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Fundamentals of Agriculture

Plant Physiology
Entomology
Plant Pathology

Vol-2

By:
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KUSHAL PUBLICATIONS AND DISTRIBUTORS
VARANASI

PREFACE TO THE FOURTH EDITION

On the consistent request made by the reader and the publisher, I feel that the present book needs new inclusions on Agricultural Entomology and Plant Pathology. The holistic study of Agriculture requires to know about the insect-pest and diseases. Therefore, despite the lack of time, I somehow managed to write down but the inclusion of new chapters on Agricultural Entomology and Pathology in the present book 'Fundamentals of Agriculture' makes it bulky and voluminous. Keeping in mind the handy nature of the book, the publisher requested me to produce it in two volumes. The first volume contains Agronomy, Soil Science, Extension Education, Agricultural Economics and Farm Management and the 2nd one consists of Plant Physiology, Agricultural Entomology and Plant Pathology.

I hope that you all will welcome the publisher's advice on new form of the book. Lastly I request you to communicate your views and my mistakes done in the book.

6th Dec. 2006 — Arun Katyayan

CONTENTS

1. Water Relation

Introduction

Plant physiology is the study of vital or functional activities of plants. And water is essential for these functional activities.

What for water is needed-

1) Water is absolutely essential for protoplasm because its hydration is essential for its proper organisation and proper functioning of its organelles.
2) Water is the carrier of various dissolved substances like gases, minerals, organic and inorganic substances etc.
3) Water is necessary for metabolic reactions of the cell e.g. photolysis of water.
4) The rigidity and turgidity of cells is maintained by and large by water.
5) Water forms a continuous network throughout the plant through which dissolved substances move up.
6) Water makes up the loss of water during transpiration and guttation.

Thus almost all the functional activities of plants depend on the water relation. Under water relation we study the following points-

a) How does water enter into the plant:- This functional activity is studied under the heading '**Osmosis**'.
b) How does water move up inside the plant:- It is studied under '**Ascent of sap**' or '**Translocation of sap**'.
c) How is water lost from the plant:- It is studied under '**Loss of water**' or '**Transpiration**'.

Diffusion: The movement of the molecules of gases, liquids or solutes from the regions of higher concentration to the regions of lower conc. until the molecules are evenly distributed throughout the available space is known as Diffusion.

Osmosis

- ⋆ Osmosis is essentially a special type of diffusion of liquids.
- ⋆ The term 'Osmosis' was given by Abbe Nollel.
- ⋆ Osmosis means:
  - a) Movement of **solvent**.
  - b) From a region of **lower** concentration of solution.
  - c) To a region of higher conc of solution.
  - d) Through **semi-permeable membrane** (SPM).
- ⋆ Plasma or cell membrane is a semi-permeable membrane. At higher temperature plasma membrane becomes permeable.

Illustration:

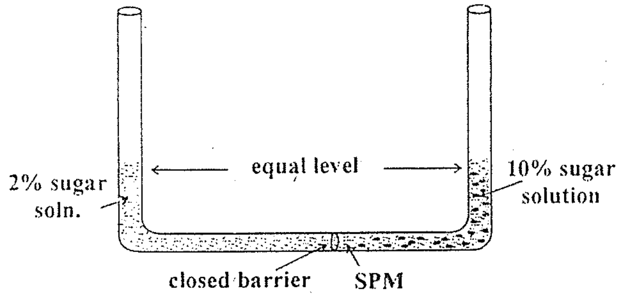


Fig : Closed barrier showing no-osmosis

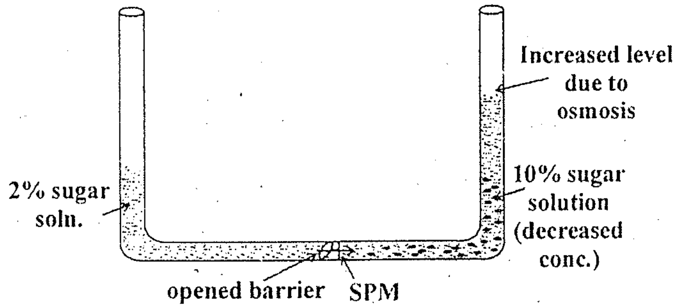


Fig : Opened barrier showing osmosis through SPM

Here when barrier between two different concentrated solution is opened and barrier remained only semi-permeable membrane, then the level of higher conc. solution is increased. It is happened only due to flow of water from lower conc. to the higher conc. through semi-permeable membrane.

- ⋆ Semi-permeable membrane is such type of membrane through which solutes of solution do not pass but solvent passes e.g. plasma-membrane.
- ⋆ Differentially or Selectively Permeable membrane is such type of membrane through which some particles pass but others do not pass e.g. lipo-protein cell membrane.

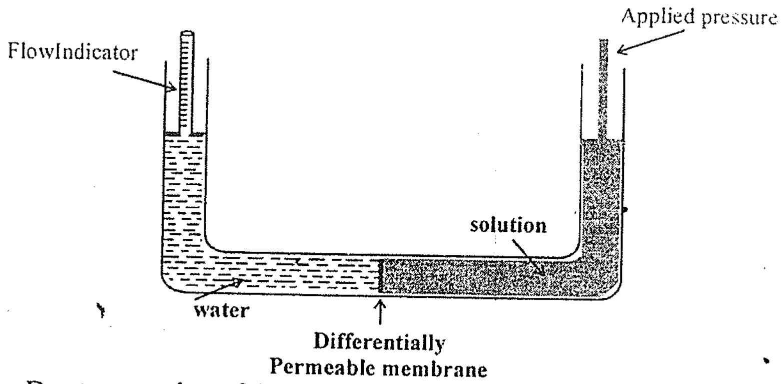
Osmotic Pressure or Osmotic Potential (O.P.):

The applied pressure required to stop osmosis when a solution is separated from pure water by a semi-permeable membrane is called osmotic pressure and usually denoted by 'π'.

The osmotic pressure of a solution is defined as the excess hydrostatic pressure which must be applied to it in order to make its water potential equal to that of pure water.

One atm. (S.I. unit of pressure) = 1.01 bars

or one bar = 0.987 atm.



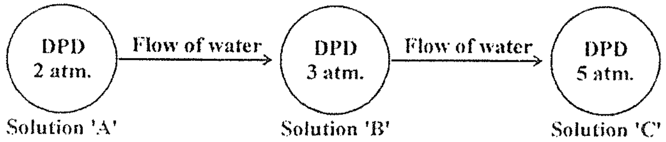
Due to a number of definitions, the term osmotic pressure is misleading since it denotes a real pressure where as it is only a property of a solution expressed in terms of pressure. Hence the term 'Osmotic Potential' is used by modern physiologists. Osmotic potential is that part of water potential which becomes more negative with addition of solutes.

Osmotic Potential = negative osmotic pressure.

It indicates decrease in pressure that occurs due to addition of the solutes. In a pure solvent, the value of osmotic potential is **Zero** which is maximum value.

Diffusion Pressure Deficit/Water Potential (DPD/WP):

Diffusion pressure deficit (DPD) is also called suction Pressure (S.P.). It is the ability of a cell to draw water. It is the force per unit area (i.e. pressure) by which water enters into a cell. A pure solvent is supposed to have maximum diffusion pressure. When certain solute particles are added to the pure solvent, the diffusion pressure of the resulting solution is lowered. The amount by which the diffusion pressure of a solution is lowered than that of its solvent at the same temperature and atmospheric pressure, is called DPD. The term DPD was introduced by Meyer in 1938.



Movement of water is from A to B and B to C

But according to the recent trend, diffusion of water is explained in terms of **Water Potential**. DPD is the positive value whereas water potential is the negative value.

Turgor Pressure (T.P.) : T.P. is the outward pressure exerted by the cell solution on the cell wall which is developed due to osmotic diffusion of water. In a equalibrium inward pressure is also given by the cell wall on the cell solution in a equal amount, which is called wall pressure or Hydrostatic Pressure.

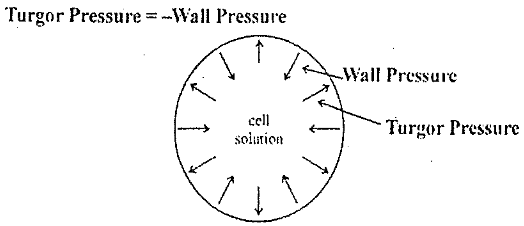


Fig. : Turgor Pressure

Turgor Pressure is also called Pressure Potential (P.P.) which has positive value.

Chemical Potential : The free energy per mole of a chemical substance is called its chemical potential. Chemical potential of water in a solution is reduced by the addition of solutes.

