**LECTURE 2: Plant development and roles of plant organs**

**Learning Objectives:**

1. **Defining the concept of development**

2. **Dimensions of development**

3. **Phasic theory of development**

4. **Phenological phases in annual crop plant**

5. **Dimensions of development, quantification of development in crops and factors affecting it (Temperature and Photoperiod)**

6. **Roles of plant organs**

a. **List and describe the major plant organs their structure and function**

**Development**

Morphogenesis as a transformational biological process; qualitative and quantitative is divided into growth and development (differentiation). Development is a qualitative change in plant over time. The qualitative aspect of development involves morphological changes and different stages of development over time-phenology. The stages of development are classified as:

1. Vegetative/ Reproductive

2. Exponential, stable and decline, based on the trajectory of dry matter accumulation

3. Functional classification that takes into cognizance the stages of leaf formation, seed/grain set and seed/grain fill

Quantitatively, development is measured as duration; Days-to-harvest-maturity, days-to-flowering, days-to-actual-accrual-of-yield. The inverse to duration of development is the rate of development. The rate of development is controlled by genetic factors but modulated by environmental influences. The predominant environmental influence is temperature and photoperiod. The rate of development to these environmental factors at the sub-optimal level is first linear, reaching a plateau at the optimal level, eventually declining at supra-optimal level.

The predominant model proposed concerning development in plant is **phasic theory of development.** The basic assumptions underlying this process are:

a. Development is phasic in nature, i.e. progression from one physiological system state of the meristerm to another

b. Identified are two phases; vegetative and reproductive phases

c. Plant system possesses the capability of development to progress autonomously

d. The identifies phases of development are irreversible

e. Development process is controlled by various environmental and genetic factors, mainly; temperature and photoperiod (G X PX T)

f. Photoperiod gene and vernalisation genes possesses delaying impact on the process of development

g. Temperature effect is through $Q_{10}$ effect on the activities of the enzymes and ultimately on the biochemical reaction

Developmental process is controlled by genetic factors and modulated by the environment. The predominant environmental factor is temperature and photoperiod.

Find below photothermal response of crops and their effect on days to flowering (DTF)

DTF

Early

Late

Base Temperature

Low High

Temperature

At reduced temperature, the delaying effect of photoperiod genes and vernalisation genes is reduced, hence the vernalisation response,; reduction in days to DTF at low temperature, with increasing temperature due to $Q_{10}$ effect, the delaying effects of those genes becomes pronounced, leading to late DTF, beyond the base temperature effects of photoperiod genes becomes predominant. There are distinctive morphological characteristics of the activities of these genes on the phenology of crops, these are listed below. One could infer that for proper development crops possesses vernalisation requirements; duration of days at low temperature to inhibit the activities of vernalisation genes, while the vernalisation response is the reduction in days to flowering due to the thermal effect at low temperature. Vernalisation responsiveness is inversely proportional to the age of the crop, but directly proportional to the duration of exposure to low temperature. Photoperiod responsiveness is directly related to the period of vernalisation and age of the crop.

Temperature effect on the rate of development in crops is expressed quantitatively as the air temperature, in Heat Units (Crop Heat Unit or Growing Degree Days) and as growing points. Quantitatively, the GDD is expressed as:

**GDD: $(T_{MAX} – T_{MIN})$ -$T_{BASE}$**

**2**

**Comparative analysis of yield components compensation**

| **Parameters** | **Organs** |
|---|---|

| | Vegetative organ | Reproductive |
|---|---|---|
| P-T combination control | Yes | No |
| Genotype sensitivity to photoperiod gene | Yes | No |
| Accumulated Biomass | High | Low |
| Net Rate of Biomass accumulation | High | Low |
| Days to Harvest Maturity | Late | Early |
| Days to Flowering | Late | Early |
| Duration of actual accumulation of yield | Late | Early |
| Harvest Index | Low | High |
| Rate of partitioning | Low | High |

Flowering plants possess three kinds of vegetative (non-reproductive) organs:

1. Roots
2. Stems
3. Leaves.

Shoots consist of stems and leaves. The shoot system of a plant consists of the stems and the leaves, as well as flowers.

