COURSE CODE: *BOT424*

COURSE TITLE: *Plant Growth and Development*

NUMBER OF UNITS: *2 Units*

COURSE DURATION: *2 Hours per week*

COURSE DETAILS:

Course Coordinator: Prof D.A. Agboola

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Office Location: A219, COLNAS Building

Other Lecturer: **Prof M. Kadiri**

COURSE CONTENT:

The role of growth regulators (auxins, gibberellins, cytokinins, ethylene and abscisic acid) in plant growth and development phenomena, such as abscission, apical dominance, tropisms and dormancy, solar radiation and plant development. Physiology of flowering plants.

COURSE REQUIREMENTS:

The course is compulsory for all 400 level students of Botany option of the Biological Sciences Department. The students are expected to attend and participate fully in all the theory and practical classes with not less than 70% attendance.

READING LIST:

1. **Dutta, A.C. *Botany for Degree Students*.**

LECTURE NOTES

GERMINATION

Germination is the resumption of metabolic activities by the seed tissues and it involves

(a) Dehydration
(b) Utilization of stored food

(c) Gradual development of synthetic systems which enable the young plant to be autotrophic ,

Life of a flowering plant starts after fertilization which is double in the embryonic sac .

The egg nucleus fuses with one male nucleus

→ (2n) → embryo

Two plants nuclei fuse with second male

Nucleus → endosperm (3n)

After this fertilization → embryo undergoes some growth →

Growth stops → water content of seed falls → metabolism slows down

Plant may die if herbaceous or annual but do not if shrubs or perennial ← seeds are dispersed

When seed are shed the degree of development of embryo varies in different plant s.

In orchids (orhidaceae) ____________ embryo consist of undifferentiated cells.

In grasses (Graminneae) _______ embryo well developed and already differentiated into leaves, nodes and roots.

In dicotyledons __________ partial development of embryo with plumule developing to shoot and radicle to roots .

The mature seed when released from the parent plants contains the embryo in a metabolically inactive dormant state.

Stored food of seeds

Seeds contains stored (reserved) food and this makes up to 85-90% dry weight of seed . In dicots the food is stored in rhe cotyledons while in monocots it is stored in endosperm s

In small lettuice seeds (Lactuca sativa), stored food support s the growth for several days when seed is grown in dark .

In fairly big peas and beans, stored food lasts for several (2) weeks. In coconut, (cocus nucifera) , halve of the stored food is utilized in 15 months of the dark growth. Stored food of seed contains lipids. Proteins , carbohydrate s , nucleic acids , amino acids ,vitamins ,coenzymes and minerals

Chlorophyll is absent in seeds. The stored food is present as insoluble compounds. Like starch stored as starch grains (Amyloplasts) ,Hemicelluloses present in all cell wall (date nut) lipids deposited as droplets of various sizes . Protein s deposited as protein bodies (aleurone grains).

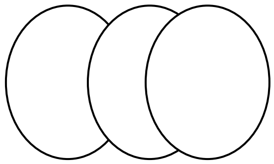
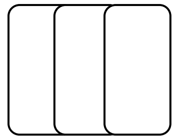
Some seeds do contain unusual amino acids which are not constituent of proteins . eg pyrazol-1-yl-alanine – found in seed of some members of the cucurbitaceae and give s 26% protein content eg canavanine found in the legume seed of canavalia ensiformis .

These amino acid s are called non- protein amino acids or free amino acid are toxic to animal and seeds containing them are avoided by insects and other seed – eating animals .

Metabolic rate

Extremely low metabolic rate found in un geminated seeds and this is due to low water content of 5-10% fresh water basis while plant tissue having high metabolic rate have 70-90% water content.

Moreover, the water in seed is bound water firmly bounded to colloids , inaccessible to hydrolytic reaction , unfreezable and under high vacuum.Because of this cells in dry seed are not round but shrunken and angular

Round Angular

PHASES OF GERMINATION

(a) Hydration phase.