Osmotic Relations : The diffusion of water depends upon its free

energy per mole. The wall pressure also increases the free energy of the water contained in a cell. The sum of osmotic potential and wall pressure denotes a net change in the chemical potential of water. This net change is called **water potential** (Ψ_w). Water potential (W.P.) is **always negative** and the maximum value is **zero**. Water potential is affected by osmotic (solutes) potential, pressure (hydrostatic or turgor) potential and Matric potential (due to water binding matrix).

$$\Psi_w = \Psi_s + \Psi_p + \Psi_m$$

Ψ_w = Water Potential.

Ψ_s = Osmotic potential; contribution made by solutes.

Ψ_p = Pressure potential; contribution made by turgor pressure.

Ψ_m = Matric potential; contribution made by matrix.

Since Ψ_m is negligible,

$$\Psi_w = \Psi_s + \Psi_p$$

$$\Rightarrow \boxed{WP = OP + PP}$$

S.No	Old term	New Term
1.	Diffusion Pressure Dificit (DPD)	Water Potential i.e. W.P. (negative value)
2.	Osmotic Pressure (O.P.)	Osmotic Potential, i.e. O.P. (negative value)
3.	Turgor Pressure (T.P.)	Pressure Potential i.e. P.P. (Positive Value)

After substituting the old term in the above equation-

WP = OP + PP

=> – DPD = –OP + TP (here osmotic pressure)

=> $\boxed{OP = TP + DPD}$ here OP → osmotic pressure.

=> Osmotic Pressure = Turgor Pressure + Diffusion Pressure Dificit.

Therefore in osmosis, movement of water takes place from:-

a) higher water potential to lower water potential.

b) lower concentration to higher concentration of solution.

c) Lower DPD to higher DPD.

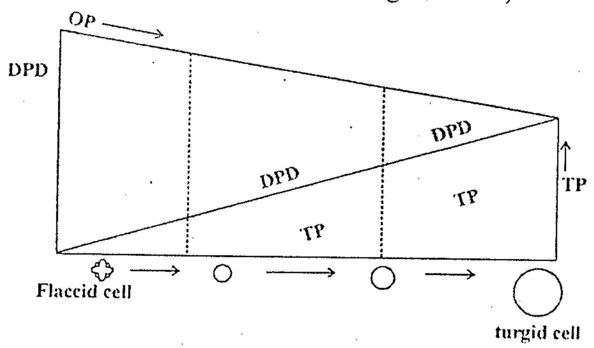
Question : A cell (A) having O.P. = 10 atm. and TP = 4 atm. is surrounded by 'B' cells of OP = 18 atm. and TP = 6 atm; then movement of water is

a) From 'A' cell to 'B' cell (surrounding cell)
b) From 'B' cell to 'A' cell.
c) Both of them.
d) No movement of water.

Solution:

For 'A' cell: WP = OP + PP (or TP)
= –10 + 4 = – 6 atm.
or DPD = OP – TP = 10 – 4 = 6 atm.
for 'B' cell: WP = –18 + 6 = –12 atm.
or DPD = 18 – 6 = 12 atm.

therefore, movement of water is from 'A' cell (i.e. higher W.P. or lower DPD) to 'B' cell (i.e. lower WP or higher DPD) means Ans. (a)



When T.P. increases, the corresponding DPD decreases.

Endo osmosis : The diffusion of solvent particles into a living cell or structure is called endoosmosis.

Exoosmosis : The diffusion of slovent out of a living cell or structure is called exoosmosis.

Role of Osmosis :

i) Plants absorb large amount of water from soil.
ii) Movement and distribution of water across cells is due to osmosis.
iii) Osmosis is responsible for turgidity of plant cells. The leaf, flower & stem tip require turgor for maintaining their form.
iv) Turgor of the guard cells is absolutely essential.

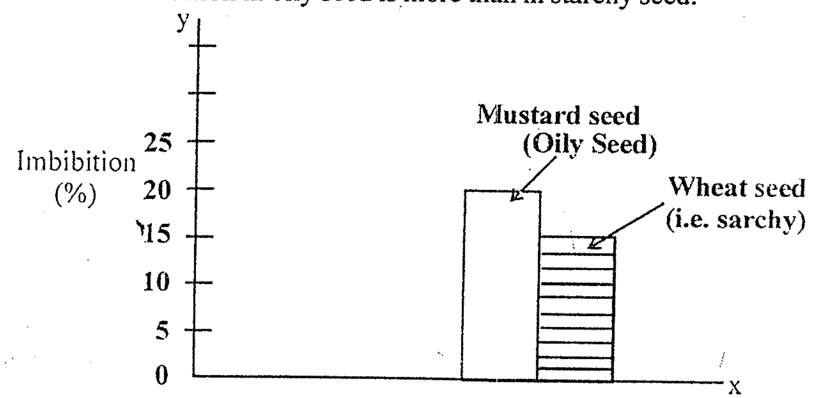
v) It is essential for the growth of young cells.
vi) High osmotic conc. increases resistance of the plants to freezing temperature and dessication.
vii) It is responsible for turgor pressure in root xylem i.e. root pressure.

Factors affecting Osmotic Pressure :

1) **Concentration of the solute particles** : Osmotic pressure depends upon the ratio of solute and the solvent particles. The increase in the solute concentration, increases the osmotic pressure.
2) **Ionisation of the solute molecules** : Ionisation increases the number of solute particles.
3) **Hydration of solute molecules** : A solution which has hydrated solute molecules is of higher osmotic pressure than otherwise because the water molecules which are associated with the solute molecules are ineffective as a part of the solvent.
4) **Temperature** : Osmotic pressure increases with increase in temperature.

Imbibition

★ The term 'imbibition' was coined by Sachs. The soaking up of water by dry substances due to hydrophillic colloids is called Imbibition.
★ It is the first step in the absorption of water.
★ The rate of imbibition increases with increase in temperature.
★ Imbibition in oily seed is more than in starchy seed.



Imbibition pressure is also called **Matric Potential** (Ψ_m). Matric potential is the component of water potential which is determined by the attraction between water and hydrating colloid or gel-like organic molecules, cell wall etc. (collectively called matrix).

The matric potential is maximum (most negative) in a dry material. Both living and dead plant cells possess a large amount of carbohydrates, proteins, and polypeptides etc. which are hydrophillic colloids and therefore, have very strong attraction for water. Seeds rich in colloidal materials are very good imbibants.

Plasmolysis

1) Plasmolysis is the shrinkage of protoplasm due to outward flow of water in a hypertonic solution.
2) The point where plasmolysis just starts (not visible) is called incipient plasmolysis.

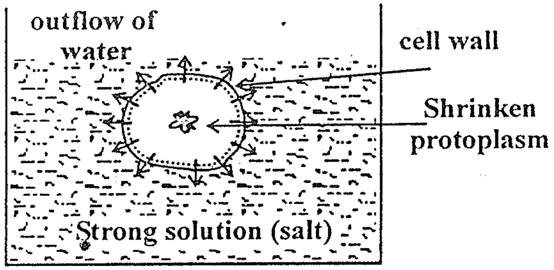


Fig. : Plasmolysis

Cell wall → either permeable (cellulose cell wall) or impermeable (cork cell, lignified, suberinised)

Cell membrane → always semi-permeable.

3) Space between shrinken protoplasm and the cell wall is occupied by plasmolysing solution i.e. external solution (or salt).
4) When a plasmolysed cell is placed in hypotonic solution or pure water, the protoplasm as well as cell as a whole attain their original shape and size respectively due to endoosmosis. This phenomenon is called **Deplasmolysis**.

Examples :

i) Raisins swell in water due to imbibition and endosmosis.

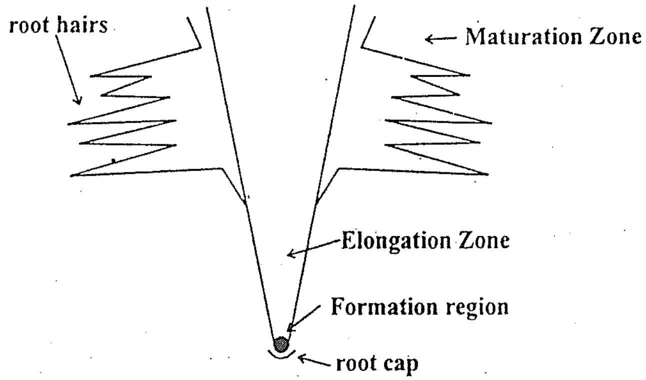
ii) Excess of fertilizer in the soil kills the plant due to plasmolysis (exoosmosis)
iii) Salted pickle or meat kills the bacteria due to plasmolysis.

Solution: is of three types:

i) **Hypotonic** solution : it means weak solution. A cell swells in hypotonic solution.
ii) **Hypertonic** solution : strong solution. A cell shrinks or become flaccid in such solution due to outward flow of water.
iii) **Isotonic** solution : not weak nor strong solution. A cell remains unchanged in it. Eye drops are always isotonic solution.