- **Leaves** are the main sites of photosynthesis in plants.
- **Stems** hold and display the leaves to the sun and provide connections for the transport of materials between roots and leaves. It may also serves as an area of storage.
- A **node** is the point where a leaf attaches to a stem.
- Regions of stem between nodes are the internodes.

The functions of these organs are

1. Photosynthesis,

2. Support

3. Transport

The functions of the root are:

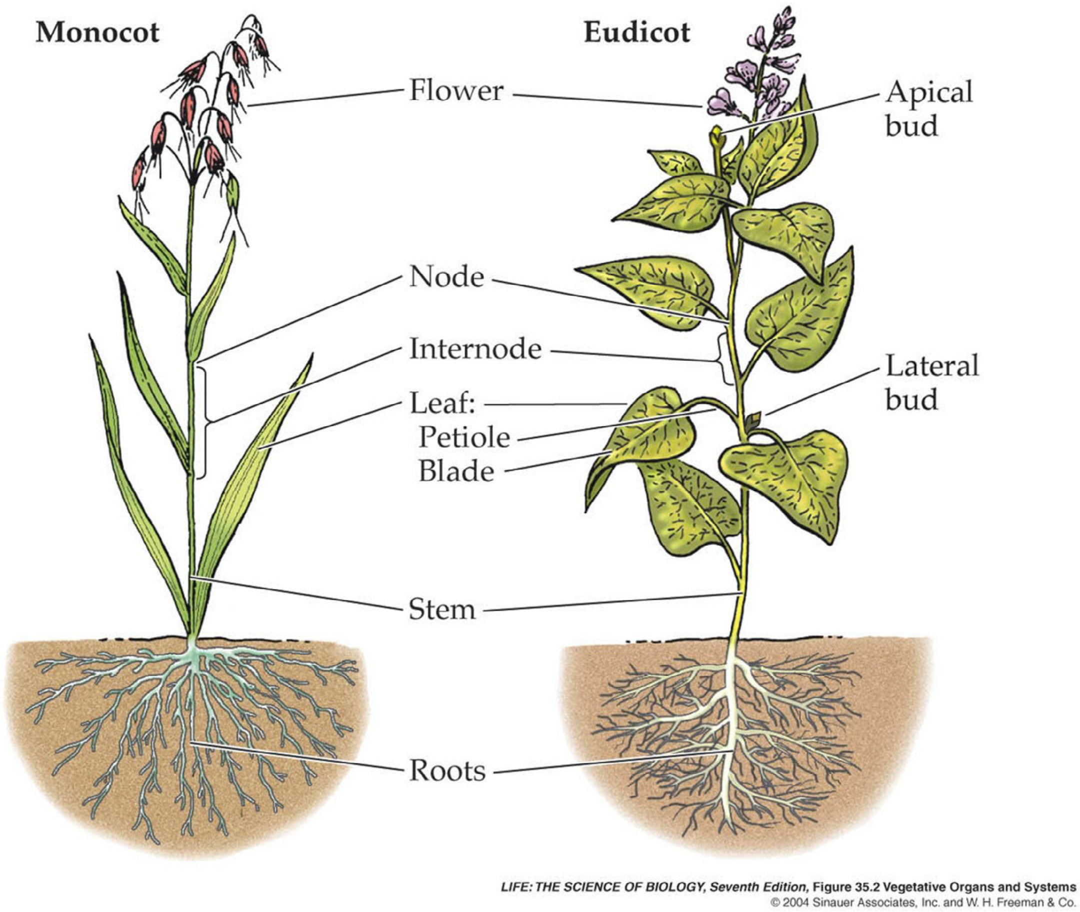
1. Anchor and absorb water and minerals

2. Provides nutrients for the shoot and

3. Acts as organ of storage

The flower is the reproductive organ of the Angiosperms. Flowers are modified leaves structure which support the microsporangia and megasporangia gametophyte generations and are involved in plant sexual reproduction. Flowers are usually located apically or a the end of a stem.