(b) Active phase of metabolism

Hydration of germination

The first process that occurs in germination is water uptake by imbibition and osmosis imbibition is dominant in the initial phase of water uptake. As the water content rises , imbibition force decreases and osmotic forces become more important and determine the final water content through the micropylar pore (Hilium) and the testa .

With the entrance of water, seed increases in size and testa gets ruptured.

Water intake is faster in the embryo tissue than in the storage tissue .

The dehydration continues until 50-60% water content (fresh water basis) is achieved by the size and shape they had before the drying out which occurred during ripening of the seed.

As the seed becomes hydrated , metabolic activities are started with the help of enzymes , co-enzymes and substrate present in the seed .For example in wheat (Triticunvulgare) proteinases ,transaminases and glutamic decarboxylase are activated at 15% water content while respiratory dehydrogenases start functioning at 25% water content

Active phase of metabolism

It occurs when water content is above 25%

Development follows a differentiation course in two functional region of the seed.

(a) In the embryo – cells begin to elongate and divide growth is visible in the radicle before the plumule (emergence of radicle is normally taken as sign for germination.

Germination could be

Epigeal- if cotyledons are taken above the ground.

Hypogeal – if cotyledon are left below the ground

(b) In the storage tissue, there is hydrolysis of the stored food and the resulting soluble products are translocated to the growing embryo. Thus no cell division in the storage tissue.

Mobilization of food reserves

Hydrolysis of stored food is carried out by hydrolytic enzymes (Table below)

Stored food	Enzymes	Product of hydrolysis
Starch	α and B	maltose, glucose
	Amylase	glucose
	Maltose	
	Phosphorylase	glucose-i-phosphate
Hemicellulose	cytases	hexoses, pentoses
Lipid	lipases	fatty acids α glycerol
Protein	proteinases	amino acids, peptides
	proteases	amino acids
	Peptidases	
Ribonucleic acid	Ribonucleases	Ribonucleotides
Cellulose	cellulase	cellobiose

Cellobiase glucose

All the enzymes are non – specific except proteinases eg. Proteinase preparation from cabbage (Brassia) seed is in active towards the ptoeins from the seed of beans.

Enzymes activity in a seed come about either by release of an enzymes present in an in active form or by enzymes synthesis

Insoluble food reserves hydrolytic soluble substances

$\xrightarrow{\text{Enzymes}}$

In maize soluble substances rise from 2% to 25% of dry weight, after five days of germination. As their reserves are exhausted, storage cells collapse.

Utilization of food reserves for seedling growth

Soluble products from hydrolysis are utilized by the growing plant. Most of the lipids are converted to glucose (the useful form for the developed plant), by glyoxylate cycle. Eg

Days germinated	Lipid	Weight per 100 Carbohydrate	seedlings(g) total dry weight
0	26.2	1.51	37.64
4	25.0	5.10	45.1
6	10.8	18.2	45.1
8	5.4	23.3	43.9
11	1.78	17.7	38.4

There is also interconversion of amino acid e.g in barley, glutamic acid and proline are converted into aspartic acid, alanine and glycocine (by transaminations).

As endosperm proteins fall, embryo proteins rise. As soon as growth begins in the embryonic regions, synthesis of RNA and DNA commences there from non – nucleic material.

The growing regions of the seedling exert a control over the activity of the storage tissues. Using pea seedlings, increases in enzymes activity in the cotyledons fails to take place if the embryo is excised.

Growing plumule contains a regulator gibberillin which promotes synthesis if enzymes in the cotyledons.

In the cotyledon of cucuirta maxima, synthesis of proteolytics enzymes is promoted by cytokinous.

Respiration during germination

They intense metabolism of the germinating seed is accompanied by high rates of respiration in both the embryonic and storage tissues in active respiratory enzymes are activated once a critical water content is passed (15%). After the initial hydration is completed (Ca 50% H_20 content), the respiration rate remains fairly constant.