Absorption of water

1) Water is absorbed by the root hairs. Root hairs are more developed in xerophytes (arid plants) and absent in hydrophytes.
2) First step in absorption of water is imbibition.
3) The absorption of water takes place in the terminal portions of roots but the **maximum absorption** of water takes place in the **zone of root hairs** i.e. 1-10 cm. behind the root tip.



★ Root cap is formed by calyptrogen (=Dermatogen+Periblem)
★ Multiple root cap is found in Pandanus (screw pine).
★ Maximum absorption of **inorganic salts** is through the **zone of cell division.**

4) Renner (1912, 1915) :- First time recognised and classified the water uptake mechanism into "active absorption" and "passive absorption".

Types of Absorption
- Active absorption
  - Osmotic Theory
  - Non-osmotic theory
- Passive absorption

Table : Difference between Active & Passive absorption

Active absorption	Passive absorption
1) Occurs against concentration gradient.	1) along conc. gradient
2) Metabolic energy (i.e. ATP) is required	2) Spontaneous
3) Involves primary active transport using ATP and secondary active transport using proton motive force.	3) No
4) Always selective uptake e.g. ion uptake (NO_3^-)	4) Non-selective e.g. water.

Active Absorption :

1) Root hairs play an active role.
2) Water enters into root hair by osmosis.
3) Process occurs against the concentration gradient and
4) Metabolic energy is spent.

There are two major theories to explain active absorption :-

a) Osmotic Theory :

1) Atkins (1916) and Priestley (1920–22) were amongst the first to postulate an osmotic theory of active absorption.
2) The value of osmotic pressure of the cell sap of the root hairs is generally 2.0 atm. (but varies between 3 to 8 atm.) and of soil water is less than 1.0 atm.
3) Higher DPD of the cell sap of the root hairs causes endoosmosis of soil water.
4) But a problem is how a sufficient conc. of solutes is maintained in the root xylem to maintain a higher DPD in the xylem sap.

b) Non-osmotic theory :

1) Water is absorbed against a concentration gradient.
2) Absorption require an expenditure of energy released from respiration.
3) Renner's active theory is called 'osmotic active'.

Passive Absorption :

1) Process occurs along the concentration gradient.
2) And hence energy is not involved.
3) Absorption is controlled by transpiration.
4) Highest DPD or Lowest Water Potential — in Leaf cells
   Lowest DPD or Highest water potential — in Root hairs

T/A Experiment :

T/A means Transpiration/Absorption ratio

let,

i) Weight of bottle with plant = 1000g

ii) Initial reading of water inside tube is 5 cc. one drop of oil is poured into side tube to check evaporation. After allowing the minimum time i.e. 30 minutes for transpiration and absorption, again reading is noted down.

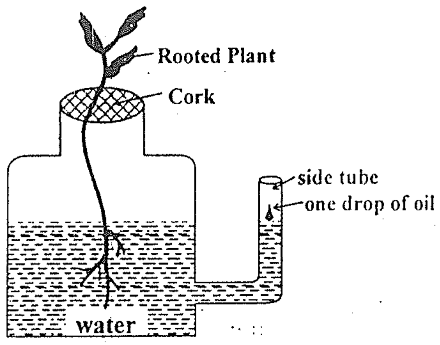


Fig. : T/A Experiment

iii) Wt. of bottle with plant = 998g.
means water lost = 1000 – 998 = 2g.

iv) Final reading of water inside tube = 3 cc.
means water absorbed = 5–3 = 2 cc.

$$\therefore \frac{\text{Transpiration}}{\text{Absorption}} = \frac{2}{2} = 1$$

Inference : water lost in transpiration is equal to water absorbed.

Factors affecting the rate of water absorption :

1) **Available Soil Water :** The rate of water absorption is uniform between the field capacity and permanent wilting percentage. The decrease in soil water below the permanent wilting point causes considerable decrease in the absorption of water.
2) **Conc. of the soil solution :** The lack of water absorption by plants growing in saline water is an example of physiological dryness.
3) **Soil aeration :** The rate of water absorption is rapid in well aerated soils. Oxygen deficiency and accumulation of CO_2 increases the viscosity of the protoplasm and decreases its permeability, both of which reduce the rate of absorption. During waterlogging conditions, there is total check on the water-absorption which is an example of physiological dryness.

Ascent of Sap

Ascent of sap is the translocation of water and inorganic solutes. Ascent of sap means-

i) movement of water and inorganic solutes.
ii) from root to the leaves.
iii) through xylem vessels.
iv) against the force of gravity.
v) and water column remains in a state of tension.

★ Ringing or Girdling experiment by Malpighi confirmed the ascent of sap through **xylem**.

★ Mass Flow or Pressure Flow theory for the movement of food was given by Munch.

Mechanism of Ascent of Sap:

To explain the mechanism of ascent of sap, various theories are put forwarded which are classified under 3 headings :-

(A) Vital Theories :

i) **Relay or clambering Pump Theory :** This theory was put forwarded by Godlewski (1884) to explain ascent of sap. According to this theory, "Rhythmic change in the osmotic pressure

of the living cells of xylem parenchyma and medullary rays bring about a pumping action of water in an upward direction."
Relay pump theory was contradicted by Strasburger (1893). He proved that ascent of sap was independent of living cells because water continued to be transported above even after the killing of living cells by poison (i.e. picric acid) or high temperature.

ii) **Pulsation Theory :** by Sir J.C. Bose (1923), experiment on **Demodium gyrans** (Indian telegraph plant, Family- Lugiminosae) According to Sir J.C. Bose, "Living cells of the inner most layer of the cortex, just outside the endodermis are in a state of rhythmic pulsations which cause the pumping of water for cell to cell in an upward direction."
Benedict (1927) found that the actual rate of ascent of sap was 8000 to 30000 times as rapid as would be possible according to the Bose theory.

(B) Root Pressure Theory :

'Root Pressure' was coined by **Stephan Hales (Father of plant Physiology)**. The hydrostatic pressure developed due to the accumulation of water absorbed by the roots is called root pressure. Root pressure is measured by manometer.

But Root pressure is not sufficient to drive water to a distance of 400 ft. in the trunks of tall trees.

(C) Physical Theories :

All these theories consider the dead cells of plant to be responsible for ascent of sap.

i) Boehm's theory (1809) : According to it, the ascent of sap is partly due to the phenomena of capillarity of the trachea and partly due to the atmospheric pressure.
The highest column of water attained by capillary forces is 4 ft. and by atmospheric pressure is 34 ft. only.
ii) Jamin's chain theory : Air and water are alternately arranged inside the plant. When air expands, it moves up carying along with it the water column present above it.
iii) Imbibition Theory : According to Sachs (1878), Imbibition activity of cell walls of xylem is responsible for ascent of sap.

iv) Cohesion and Adhesion theory or Transpiration Pull theory : This theory was given by **Dixon & Jolly** (1894) and Askenasy (1895). This theory is most accepted theory. There are three features of this theory :

a) Strong cohesive force or tensile strength of water.
b) Continuity of water column in the plant.
c) Transpiration pull or tension on the unbroken water column.

Loss of water

The loss of water from the living tissues of plants takes place either in vapour form (i.e. transpiration) or in liquid form (i.e. Guttation, Bleeding).

Transpiration

The loss of water in the form of vapour from the living aerial parts of the plant is known as transpiration. The principal organ of transpiration is leaf. Transpiration may be foliar or lenticular. Again foliar transpiration is of two types viz. stomatal (through stomata) and cuticular (through cuticle).

★ Dry cobalt chloride ($CoCl_2$) is deep blue in colour but when comes in contact with water, it turns into red colour.

Transpiration
- Foliar through leaves
  - Stomatal through stomata (Most of the transpiration is stomatal)
  - Cuticular through cuticle
- Lenticular through lenticels (Lenticels are the pores in the bark of fruits and woody stems)

Difference between Transpiration & Evaporation

Transpiration	Evaporation
1) It is a vital & Physiological phenomenon.	1) It is simply physical phenomenon.
2) The loss of water occurs in the form of vapour from the living cells.	2) It occurs in the form of vapour from the non-living cells.

3) It is regulated by the guard cells.	3) There is no such regulation.
4) It prevents the dryness of the cell surface.	4) Evaporation results in the dryness.
5) There are several mechanism & forces involved in it.	5) There is no such mechanism & forces involved.

Stomata :

i) Stomata are specialised epidermal cells which are distributed all over leaf surface but in case of terrestrial plants, mainly on lower surface of leaves. Therefore approximately 97% of transpiration takes place from the lower surface in such plants.
ii) Each stoma (open) has two kidney (or bean) shaped guard cells.
iii) Inner wall of guard cell is thick and outer wall is thin.