See below a pictorial representation of plant organ part




**NOTE:** Phenological phases of annual crops shall be discussed in the class.

**Topic: PLANT HORMONES**

**Learning objectives:**

1. Understanding the concept phytohormones and their roles in growth and development of crop plant

2. Classification of phytohormones

3. Hormonal balance, growth and development in plant

**Theoretical background:**

Phytohormones are physiologically active substances that affect plant growth and development. They act as chemical messengers or plays signalling role in plant; hence they are functionally integrators and regulators of physiological processes in living organisms. Unlike the animal hormones, plant hormones are fewer in number, they affect most cells in the plant, the response of plants to them is diverse (pleiotropic effect) and they are modulated by environmental, developmental and other hormones through cross-regulation of their actions that could be antagonistic or synergistic in nature. They are required in small quantity, transported from the site of synthesis to mediate physiological response in other parts of the plant.

Recognised over the years are classical phytohormones; Auxin, Gibberellin, Cytokinin, Abscissic Acid and Ethylene and newer ones; Jasmonic Acid, Salicylic Acid, Brassinosteroid and Strigolactones. Apart from the aforementioned substances there are other substances in plant that play signalling role , though they cannot be classified as hormones, such as polyamines, Reactive Oxygen Species (ROS), Signalling Peptides and Nitric Oxide. Among the classical hormones are growth promoters (Auxin, Gibberellin and Cytokinin) and growth inhibitors (Abscissic Acid and Ethylene).

The mechanism of hormonal action is quite complex and attempts had been made to elucidate its action. After synthesis and accumulation of hormones it is transported to the site of action through the phloem or xylem stream or via diffusion. It it sometimes transported by regulated transport proteins. Perception of environmental perturbation is mediated through binding of hormones to transmembrane or intracellular receptors. Signal transduction or amplification is mediated by the activation of kinase activities through the process of phosphorylation where ATP molecules bind to protein through protein kinase eventually leading to signal amplification.

The reverse process of inactivation is through the action of phosphatise. Other elements of signal transduction include the allosteric changes of protein, phophorelay system and regulated protease.

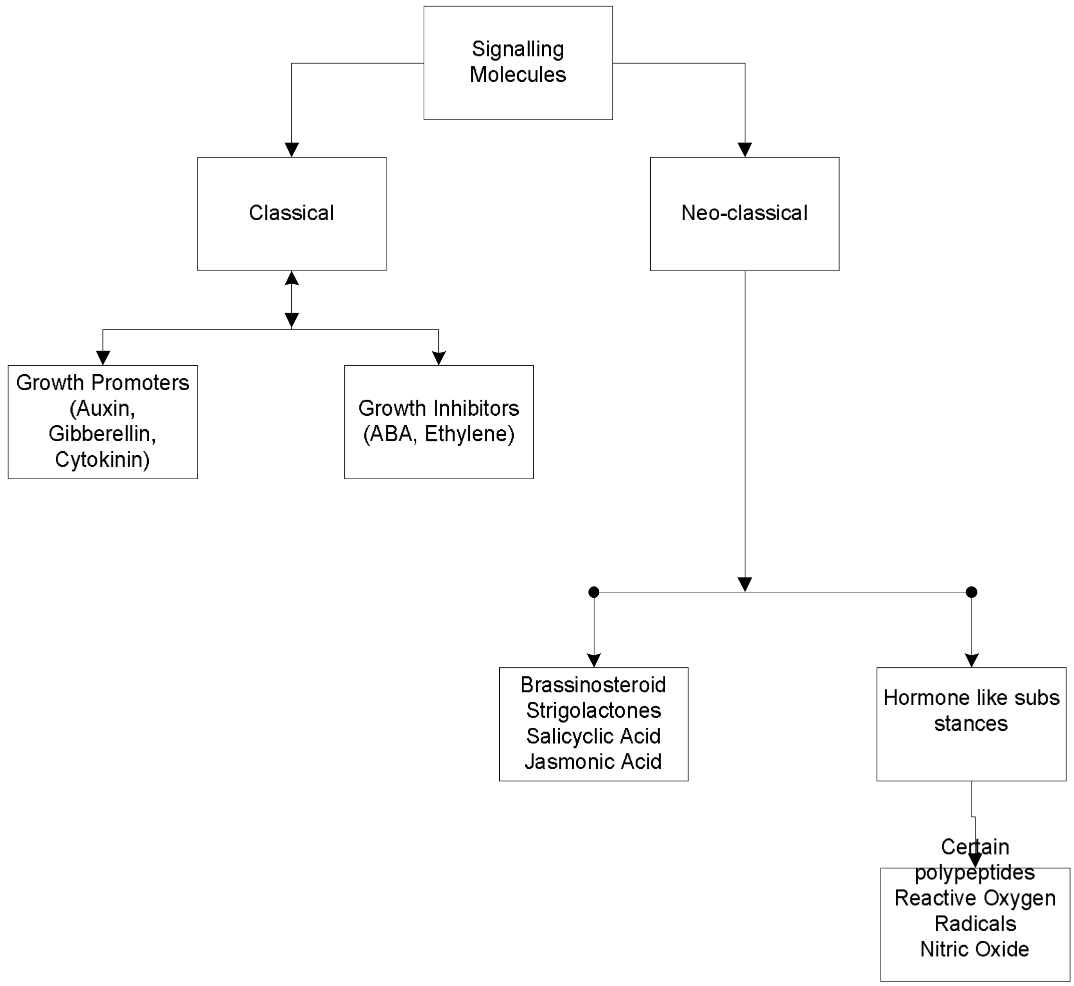
The downstream effect involves:

1. Alternation of gene expression pattern via transcription proteins
2. Non-genomic function

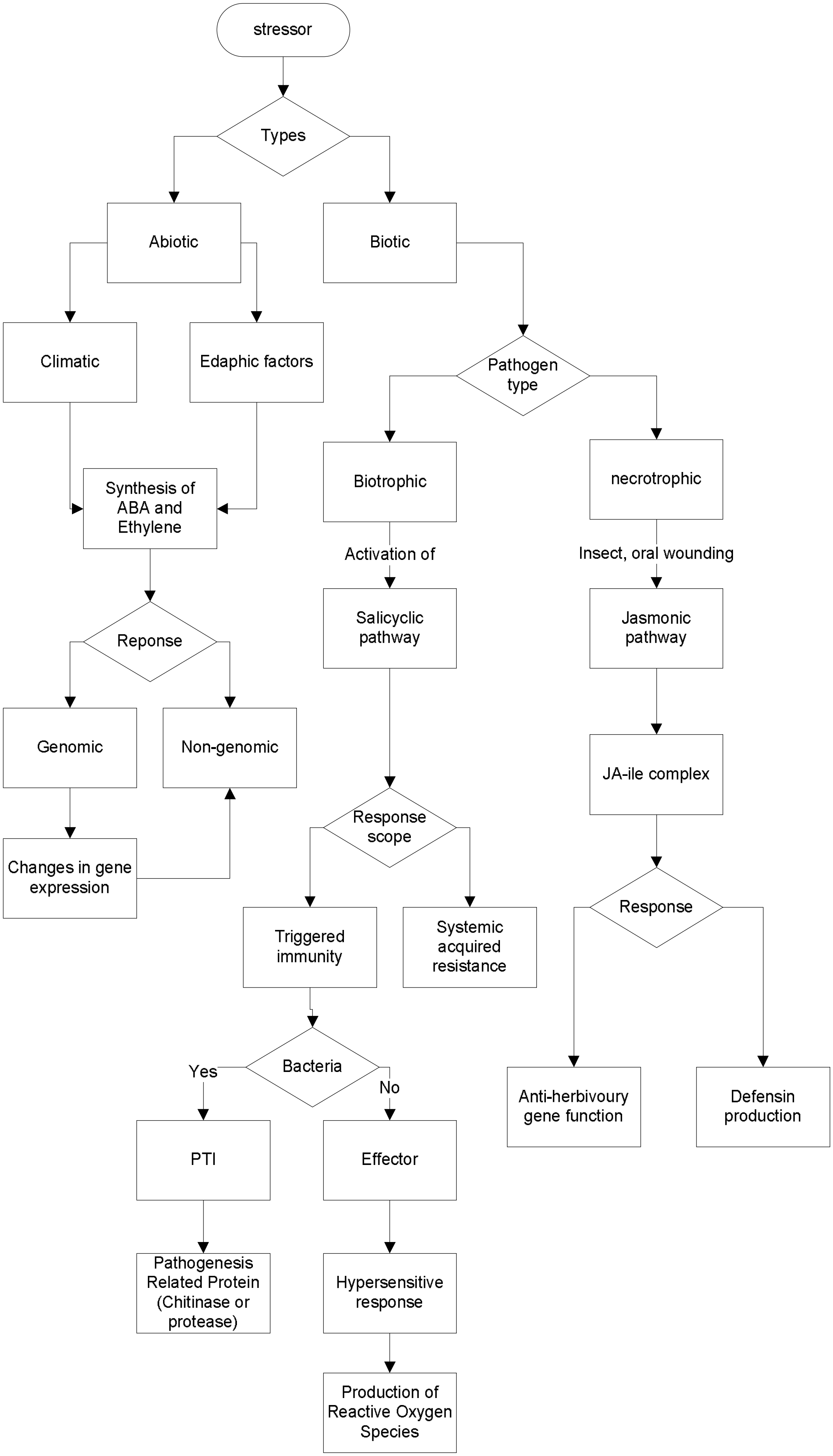
In crop production, most cultivated crops are subjected to actions of various stressors; biotic and abiotic. In the case the crop plant is subjected to both stressors, priority is given to amelioration of the actions of abiotic stressors at the expense of biotic stressors. In all instances of abiotic stressors, there is increased synthesis of ABA, production of induced proteins and other osmoprotective and regulatory substances like Heat Shock Proteins, Proline, Glycine Betaine etc. Biotic stressors, depending on the nature of the biotic stressors leads to production of salicyclic acid if biotrophic or Jasmonic acid or Ethylene if necrotrophic. The production of these hormones interferes with GA/Auxin induced growth pathways. The non-genomic function leads to the production of antiherbivory function, anti microbial function i.e. defensin protein and the production of plant volatile to suppress the incidence of biotic stressors. Hormonal actions vary throughout the phenological phases. At juvenile or vegetative phase, growth promoters are more predominant in their actions. Auxin aids cellular division and elongation. Cytokinin controls stomatal aperture and water potential of the leaf, while GA is responsible for the protection of chlorophyll, RNA and degradation of protein. With