Physiology of dormancy

Defined as a state in which viable seeds, or buds fail to germinate under optimum conditions of moisture, temperature and oxygen. Dormancy is accompanied by low metabolism, low water content and zero growth during which the seed is very hardy and can withstand cold and drought. Ceasation if growth that occurs in response to unfavourable external conditions such as low temp lack of water is called quiescence or enforced dormancy.

Advantages of Dormancy

(a) Enables some seeds and buds to remain viable for some time under harsh environmental conditions like some seeds being able to withstand the dry and cold seasons.

(b) Prevents wastage of seeds as in the cereals by preventing germination immediately after the harvest of the seeds. The seeds can germinate after been stored in a dry place for months.

Types of dormancy

(a) Seed coat dormancy- obtains when seed coat is hard and

- (i) Impermeable to water e.g. in leguminous like flamboyant, parkia.
- (ii) Impermeable to gases e.g. xanthium
- (iii) Physically prevents embryo expansion e.g. Amaranthus.

(b) After – ripening dormancy - Occurs when plants produce seeds which do not germinate immediately under favourable optimum conditions butt do so after a period of dry storage. Examples are cereals like wheat, maize, rice, sorghum millet, barley, oat.

(c) Immature embryo dormancy - Obtains when the embryo of the seed is partially mature when fruits are shed. Fully mature embryo has to be attained before germination could be obtained. E.g. Ricinus.

(d) Inhibitors presence dormancy - If inhibitors are present in seeds at 5 – 10ppm, dormancy result e.g. in Milicia excelsia, Francinus Excelsus, Absicisic acid, ammonia, parasorbic acid, dehydracetic acid.

(e) Promoters absence dormancy - If promoters are lacking in seeds, dormancy results. Examples of promoters are Gibberilins, cytokinins, auxins and ethylene. No example yet.

(f) External factor requirement dormancy

- (i) Light requirement - some seeds need exposure to red light or white light before they will germinate e.g. letuce seed (Lactuca sativa) pepper grass seed (Lepidium virginicum) Xanthium pennsylvancium, Rumex cripsus L. Rumex obtusifolius
- (ii) Cold requirement - some seeds need a period of pre – chilling (0 – 15^{0}C) with adequate aeration for weeks before germination is obtained. e.g. Brassica juncea; Poa pratensis; lettuce seed where low temp (15^{0}C) can substitute for red light promotion of germination.

Methods of Breaking Seeds Dormancy

The method depends on the dormancy type in question.

(a) Scarification method - Refers to any treatment that renders the seed coat permeable to water and/or oxygen or weakens the seed coat so that embryo expansion is possible. Divisible into

(i) Mechanical scarification - Treatments which crack or scratch or weakens seed coat like shaking the seeds with sand; filling the seeds with sand – paper; cutting the seed – coat with a knife; breaking the seed – coat with a pressure of 500 – 2000 Atmospheres; heating the seeds in boiling water or in the oven and applying radiations like infra – red, X – ray, on the seeds.

(ii) Chemical scarification - Treatments which dissolve or weaken the seed coat. Achieved by dipping seeds into strong acids e.g. H_2s04; organic solvents e.g. acetones alcohol; using enzymes like hemicellulase and pectinase, soaking in water, salt and hormones solutions.

(b) Drying of seed - Employs for seeds having after – ripening dormancy. The seed are either stored in a dry place or are placed in heaters to reduce the seed water content.

(c) Allowing embryo to mature - Seeds with immature embryos are left in an environment favourable to germination until when the embryo is fully mature.

(d) Light treatment - This is by exposing wet seeds to red light (climax 660nm) for 10hours at 25^0C.

(e) Cold treatment - this is by exposing seeds to low temperatures (0 – 15^0C) for weeks under an aerated condition (pre – chilling treatment).

(f) Solvent treatment - this is by leaching out growth inhibitors from dormant seeds that contained them using solvents most especially water. E.g H_20 leaching of dormant seeds of chlorophora excelsia which contains ABA cause dormancy breakage.