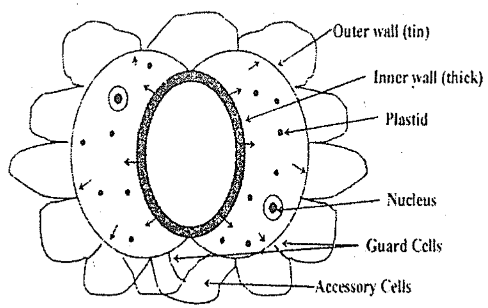


Fig. : Single Stoma

iv) Guard cells are surrounded by epidermal or subsidiary or accessory cells.

Classification of Stomata :

According to the distribution of stomata, plants are of five categories:

a) **Apple and Mulbery type :** In such plants, stomata are present on **under surface only**.
b) **Potato type :** More stomata on the lower (or under) surface than on upper surface.
c) **Oat type :** Stomata are equally distributed on both surfaces.
d) **Water Lily type :** Stomata **only** on upper surface.

e) **Potamogeton type :** In such plants stomata are either absent or functionless. Such plants are most of the submerged aquatic plants.

On the basis of daily movement of stomata, Loftfield classified it into three main groups.

1) **Alfalfa type** : Such stomata are open throughout the day and night and are found mostly in thin leaved mesophytes e.g. pea, bean, radish, mustard, vitis etc.

2) **Potato type** : Such stomata are open throughout day and night except for a few hours in the evening. e.g. onion, plantain, cabbage, pumpkin etc.

3) **Barley type** : Such stomata are open only for a few hours during the day e.g. cereals.

Mechanism of Stomatal Opening and Closing :

Opening and closing of stomata are due to its turgidity and faccidity respectively. It means stomatal movement is governed by turgor movement. When T.P. of guard cells increases, stomata are opened and when decreases, stomata are closed.

[1] Photosynthetic Production in the guard cells :

According to Von Mohl (1856) : Chloroplasts of guard cells synthesize osmotically active substances in the day which increases their osmotic pressure and thus endosmosis. This ultimately leads to stomatal opening and vice versa in the night.

In day :-

i) Conc. of sugar in guard cells increases.
ii) DPD of guard cells increases.
iii) Water enters into guard cells by osmosis.
iv) TP of guard cells increases.
v) Stomata open.

In night, the process is reverse.

This proposition is not acceptable due to

a) Increasing the CO_2 conc. around leaf in bright light causes partial closure of stomata.

b) Chloroplasts of guard cells are either total incapable of photosynthesis or can have only feable photosynthesis.

[2] The starch = Sugar hypothesis :

Lloyd (1908) observed that the amount of starch in guard cells increases at night but decreases in day. It means turgidity of guard cells is governed by change in O.P. caused by interconversion of starch and sugar. Scarth (1932) supported the Sayre's hypothesis of starch = sugar interconversion. Sayre thought that the removal of CO_2 by photosynthesis during thelight period caused increase in the pH resulting in the conversion of starch into sugar. This interconversion is catalysed by phosphorylase.

$$\text{Starch} + n\text{ (inorganic phosphat)} \xrightarrow{\text{Phosphorylase}} n\text{ (Glucose} - 1 - PO_4)$$

But in 1964 Steward said that O.P. of guard cells would not be affected appreciably unless glucose–1–PO_4 was further converted to glucose and inorganic phosphate.

$$n(\text{Glucose}-1-PO_4) \xrightarrow{\text{Phosphotase}} \text{Glucose} + PO_4$$

Illuminated guard cells	Dark guard cells
i) Respiratory CO_2 of intercellular spaces is used up by mesophylls in photosynthesis.	i) Accumulates in spaces
ii) pH of guard cells rises	ii) Falls
iii) The decrease in acidity favours hydrolysis of starch into sugar	iii) The increase in acidity favours sugar → starch
iv) O.P. cell sap of guard cells increases.	iv) Decreases
v) Water enters into guard cells and T.P. and volume increase.	v) Water leaves the guard cells and T.P. and volume decreases.

Drawback :

i) How does the change in CO_2 raise the pH form 4.5 to 7.O.
ii) Either at the time of opening of stomata or disappearing of starch, sugar is never seen in guard cells. Starch is always changed into organic acid.
iii) In monocot, starch is not formed at all in guard cells.

[3] Active K^+ transport mechanism :

According to Immamura (1943), Yamashita (1952), Fischer and Hsiao (1968) there is a direct correlation between stomatal movements and K^+ concentration of guard cells. K.Raschke (1975) propounded that any of the following processes can initiate stomatal opening :-

i) disappearance of starch from the guard cells;.
ii) production of organic acids, particularly malic acid.
iii) excretion of H^+ from guard cells;
iv) uptake of K^+ into the vacuoles of the guard cells;
v) uptake of Cl^- into the vacuoles.

According to Raschke, the excretion of H^+ ion from the guard cells is of primary importance in the stomatal opening. The H^+ ions are to be availed by dissociation of organic acids for exchanging K^+ ions.

Abscisic acid (ABA) blocks the active excretion of H^+ ions from guard cells and thus results in the stomatal closure.

[4] Proton transport concept : It deals with the matter under two heads viz. photoactive opening and scotoactive opening:

a) Photoactive opening : 'The proton transport concept of photoactive stomatal opening' was proposed by Levitt (1974). Actually it is a synthetic theory in which good points of Scarth's classical pH theory and active K^+ transport theory.

b) Scotoactive opening : This theory was proposed by Pallas (1969) and Ehrler 1972. This theory deals with the opening mechanism of stamata during night especially in succulent plants. In succulent plants stomata open during night. In such plants initially stomata close when darkness sets in. It results in O_2 deficiency and is more pronounced in thicker leaves where oxygen is utilised in respiration. This decreases the mitochondrial activity and gives the way to anaerobic respiration. The mitochondrial induced proton transport to cytoplasm is stopped and the resultant acidification of cytoplasm is removed. This raises the pH of cyto plasm and larger amount of PEP (Phosphoenol Pyruvic Acid) is converted to R $(COOH)_2$ (i.e. organic acid) by PEPC (Phosphoenol Pyruvate Carboxylase Enzyme). It is followed by K^+ absorption. The remaining steps are same to those of photoactive opening.

★ Rate of transpiration is determined by Potometer i.e. **Farmer's Potometer** and Ganong's Potometer.

★ Stomatal opening is measured by Knight's porometer.

Guttation

1) The exudation of sap (water) through hydathode (structure present at the tips of veins of leaves) is called guttation.
2) The cause of guttation is root pressure (positive hydrostatic pressure developed in the xylem ducts of the root system.)
3) Necessary condition for guttation : -
   i) Increased absorption of water and decreased transpiration.
   ii) Warm soil & humid or cool atmosphere.
   iii) Warm day and cool night (such condition is available in winter season).
4) Guttation normally occurs at night.
5) Accumulation of salts at leaf tip or leaf margin of some plants during winter is due to guttation.

Hydathode : It is a specialised epidermal cell found at leaf tip or leaf margin i.e. end of veins and veinlets. The group of parenchyma beneath hydathode is known as epithem.

Bleeding

1) The loss of sap (water) from the injured parts of the plant is called bleeding.
2) The cause of bleeding is root pressure.

Difference between Transpiration & Guttation

Transpiration	Guttation
1) It usually occurs in day time	1) It occurs during night.
2) The loss of water occurs in the form of vapour	2) Here occurs in the form of liquid.
3) It occurs through stomata, leticels & cuticle.	3) It occurs through hydathodes.
4) It is regulated & controlled by stomatal activities.	4) It is regulated by the root pressure and the climatic condition.
5) The after affect of transpiration is cooling the leaf surface.	5) There is no such effect.
6) The transpiring water is pure.	6) Guttation water contains dissolved salts & minerals.

2. Photosynthesis

Introduction :

1) About 90% of the world's photosynthesis is carried out by marine and fresh water algae.
2) From Aristotles's time to 17th century it was generally believed that plant and animal debris of the soil was the source of plant nutrition.
3) According to Van Helmont in early 17th century, it was water and soil which contributed to the plant growth.
4) Stephan Hales (1727) : Green plants may get part of their nourishment through their leaves and sunlight may have to do something with it.
5) Priestley (1772) : Idea of gas exchange taking place in photosynthesis.
6) **Ingenhouz** (Austria, 1779) : Plants purify the air only in the presence of light. Only the green parts of the plant produce the purifiying agent (O_2) while non-green tissue contaminate the air. Thus Ingenhouz recognised **the participation of chlorophyll and light** in the photosynthetic process.
7) Jean Senebier (1800) : Oxygen, liberated from the plants in this process, comes directly from CO_2 which was absorbed by plants. Red wavelengths of light is the most effective in this process.
8) de Saussure (1840) : Confirmed thefinding of ingenhouz regarding the gas exchange one in light and other in darkness (respiration). He also discovered that water was also utilised in the process.
9) Dutrochet (1837) : Green part of the plant is essential for photosynthesis.
10) Liebig (1840) : The sole source of 'C' in plants was CO_2 of the air.
11) Robert Mayer : Law of conservation of Energy (1845) and idea of organic synthesis and energy transformation (1848).