transition to reproductive phase, though genetically controlled and mediated by environmental factors, hormonal actions equally mediate this process, with growth inhibitors; ABA and Ethylene affecting rate of senescence and maturation, both physiological and harvest. Maturation referred to here is the expression of full reproductive potential, while at physiological maturity; there is a cessation of sexually induced reproductive growth.

Refer to the attached table for comparative analysis of phytohormones.

**Classification of signalling Molecules**




Find below Mechanism of hormonal action under different stressors


stressor
Types
Abiotic
Biotic
Climatic
Edaphic factors
Pathogen type
Synthesis of ABA and Ethylene
Biotrophic
necrotrophic
Activation of
Insect, oral wounding
Reponse
Salicyclic pathway
Jasmonic pathway
Genomic
Non-genomic
JA-ile complex
Changes in gene expression
Response scope
Response
Triggered immunity
Systemic acquired resistance
Bacteria
Yes
No
Anti-herbivoury gene function
Defensin production
PTI
Effector
Pathogenesis Related Protein (Chitinase or protease)
Hypersensitive response
Production of Reactive Oxygen Species

UTO

# PLANT HORMONES

Hormone = Greek; to excite or arouse

* They are defined as naturally occurring organic substances that at low concentration exert a profound influence on physiological processes.

* They are in animals

1- Synthesized in a discrete organ or tissue.