(g) Application of growth promotions - 1 – 5ppm of cytokinin + gibberellin; auxin + gibberellin; ethylene + gibberellin will induce germination in dormant seeds for example letuce seeds.

Khan (1971) indicated how the presence of growth inhibitors (ABA, coumarih) and growth promoters (gibberellin, cytokinins) could cause a seed to germinate or be dormant.

Situation	Gibberellins	Cytokinin	Inhibitor	Result

1	+	+	+	Germination
2	+	+	-	Germination
3	+	-	-	Germination
4	+	-	+	Dormancy
5	-	-	-	Dormancy
6	-	-	+	Dormancy
7	-	+	+	Dormancy
8	-	+	-	Dormancy

+ = physiologically effective level   - = physiology ineffective level.

THE PHYSIOLOGY OF SENESCENCE AND ABSCISSION

Senescence

Senescence is the process of decomposing changes which are natural causes of death. Similar to the ageing process and measured as a loss of chlorophyll or protein.

Ageing is gradual accumulation of physiological changes with time; which increases susceptibility to death but are not lethal in themselves.

Aging–gradual changes in time, some of which may be decomposing changes and increases susceptibility to death.

Senescence – decomposing changes that cause death.

TYPES OF SENESCENCE

Senescence may be from single cells to the whole organism. While plant is growing there is continuous loss of older organs (particularly leaves) and production of new organs. Leaf senescence is thus the most conspicuous of plant senescence.

- Whole organisms senescence: Senescence of whole plants shown by monocarpic plants- plants that undergo a single flowering/fruiting phase followed by sudden death e.g. annuals and some biennial and perennial e.g. bamboo (polycarpic plants eventually die after many times of flowers and fruit productions) flowers/fruit removal prevents or delays this senescence type.
- Organ senescence: organ senescence is followed by abscission of the affected organ. Leaves, cotyledons, flower parts and fruits are affected .Some organs may senesce without abscission (e.g. leaves of grasses).
- Deciduous senescence- all the leaves undergo senescence at the same time.
- Top senescence – where the above ground (soil) part of plant die leaving a rhizome, bulb etc to produce new shoot.
- Local senescence – a single or small number of organs senesce independently (for example where adverse conditions of the basal leaves as new ones are formed at the apex.

Organ senescence is generally accompanied by a massive exodus of nutrients, but this does not occur in ripening fruits.

Correlations

Leaf senescence is promoted by actively growing regional such as stem apices or fruit. Fertilization causes flower parts to senesce (e.g. petals) and at the same time preserve others (e.g. carpels).

PHYSIOLOGICAL CHANGES IN SENESCENCE TISSUES

- Chlorophyll content decreases, also photosynthesis and yellowing of the leaves results.
- Chloroplast lamellae collapse
- Loss of protein (protein and RNA decrease)
- Respiratory rate remains fairly high until relatively late in senescence and then decrease, (decrease in activity of mitochondria)
- Increased amino acids from protein breakdown and are used for respiration.
- Increase activity amino acid metabolizing enzymes
- Lysosome equivalents in plant cells which contain acidic hydrolytic enzymes go into operation digesting the cells (autolysis).
- The tonoplast breaks down releasing the vacuolar content and a change in permeability of plasmalemma with anthocyanous and other pigments being released.

NUTRIENT DISTRIBUTION IN RELATION TO SENESCENCE

- Movement of photosynthate: Young actively growing leaves are net importers of carbon crops but when they are about to be fully developed they become net exporters. The mature leaves export photosynthates to young leaves, growing roots and developing flowers and fruits. In fruit development the mobilizing centre for photosynthates shifts away from the root, stem, apex and young leaves to developing fruit roots/apice developments lessened with fruit development to reduced mineral uptake.