12) Sachs (1887) : Green Chloroplast, were the organs where CO_2 was used up and O_2 was liberated. And starch was the first visible product of photosynthesis.
13) Moll's half leaf experiment showed that CO_2 was necessary for photosynthesis.

Photosynthetic Pigments

[A] Chlorophyll Pigments :

★ Chlorophylls occur **mostly in the grana** and are associated with the thylacoid membrane.

★ At least 7 types of chlorophylls are known viz chl a, b, c, d, e, bacteriochlorophyll and bacterio viridin.

★ All chlorophyll (Chl a & Chl. b) molecules contain a tetrapyrrole skelton formed into ring with 'Mg' at the centre. Thus it has five atoms i.e. 4 carbon and one nitrogen. The base unit of the chlorophyll molecule is a porphyrin ring system made up of 4 simple pyrrole nuclei (tetrapyrrole) joined by carbon linkages. The centre of the porphyrine ring is occupied by a **single atom** (nonionic) of **Magnesium (Mg)**. Only chl.a & chl.b contain Magnesium.

★ Chl. a and chl. b are the most abundant ones found in all autotrophic plants except pigmented bacteria. Other chlorophylls (viz chl. c, chl. d, chl. e) are found only in algae and in combination with chl. a.

★ Precursor of chlorophyll is protochlorophyll but according to recent view the immediate precursor is chlorophyllide.
Protochlorophyllide → chlorophyllide → chl. a → chl. b

★ In fresh green leaves, the proportions of photosynthetic pigments are as follows:

S.No.	Name of pigment	Proportion	Remarks
1.	Chlorophyll a	2 parts	Green pigment
2.	Chlorophyll b	2/3rd of one part	
3.	Carotene	1/6th of one part	yellow pigment
4.	Xanthophyll	1/3rd of one part per 1000 parts	

★ **Difference between chl a & chl. b.**

S.No.	Chl. a		Chl. b
1)	It is a blue-green micro-crystalline solid	1)	It is a green-black microcystaline solid.
2).	Empirical formula of chl a is $C_{55}H_{72}O_5N_4Mg$	2)	Empirical formula of chl.b is $C_{55}H_{70}O_6N_4Mg$
3)	It gives a blue-green solution in ethyl alcohal, etc.	3)	It gives yello-green solution in ethyl alcohal.
4)	Its occurence is universal in green plants.	4)	Its occurance is in higher plants and green algae but absent in blue-green, brown and red algae.
5)	It possesses a $-CH_3$ group (methyl group) attached to carbon no. - 3.	5)	It possesses $-$ CHO (aldehyde) group in place of $-CH_3$ group.
6)	Maximum absorption occurs at 449 mμ in blue end and 2nd peak at 660 mμ in red end of spectrum.	6)	Maximum absorption occurs at 453 mμ in blue end and 2nd max. at 642 mμ in red end of spectrum.
7)	Light absorbed by chl a is utilised by itself in photo-synthesis.	7)	Light absorbed by chl. b or its substitutes (chl. c and chl. d) is passed on to chl. a.

[B] Carotenoid Pigments :

★ Carotene and Xanthophyll are together called carotenoids.
★ These are fat soluble yellow pigments.
★ Carotenoids are located in chloroplast and chromoplast.
★ Yellw colour of etiolated and variegated leaves is due to carotenoids.
★ Such pigments are composed of two 6–membered rings with a hydrocarbon chain stretched between them.
★ Light energy absorbed by carotenoids is shunted to chl. a and light absorption results in fluorescence of chlorophyll.

★ Strong absorption takes place in the blue violet and ultraviolet end of spectrum with almost no absorption in the red end.

Carotene :

★ Its colour is Orange-yellow having empirical formula $C_{40}H_{56}$ (i.e. exclusively of C & H.)
★ It is abundant in roots of carrot hence the name carotene.
★ It is insoluble in water.
★ Its most common form is β-carotene. β-carotene is the precursor of vit. A. Other forms of carotene are a-carotene, R-carotene.
★ It is quickly oxidised in air and hence the rapid change of colour takes place in the scaped carrot.

Xanthophylls/Carotenols :

★ It is more abundant than carotenes.
★ It occur in many isomeric forms having colour yellow to brown.
★ Empirical formula is $C_{40}H_{56}O_2$
★ It is also called carotenol.
★ The commonent form is Luteol (lutein) followed by violaxanthal (violaxanthin).
★ The principal yellow pigment of maize is zeaxanthin.

[C] Phycobilin pigments

★ Phycobilins are found in **blue-green** and **red algae**.
★ It has tetrapyrrole rings but in straight chain.
★ Light absorbed by phycobilins is transferred to chl. a where is used in photosynthesis.
★ It contains no magnesium (Mg.)
★ Red pigment is called phyco-erythrin and blue pigment is phycocyanin found in red algae and blue-green algae respectively.
★ It is soluble in hot water while chlorophylls and carotenoids are soluble in organic solvent.
★ It masks the green colour like anthocyanin.

[**Anthocyanin** : is a purple pigment, soluble in water hence it occurs in solution in the water of the cells means it is actually dissolved in the cell sap and not in cytoplasm; does not take part in photosynthesis; present in sugarbeet].

Photosynthesis/CO_2 assimilation/Food Production

It has two phases viz. light phase and a dark phase.

- ★ Reaction of the light phase is light sensitive hence called photo-chemical reaction.
- ★ The reactions of the dark phase are temperature sensitive and don't require light. These are purely chemical reaction and called **Blackman reactions** on the name of F.F. Blackman who first demonstrated its existence.
- ★ These two steps are

$$\xrightarrow[\text{Photochemical reaction}]{\text{Step I}} \xrightarrow[\text{Chemical reaction}]{\text{Step II}} \text{Photosynthetic Product}$$

- ★ Reactants : $CO_2 + H_2O$
  - ii) Requirement : Energy (light) + Catalyst (pigments)
  - iii) Products : Food (carbohydrate) + O_2
- ★ Ancient view :

  $6\,CO_2 \; + \; 6H_2O \;=\!=\!=\; C_6H_{12}O_6 \; + \; 6O_2$

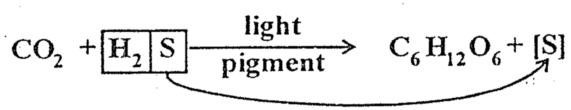
  (12 oxygen atoms) (6 oxygen atoms) Product (12 oxygen atoms)

  Source of $O_2 = CO_2$
- ★ Modern View :

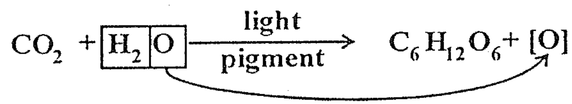
  Source of $O_2 = H_2O$

Evidences in support of source of O_2 is H_2O are given by following scientists:

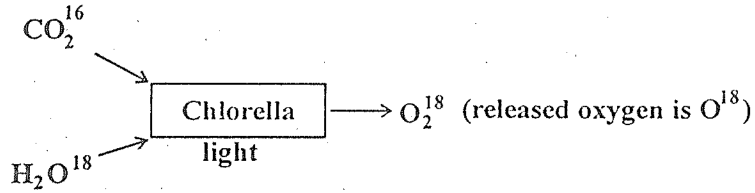
1) Von Niel : Experiment on bacteria i.e. purple sulphure bacteria. These bacteria are autotrophic and photosynthetic. (Normally bacteria are hetero-trophs)



Similarly in higher plants,

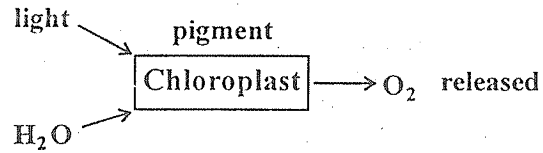


2) Ruben : Experiment by Ruben is more authentic work. His experiment was on Alga (i.e. chlorella) through isotopic studies (O^{16} and O^{18})



Conclusion : Source of Oxygen is water

3) Hill : Experiment on cell free or isolated chloroplast

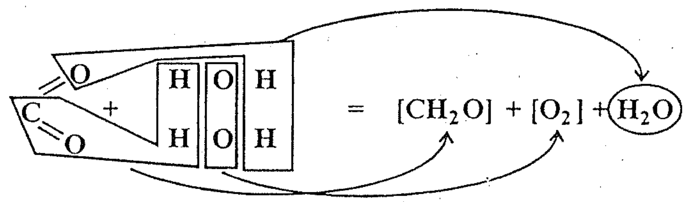


Here CO_2 is not supplied to isolated chloroplast although O_2 is released. This reactionis called Hill's reaction.