2- Transported in blood stream to a specific target tissue.

3- There they control a physiological response in a concentration-dependent manner.

**Plant Growth Regulators or Plant Hormones**

Physiological action of auxin;

* Cell growth and differentiation

* Shoot and Root development

    1- Auxiliary bud growth \ Apical dominance.

    2- Leaf abscission-abscission layer.

    3- Root elongation and development.

    4- Flower and fruit development \ Imperfect flowers

    Monoecious

Dioecious

Parthenogenetic

Plant Hormones and Plant Growth and Development

Auxins, Growth and Tropisms

Hormones; are chemical messengers that are used to work as intercellular communication mediators

In cells; Hormones interact with specific protein called "Receptors"

Plant Hormones are grouped into (5) five main groups;

a) Auxins,

b) Gibberellins,

c) Cytokinins,

d) Ethylene,

e) Abscisic acid(ABA).

AUXINS

* First plant hormone discovered, in elongation and tropism

* 3 techniques used for detection and analysis of auxin

A) Avena - coleoptiles curvature assay.

- Coleoptile straight growth.

B) Thin layer chromatography (TLC), HPLC, GC

C) Radioimmunoassay (RIA)

* Mediation of plants responses to unidirectional light (phototropism) and gravity (gravitropism)

* Accurate measurement of amount of auxin in plant tissue is critical for understanding of the role of this hormone in plant physiology

* Regulation of growth in plant depend in part on the amount of free auxin present in cells and tissues and organs

* This depends on: -

- Synthesis and breakdown of conjugated IAA (bound)
- Active transport of IAA
- IAA metabolism

* Also, biophysical parameters:

a) Water uptake

b) Irreversible cell wall expansion.

* loosening of cell wall by IAA- it is exposed to acidic PH, H+ --à cell wall

* Synthesis and deposition of polysaccharides to cell wall

* Promote uptake of solutes into cells à sustain elongation.

* Tropism; there stages of, + detection of stimulus, +signal translation, +Response

* Cholodny –Went theory: Auxin is the primary signal molecule- phototropism and gravitropism

* Promote lateral root formation and fruit development

* Inhibit lateral bud development and leaf abscission.

Gibberellins (GA), are a family of compounds, over 80 of defined structure.

Not all GA found in higher plants, some biologically inactive

* Discovered as product of fungus gibberellins

* Terpnoid compounds, made up of Isoprene units derived from mevolonic acid

* It cause\ - stem elongation in dwarf plants

- Bolting in long-day plants ( grow along flower stalk)

- Promote fruit set, fruit growth.

- Promote seed germination

Notice: GA conc. In plant …..and whether it being long or dwarf

GA, induction of the enzyme ɑ- amylase in aleurone cells of germinating cercal grains.

GA from the embryo induce the transcription of the gene for α-amylase mRNA

Commercial applications of GA

- Enhancing seedless grape
- Malting of barley
- GA- synthesis inhibitors are used as dwarfing agents

CYTOKININS:-

- Delay of senescence in detached organs
- Mobilization of nutrients
- Chloroplast maturation
- Expansion of cotyledons
- Control of morphogenesis
- Regulate cell division

Notice: cell division is not necessarily a component of these other responses

* Kinetin (an example); is not naturally occurring (from autoclaved herring sperm

DNA) It works in presence of auxin only

* Zeatin ( an example) naturally occurring isolated from the extract of immature

endosperm of corn (*zea mays*) as riboside, ribotide, glucoside

- Cytokinins are N6 – substituted aminopuines.
- Initiate cell proliferation in mature tobacco pith tissue …. +Auxin
- Synthesis occur in a) Roots, b) Developing embryo, c) crown gall tissue

Crown gall … infected plants by *Agrobacterium tumefaciens* inject Plasmid T-DNA into wounded plant cells…. Incorporated into plant cells Phyto-oncogenes …….. Genomes

- Concentration in young rapidly dividing cells of the shoot and root apex
- Translocated passively in the water and mineral in xylem.