- Movement of mineral: minerals mobile ones (N, P, K, Mg, Fe, Ca) migrate out of senescing organs before they are shed. In general minerals move from the roots, leaves and stems to inflorescences and seeds

Mechanisms for Nutrient Distribution

- Source – sinks \echanisms – young growing tissues are the sinks and mature ageing tissues the sources (due to high demand of the growing tissues) evidence – if senescing cotyledons and leaves are detached, their senescence is delayed.

  N.B: Detachment of normal young leaves accelerates senescence.

- By direct transport – BUT a no of observation are against the source – sink hypothesis.
  - Folial applications of minerals do not prevent senescence of some plants.
  - Baspetal movement of sugars and nitrogen continues in leaves detached from the original sinks of some plants.
  - Certain hormone treatments can direct movement independent of sinks e.g. kinetin application on a leaf directs the movement of a non-protein amino acid and aminobutyric acid towards the leaf.

CONTROL OF SENESCENCE

a. **Physical:** removal of fruits and flowers

b. **Chemical:** using cytokinin on the organs because . Cytokinin prevents chlorosis and can restore greenness to yellow leaves and cause the organ to be sink.
   - Using gibberellins and auxins (synthetic ones)

- Using calcium, potassium salts chelating agent (EDTA), ascorbic acid, coumarin, protein synthesis inhibitors- actinomycin D, sucrose, promoters of senescence are ABA and ethylene, serine, cysteine, glygiene, alanine and 2,4-D.

ABSCISSION

This is the separation between cells or organs leaf, stem, and flower and fruit abscission.

Advantage removal of leaves which become inefficient through aging and for fruit facilitates distribution of seeds, adaptations to harsh environmental factors e.g. shedding of leaves as adaptation to desiccation or winter

CAUSES OF ABSCISSION

As the leaves become senescence they produce an abscission-stimulating substance instead of the inhibitor.

Growing apex, enlarging leaves or ripening fruits promote abscission.

Likewise environmental factors like short photoperiods, water stress (desiccation), heat stress and nutrient deficiency.

CONTROL OF ABSCISSION

a) Using auxins – inhibits abscission at higher consent, but promotes at lower concentration

N.B ethylene and ABA promote abscission

b) Using gibberellins and cytokinins

c) Using calcium salts which inhibit abscission.

SEPARATION PROCESSES IN ABSCISSION

Separation in abscission is by one or more of the followings

a. A weakening of the cementing ability of the middle lamella in cells at the separation zone
b. A softening of the entire wall of cells at the separation zone.
c. Cytolysis of the entire cells in the separation zone
d. Cellulases and hemicellulases activities are stimulated
e. Development of a suberized protective layer on the layer of cells left exposed by the abscission.

In many experiments: I.A.A applied to petiole stumps , leaf and flower retarded abscission while I.A.A application to the adjacent stem tissues has speeded it up.

GROWTH HORMONES

Living organisms are capable of taking simple molecular substances to build them into complex substances (process known as anabolism).

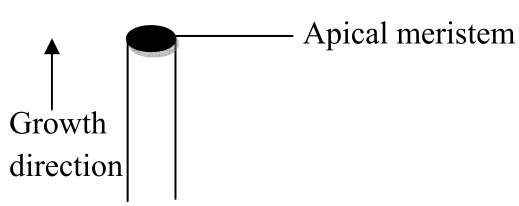
The complex substances formed cause an increase in the living material and later growth. This is under the control of certain substances known as phytohormomes

In unicellular plants, growth is by division into two or more individuals.

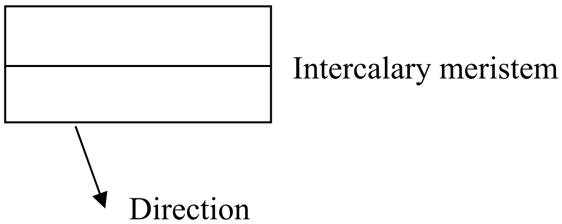
In multicellular plants growth is limited to the meristems.