On the basis of the above evidences, the revised reaction of photosynthesis is-

$$6CO_2 \underset{\text{reactant}}{+12H_2O} \xrightarrow[\text{chlorophyl l}]{\text{686 KCal. of radiant energy}} C_6H_{12}O_6 + 6O_2 \underset{\text{product}}{+6H_2O}$$

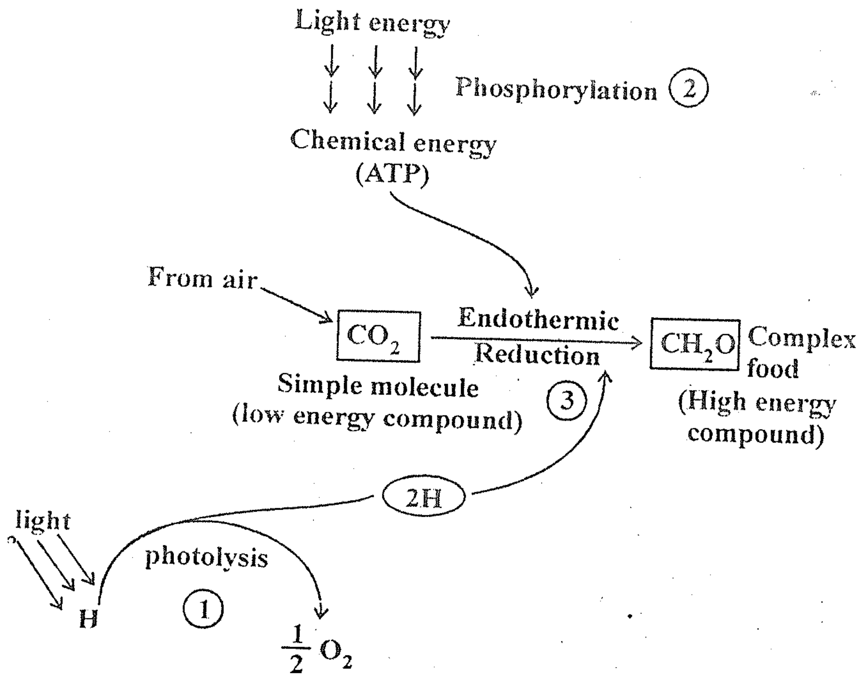
Empirical molecular reaction :-



three inferences are drawn from the empirical molecular formula-

a) Breakdown of water molecule to release of O_2
b) 50% Hydrogen from water combines with C = O of CO_2 to produce food
c) Remaining 50%H of H_2O combines with [O] of CO_2 to produce water.

Division of labour : Light and Dark reaction :



$$ADP + Pi \xrightarrow{Light} ATP$$

Pi is Inorganic Phosphate

The conversion of light energy into chemical energy i.e. ATP is called *Photophosphorylation.*

ATP = Adenosine triphosphate; ADP=Adenosine Diphosphate

The breakdown of water molecule (H_2O) into hydrogen and oxygen by light energy is called *Photolysis* of water. (Photo means light and lysis means to break).

Origin of Food : Three major reactions are

1) Photolysis of water : For hydrogen (2H) } Both light dependent
2) Photophosphorylation : For ATP }
3) CO_2 - reduction : For carbohydrate - Dark dependent.

Hence there are two phases viz. Light phase and Dark phase.

Light Reactions

Evidences :

a) Hill's work with isolated chloroplasts : Hill (1937, 1939) and Scarisbrick (1940).

Light → [Isolated Chloroplast] + H_2O ⟶ O_2 released

\+

If Oxidant (H-acceptor) (Called Hill reagent) ⟶ reduced oxidant by chloroplasts

If Oxidant (i.e. H-acceptor) is present with isolated chloroplast, oxidant is reduced by chloroplast in presence of light. This reaction is called **Hill reaction** and oxidant is called Hill reagent. The common Hill reagent is **Ferricyanide** and **Benzoquinone.**

Robert Hill discovered firstly that chlorplasts use cytochromes for photosynthesis just as mitochondria use them for respiration.

Warburg (in early 1940's) : Cl^- has stimulating effect on the Hill reaction probably by facilitating the release of O_2 from OH^- ions.

b) D.Arnon's work with isolated chloroplasts :

i) Arnon (1951) : H-released by splitting of H_2O molecule was accepted by coenzyme II (i.e. TPN^+, now called $NADP^{++}$).

(NADP : Nicotinamide Adenine Dinucleotide Phosphate)

ii) Arnon (1954) : In addition to carrying out the Hill reaction, The isolated chloroplasts could also synthesize ATP in the light.

$$ADP + Pi \text{ (inorganic phosphate)} \xrightarrow{\text{light energy}} ATP$$

iii) Arnon (1959) : Isolated chloroplast also reduced CO_2 in presence of light and this would result in the synthesis of carbohydrate. The conversion of CO_2 into sugar (dark reaction) actually took place in the stroma (the chlorophyll-free portion of the chloroplast) and the Hill reaction (Light reaction) took place properly in the grana.

★ The site of light reaction is grana and dependent on pigment.

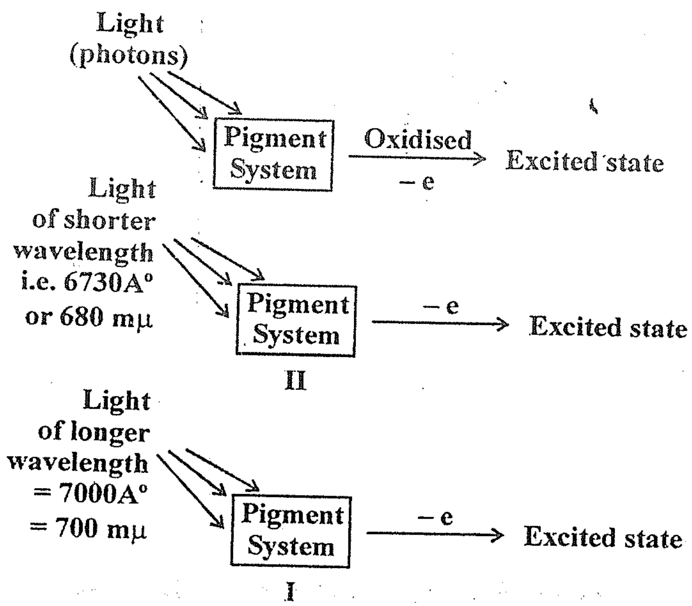
For better perception, let's divide the light reaction into four (4) steps:

1st Step : Photo-excitation of pigment electrons. The effect of photo-excitation is oxidation of pigments. Emerson's work discovered the two pigment systems:

$1\,m\mu = 1$ milli micron $= 10^{-3} \times 10^{-6}$ metre $= 10^{-9}$ m

1 nm = 1 nano metre $= 10^{-9}$ m

$1\,A^0 = 1$ Angstrom $= 10^{-10}$ m



It means pigment system works on quality of light i.e. blue and Red.

2nd Step : Photolysis of water

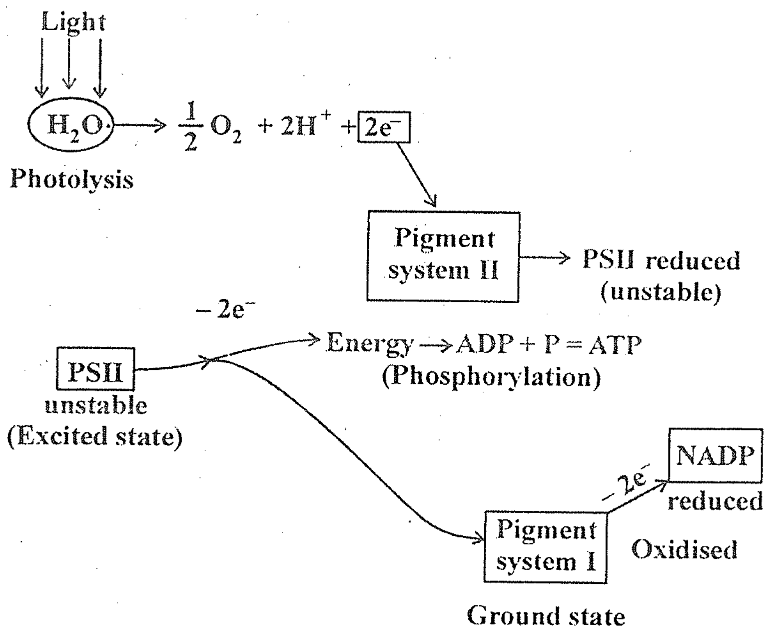
↓

release of electron

↓

Deposited on P.S. II

i.e. reduction of PSII



3rd Step : Return of Excited electron from PSII to PSI in ground state.