* Ethylene: is the only known gaseous plant hormone

  - Inhibitors of growth and metabolic processes
  - Formed in most organs of higher plants
  - Senescing tissue or ripening fruits produce more ethylene than young or mature tissues

- The precursor of ethylene *in vivo* is amino acid methionine
- Biosynthesis is triggered by… auxin and environmental stresses
- The physiological effects of ethylene can be blocked by biosynthetic inhibitors or by antagonists (AVG, AOA)
- $CO_2$ and Hg (silver ion) inhibit ethylene action
- Regulates
  - Fruit ripening
  - Leaf and flower senescence
  - Leaf and fruit abscission
  - Seedling growth
  - Hook opening
- Regulate ripening- associated gene expression….

Accumulate mRNAs for cellulase and polygalacturonase for cell wall solubilization and fruit softening

ABSCISIC ACID (ABA),

a growth inhibitor that plays a major role in seed and bud dormancy stomata closure

- 15-carbon compound – resembles the terminal protein of carotenoids

- Biosynthesis, a) direct pathway from mevalonate

  b) a 15-C precursor

  c) Cleavage of a 40-C carotenoids precursor

- Inactivated by oxidative degradation.... To phasiec acid and conjugation to form

  ABA-glucose ester

- synthesized to both the xylem and phloem

- ABA-mediate: growth inhibition dormancy

-Regulate: * water balance of plants under water stress

  * Cause stomatal closure

  * Maintain water uptake by roots

  * Regulate cellular processes through effects on ion movements

  across membrane and synthesis of special proteins

  * Inhibits, the synthesis of Gas-induced α-amylase in the alueurone

  layer

**Phytochrome and Phytomorphogenesis**

● Phytomorphogenesis refers to the dramatic effect of light on plant development and cellular metabolism

● "Red light" exerts the strongest influence, and the effects of red light are often reversible by "far-red light"

● Phytochrome is the pigment involved in most Phytomorphogenesis Phenomena

● Phytochrome is a large dimerse protein made-up of tow equivalent subunits

the monomer has a mass of 124.000 Da, and covalently bound to a chromophore molecule, an open chain tetrapyrrole

● Phytochrome exists in tow(2) forms;

1- Pr a "red light –absorbing form

2- Pfr a "far-red light-absorbing form

● Absorbing of red light by Pr convert it to Pfr , and

Absorb far-red light by Pfr convert to Pr

- Absorption of spectra of the two forms (red\far-red) overlap in the red region of the spectrum leading to an equilibrium between the two forms called Photo stationary rate

● Pfr is considered to be the active form in most cases, that is it gives rise to the physiological response.

● Of the other factors in addition to light regulate the steady-state level of Pfr include a) Dark reversion, b) degradation c) Rate of synthesis

● Phytochrome. Is most abundant in etiolated tissues and is concentration in meristimatic regions

● During photo-conversion to Pfr in higher plants, the phytochrome. Distribution within the cell changes from a diffused to a sequestered pattern

● Thus far, no organelle has been specifically associated with Pfr in higher plants. I alga *Moug eotia* phytochrome appears to be located on the plasma membrane, where it mediates chloroplast rotation by undergoing a 90º shift in orientation

● Phytochrome. Response, a- very low flounce (VLF)

b- Low flounce (LF)

c- High flounce (HF)

Also differ by; escape time, action spectra, and photo-reversibility

● Phytochrome Defection of shade in plants adapted to high level of sunlight

- Regulate circadian rhythms sleep movement of leaves
- Exert its effects by increasing free $Ca^2$ levels.

Formation of a Ca-calmodulin complex… activate enzymes important for cell regulation

- Phytochrome;

Regulate the transcription of a number of genes.

Many of genes involved in greening, such as the nuclear-enclosed gene for small

subunit of enzyme Rubisco and chlorophyll a\b protein of the light harvesting

complex, are re-activated by red-light

Gene activation is thought to mediated by regulatory protein that bind to the promoter

region of the gene

- Red light also repress the transcription of a number of genes, including the gene for phytochrome

The repression of the gene for phytochrome is also presumed to be mediated by DNA binding regulators proteins.