its regions.

(iv) Which plant hormone is found in gaseous form?

Ans. Ethylene is found in gaseous form.

(v) Which hormone is used to speed up the malting process?

Ans. GA_3 is used to speed up the malting process in brewing industries.

Chapter Test

Multiple Choice Questions

1. Identify the correct statement.
(a) PGR has diverse physiological effects on plants
(b) PGR may act synergistically or antagonistically
(c) Two PGRs can have same effect
(d) All of the above

2. Widely different organisms such as plant and fungi contain how many types of gibberellins?
(a) More than 50
(b) More than 75
(c) More than 100
(d) More than 25

3. Length of grapes stalks increases due to
(a) auxin (b) cytokinins
(c) gibberellins (d) ethylene

4. I. Leaf abscission is ... *A* ... by auxin in younger leaves and fruits.
II. Apical dominance is ...*B*... by auxin.
Identify *A* and *B* from the options given below.
(a) *A*–inhibited, *B*–promoted
(b) *A*–inhibited, *B*–inhibited
(c) *A*–promoted, *B*–promoted
(d) *A*–promoted, *B*–inhibited

5. Which combination of hormones can be applied to artificially induce flowering in pineapple plants throughout the year to increase yield?
(a) Auxin and ethylene
(b) Gibberellin and cytokinin
(c) Gibberellin and abscisic acid
(d) Cytokinin and abscisic acid

Assertion-Reasoning MCQs

Direction (Q. Nos. 1-3) *Each of these questions contains two statements, Assertion (A) and Reason (R). Each of these questions also has four alternative choices, any one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.*
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true, but R is not the correct explanation of A
(c) A is true, but R is false
(d) A is false, but R is true

1. **Assertion** (A) Gibberellins induce elongation of genetic dwarfism in maize.
Reason (R) GA_3 reduces α-amylase synthesis in seeds.

2. **Assertion** (A) Kinetin is found naturally in plants.
Reason (R) Cytokinins do not break seed and bud dormancy.

3. **Assertion** (A) Ethylene synthesis increases in case of wounds and thus help in wound healing.
Reason (R) Ethylene causes tropic response in plants.

Short Answer Type Questions

1. What are plant growth hormones? How do they differ from plant growth regulators?

2. How do IBA and 2, 4-D are used in agriculture?

3. What conditions can induce the phenomenon of bolting naturally and how can it be induced artificially?

4. Fill in the blanks.
(i) ..... is a simple gaseous hormone.
(ii) ..... is shedding of leaves, fruits or flowers by a plant.
(iii) Plant growth is generally confined to ..... regions and in ..... tissues.
(iv) Cytokinins are synthesised in areas where ..... is occurring.

5. Give one antagonistic function of each of the following hormone pairs.
(i) Gibberellins — Abscisic acid
(ii) Cytokinin — Ethylene
(iii) Abscisic acid — Auxin

Long Answer Type Questions

1. (i) Name the cytokinin like substance isolated from corn kernels and coconut milk.
(ii) How gibberellins are different from auxins?

2. (i) What will you do to prevent leaf and fruit drop in plants? Support your answer with reason.
(ii) Write a note on ethephon.

Answers

Multiple Choice Questions

1. *(d)* ***2.*** *(c)* ***3.*** *(c)* ***4.*** *(a)* ***5.*** *(a)*

Assertion-Reasoning MCQs

1. *(c)* ***2.*** *(d)* ***3.*** *(c)*