Effect :

- Direct : Reduction of PSI
- Indirect : Photophosphorylation

i.e. production of ATP by the involvement of photons (light)

i.e. Energy stored in the form of ATP

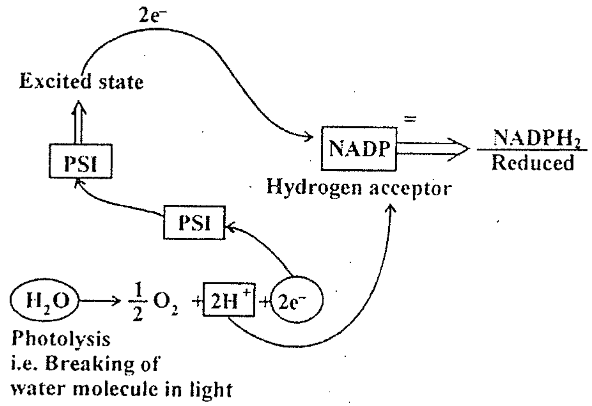


Photo phosphorylation = Photo + Phosphorylation

↓ Photo: light

↓ Phosphorylation: production of Adenosine tri phosphate (ATP).

NADP = Nicotinamide Adenine Dinucleotide Phosphate.

4th Step : Transfer of electron from PSI to NADP.

Result : NADP is negatively charged

$\boxed{NADP^{=}} + 2H^+ \rightarrow NADPH + H^+ = NADPH_2$

Products of Light reaction :

1) 1/2 O_2 gas – lost to the atmosphere
2) ATP : in 3rd step
3) $NADPH_2$: a reducing agent in 4th step.

Here ATP and $NADPH_2$ are the desired products for Dark reaction to reduce CO_2 ATP and $NADPH_2$ are the assimilatory power because they help in the process of CO_2 assimilation. There are two pathways of the transfer of electron i.e. (a) Non-cyclic and (b) cyclic. Since ATP is released in the both above pathway. Thus photo phosphorylation is the name.

(a) Non-cyclic photophosphorylation : It involves both PSI & PSII systems and occurs in green plant.

$$\text{Products : } \frac{1}{2}O_2 + ATP + NADPH_2$$

$$ADP + Pi \xrightarrow[\uparrow]{\text{chemical bonds}} ATP$$

energy

7 – 11 kilo calories

x =	unknown compound
Q –	Quinone
PQ –	Plastoquinone
Cyt –	Cytochrome
PC –	Plastocyanin
FRS –	Ferredoxin Reducing Substance
Fd –	Ferredoxin

$4H_2O = 4H^+ + 4OH^-$

$4OH^- = 4OH + 4e^-$

$4OH = 2H_2O + O_2$

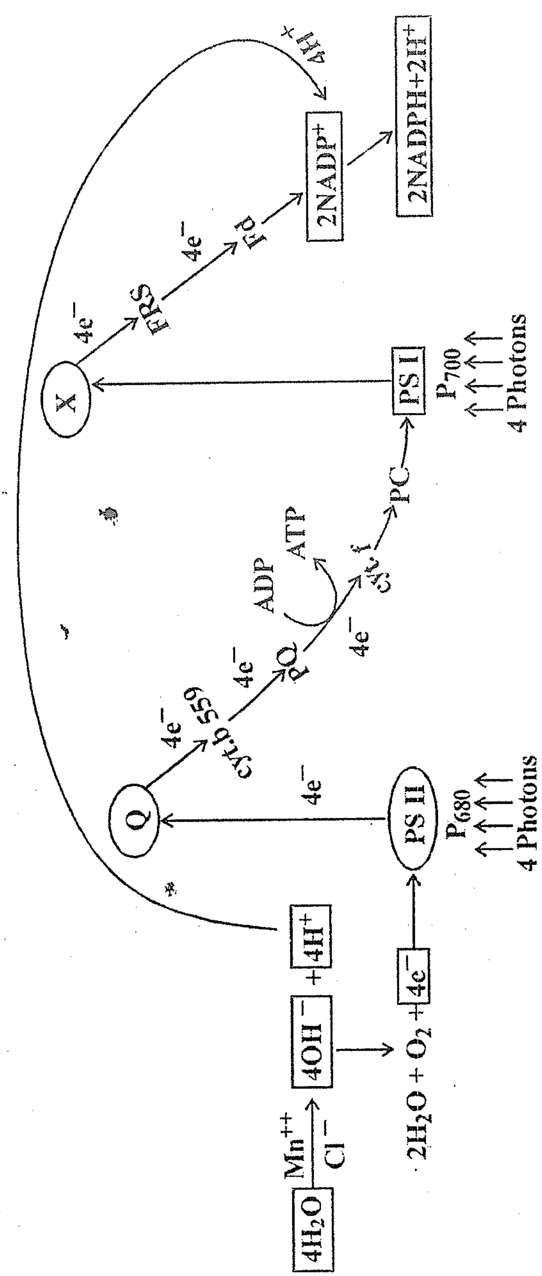


Fig. : Non-cyclic pathway of Electron i.e, Non-cyclic photophosphorylation

(b) Cyclic photophosphorylation : It involves only PSI and wavelength of light greater than 680 nm.

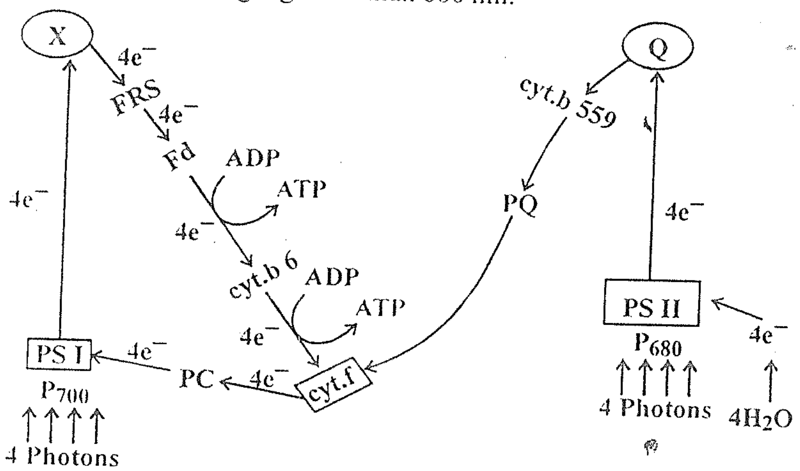


Fig. : Cyclic pathway

when green plant treated by Dichloro Dimethyl Urea (DCMU: a selective poision which inactivates the PSII); ATP production was continued. From this experiment two conclusions were drawn:

1) Alternative pathway is present to produce ATP other than non-cyclic.

2) Alternative pathway was entirely dependent on only PSI.

According to Park & Sane (1971) stromal lamellae has PSI whereas granal lamellae has both PSI & PSII. It means

Stroma ≡ PSI ≡ cyclic photophosphorylation

Grana ≡ PSII ≡ Non-cyclic photophosphorylation.

Difference between Non-cyclic & cyclic photo phosphorylation:

Non-cyclic	Cyclic
1) It is dependent on both PSII & PSI	1) Dependent on only PSI
2) Presence of Mixed light i.e. long & short wavelength required.	2) Monochromatic light of longer wavelentgh.
3) ATP is produced when movement of electrons from PSII to PSI	3) ATP production when movement of electron from PSI to PSI
4) Products : $\frac{1}{2}O_2 + ATP + NADPH_2$	4) Product : Only 2 ATP
5) Photolysis of water essential	5) No need of photolysis of water.
6) Water molecule is the source of electron (e^-) which helps the chlorophyll molecule to come to ground state.	6) Electron comes from P_{700}. Water is not the source.
7) The electron (e^-) does not complete the cycle. It starts from PSII and drained off in the carbohydrates produced by CO_2 reduction	7) Electron moves from P_{700} to P_{700} through 2-3 transfer steps to decreasing redox potential

Robert Emerson's work & Red Drop :

Robert emerson found that 8 quanta of light energy would be required for the reduction of one molecule of CO_2 to carbohydrate.

8 quanta of photons (i.e. light energy) = For reduction of 1 molecule of CO_2 to carbohydrate
≡ i.e. Production of 1 molecule of O_2 .

8 quanta ≡ 1 molecule of CO_2 ≡ 1 molecule of O_2
(reduction) (production)

Thus quantum yield or yield per quantum = 1/8 = 12%

The average maximum quantum yield in photosynthesis is 12 percent.

Quantum yield may be defined as the number of O_2 - molecule released per light quantum absorbed.

Reduction of 1 molecule of CO_2 ≡ transfer of 4 electrons

8 quanta ≡ 4 electrons-transfer

2 quanta of light = one electrons transfer.