TYPES OF MERISTEMS

a. Apical meristem – found in root/shoot tips



b. Intercalary meristem – found in between tissues e.g. at the base of the leaf or at the base of the node.



c. Lateral meristem – found on the sides e.g. cambium of the stem

Plant growth is a complex process which is regulated by plant growth substances called plant hormones or phytohormones or growth regulators

	Animal hormones	Plant hormones	
1.	Secreted by glands	1.	Secreted by tissues

CLASSIFICATION OF PHYTOHORMONES

Polytohormones
- Growth promoters
  - (a) Growth promoters
  - (b) Gibberellins
  - (c) Cytokinins
  - (d) Ethylene
- Growth inhibitors
  - Abscissic acid (ABA)
  - Phenolics e.g. caffeine
  - cyanidine and glycosides
  - coumarins, Actinomycin
  - Alkaloids

AUXINS

Are substances chemically and/or biologically related to I.A.A (indole-3-acetic acid). Natural auxins are indole compounds of which I.A.A is the most important. Other natural auxins are indole ethanol (Iethanol), indoleacetonitrile (IAN) and Indolepyruvic acid. (IPA).

Site of production fo natural auxins is the stem apical tip while site of activity is the cell. Natural auxins occur as

a. Free and diffusible auxinss
b. Bound auxins

TRANSPORT OF AUXINS

a. Diffusion
b. Electropotential
c. Cell metabolism i.e. through the phloem

PHYSIOLOGICAL EFFECTS

Cell elongation

I.A.A

Cell elongation by auxin is due to

1. Increase in osmotic potential of the cell
2. Increase in permeability of the cell wall to water
3. Reduction in wall pressure
4. Inducing cell wall plasticity and extension.

Apical dominance by auxin due to

1. Stimulationsof a metabolic centre in the shoot apices which acts as sink for metabolites.
2. Inhibitors are produced in the apices are transported to auxiliary buds where growth is inhibited

Phototropism by auxin is because plant

Synthetic auxins are man-made auxins and examples

2,4 – dichlorophenoxy acetic acid (2,4 – D)

Indole -3 – butyric acid (IBA)

Naphthalene acetic acid (NAA)

Indole – 3- propionic acid C1, - 3 – PA)

Phenylacetic acid (PhA)

2-Naphthoxy acetic acid (NoA)

Phenoxyacetic acid (PAC)

2,3,6 – Trichlorobenzoic acid (2,3,6 –T)

2,4,5 – Trichlorophenoxy acetic acid (2,4,5 – T)

PHYSIOLOGICAL EFFECTS OF AUXINS

a) Cell enlargement

b) Rooting of twig

c) Permeability of the cell membrane

d) Maturation of fruits

e) Inhibition of abscission and fruit fall

f) Apical dominance

g) Geotropism and phototropism

h) Parthenocarpy

i) Herbicides (synthetic ones only) – also are antitranspirant plants

j) Bending towards a unilateral light is caused by cells elongatating on the shaded side at a much greater rate than cells on illuminated side because of higher concentration of I.A.A. on the shaded side.

k) GIBBERELLINS

l) More than 60 have been isolated are numbered as GA1 to GA60

m) $GA_1 = C_{19}H_{24}O_6$; $GA_2 = C_{19}H_{26}0_6$; GA_3 Gibberellic acid most commonly found in plant

n) $GA_4 = C_{19}H_{24}O_5$; GA_5; $= C_{19}H_{22}0_5$; $GA_9 = C_{19}H_{24}0_4$

o) $GA_7 = C_{19}H_{22}O_5$; $GA_8 = C_{19}H_{24}O_7$; $GA_9 = C_{19}H_{24}O_4$

p) $GA_{10} = C_{19}H_{26}O_5$; $GA_{11} = C_{19}H_{22}O_5$; $GA_{12} = C_{20}H_{28}O_4$

Transport is through the phloem up to GA60

Physiological Effects

a) Cell elongation

b) Parthenocarpy

c) Promote cambial activity

d) Induce new RNA and protein synthesis

e) Inhibiting leaf senescence

f) Overcoming genetic dwarfism when gibberellins are applied on a short mutant, it becomes taller so as to be like normal one.

g) Induce flowering

h) Mobilization of stored carbohydrates during germination

i) Breaking of dormant seeds and buds in dormancy

j) Could alter sex expression e.g. female plant changes to male plant in cucumber papaya

k) Could substitute for low temp and long day condition in flowering

CYTOKININS

Named after compounds with kinetin like action. They are degradation products of DNA and RNA and they promote cell division in conjunction with auxins coconut milk contains cytokinins.

Natural occurring cytokinins are transported from the root to the leaves

Zeatin (from maize) ribosylzeatin (from maize)

6- methylamino purine (from microbes RNA

Synthetic cytokinins

Kinetin C6- furfurylamuopunney from maize 2, ι-pC_2 Bepentenyladewney from microbes

6, BAP C6- Benzy lamminopunney DNA

Physiological effects

i. Cell division with auxish e.g. in tissue cuture
ii. Root initiation and growth
iii. Breaking of dormant seeds and buds e.g lettuce seed
iv. Inhibition of leaf senescence
v. Parthenocarpy
vi. Stimulation of H_20 loss by transpiration
vii. Promotion of bud formation in leaf

Coconut milk has been shown to contain cytokinin like substances **ABSCISIC ACID (ABA)**

Growth inhibitor. Act opposite to auxins, gibberellins and cytokinins e.g. inhibition of lettuce seed germination, promotion of abscission and senescences other inhibitors are phenolics like glycosides, alkaloids,

Transport is through the phloem and xylem

Ethylene (C_2H_4)

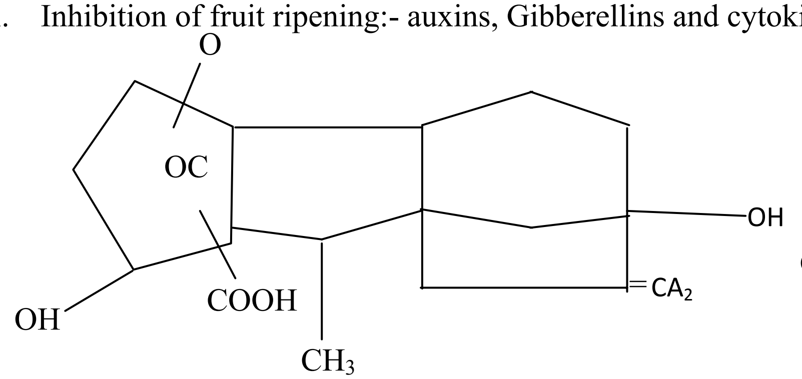
A gas at room temperature physiological effects.

Jasmonie acid a deviative of fatty acid enhance senescence

a. Fruit ripening
b. Inhibition of geotropism etiolated pea stems in ethylene is not affected by gravity.
c. Promoter of dormant bud and seed germination.
d. Inhibition of auxin transport
e. Promoter of enzyme synthesis e.g.
   X-amylase and abscission
f. Promoter leaf senescence and abscission transport is through the intercellular space

Economic Importance of Hormones

a. Synthetic auxins are used as herbicides that destroys, dicots but not monocos because they are not readily broken down by plants e.g 2, 4-D is a
b. Control of dwantism in plants Gibberellins.
c. Formation of fruits without fertilization from flowers (parthenocarpy): - I.A.A
d. Flower initiation: Gibberellins
e. Breaking of dormant seeds and buds dormancy-kinetin and Gibberellins
f. Fruit ripening ethylene
g. As antitranspirants ABA and synthetic copies of BU/BS/T6188, T6-436, T6 439
h. Acceleration of leaf and fruit fall – ABA and ethylene
i. Inhibition of fruit ripening:- auxins, Gibberellins and cytokinins



GA_1