Thus for the movement of one electron through the complete system, 2 photons are needed, one at PSI and one at PSII. For the removal of $4e^-$

from the 4 water molecules, 8 photons are required which generate 1 molecule of O_2; 2 molecules of ATP and $NADPH_2$. In reductive pentose phosphate pathway (PPP), 3 molecules of ATP are required in the assimilation of 1 molecule of CO_2. An additional 2 photons are sufficient to provide an extra ATP making them to the requirement of 10 photons.

According to Emerson & Arnold (1932): 2500 chlorophyll molecules (a photosynthetic unit) collaborated together to evolve one molecule of O_2 and10 quanta of light were needed for that.

Photosynthetic Unit : It is the smallest group of pigment molecules which collaborate together to cause a photochemical act i.e. the absorption and migration of a light quantum to a trapping centre where it brings about the release of an electron.

Photosynthetic unit = 2500 molecules of chlorophyll.

Example : $P_{700} = P_{680}$

Emerson's Effect :

a) **Green Plant** ⟸ exposed to monochromatic light i.e. wavelength greater than 680 nm in red zone.

⇓ prolonged duration of Red zone

Rate of photosynthesis decreased

i.e. quantum yield decreased

This effect is called Red Drop

Emerson's first effect.

The decrease in the quantum yield or photosynthetic rate after using the monochromatic light i.e. red, for the long duration is called Red Drop.

b) **Plant A** ⟶ (X) **Quantum yield**

↑↑↑↑

Wavelength greater than 680 mm of light

Plant A ⟶ (Y) **Quantum yield**

↑↑↑↑

Light of the shorter wavelength

Plant A ⟶ (Z) **Quantum yield**

↑↑↑↑

Mixed beam of light

Emerson found that (Z) > (X) + (Y)

The quantum yield produced by the mixed light was greater than the total yield got from the two beams of light used separately. This enhancement of photosynthetic rate is called Emerson's Enhancement Effect or Emerson's 2nd Effect.

Explanations of Emerson's Effect :

In monochromatic light, only one type of pigment is Functional and hence the decrease in the photosynthesis. If plant is exposed to red light, gradually PSII becomes inactive and non-cyclic pathway stops resulting in the decrease in photosynthetic rate.

Dark Reactions

Dark phase of photosynthesis i.e. CO_2 Fixation.

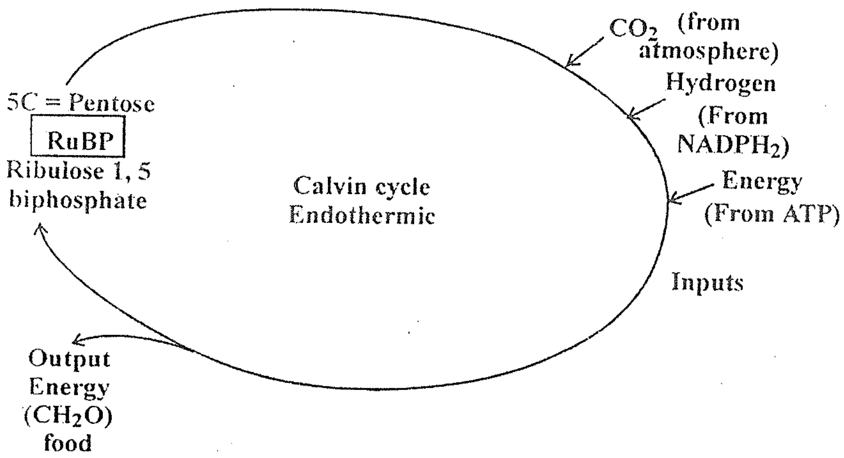
Dark reactions are dependent on Enzymes but light reactions are dependent on pigments. In Dark reaction, CO_2 is reduced to carboydrates with the help of the products of light reaction. i.e. ATP and $NADPH_2$. There are three pathways of dark phase of CO_2 Fixation.

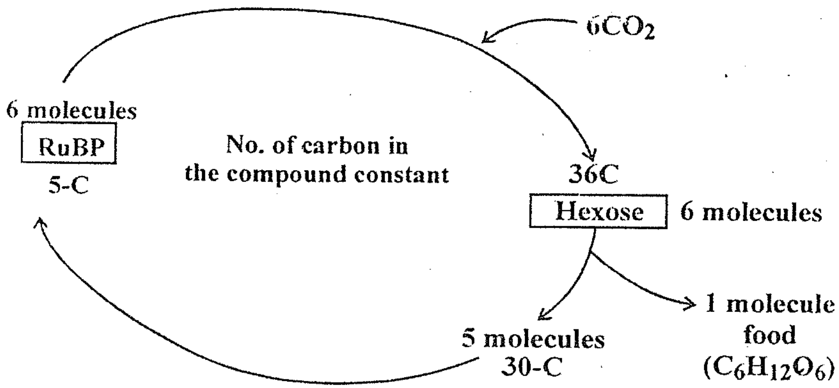
a) Calvin Cycle : C_3 cycle
b) Hatch and Slack cycle : C_4 cycle
c) CAM cycle.

Calvin cycle/C_3-cycle

This cycle is predominantly found in wheat, rice, barley, pulses etc. and such plants are called C_3 plants because in the cavin cycle, first stable product is C-3 compound (i.e. having three no. of carbons in a compound).

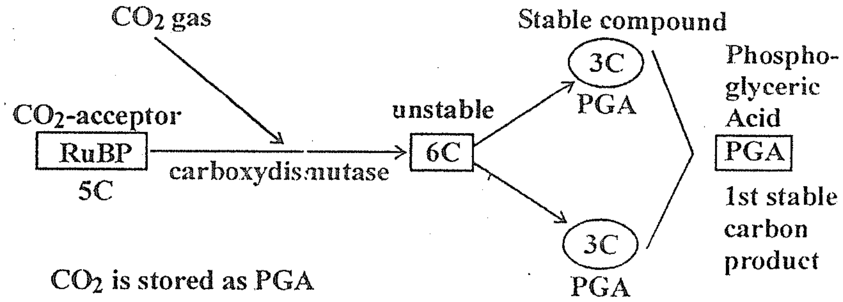
1) 6 molecules of RuBP (Ribulose biphosphate, earlier called RuDP) combine with 6 molecules of CO_2 which produces 6 molecules of carbohydrate (hexose).
2) One out of 6 molecules of Hexoses is consumed as food.
3) Remaining 5 molecules of Hexoses are reconverted to RuBP (6 molecules) and thus completes the cycle.



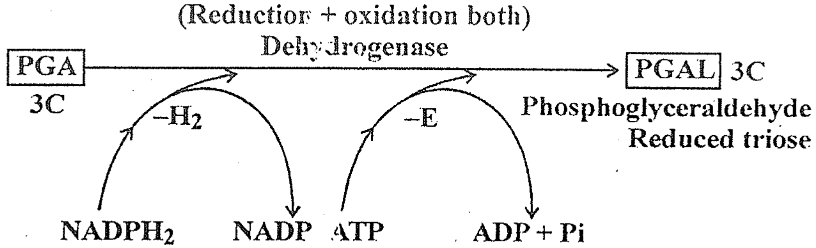


Procuction of Hexose :

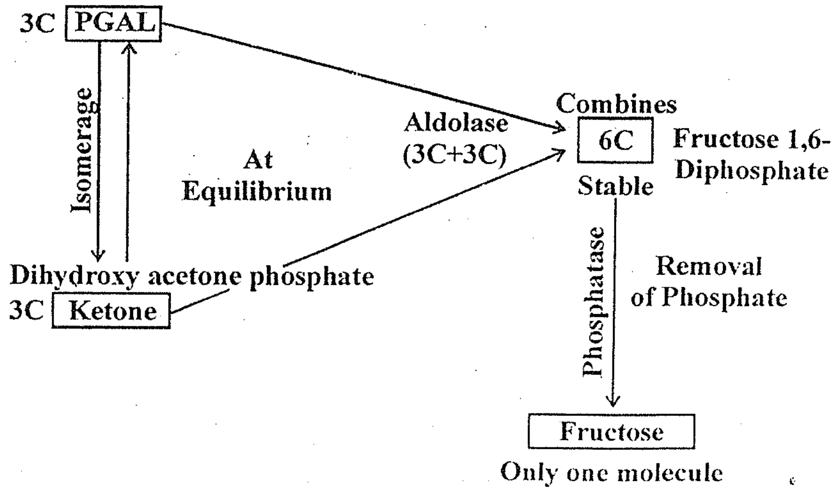
a) Reception of CO_2 :



b) Reception of H_2 :-- Reduction



c) Generation of Hexose



Regeneration of RuBP (5C)

6C ⟶ 5C.

Fructose 6–PO_4 + 3PGAL ⟶ Xylulose 5–PO_4 + Erythrose 4–PO_4
6C 3C 5C 4C

Erythrose 4–PO_4 + Ketone ⟶ Sedoheptulose 7–PO_4
4C 3C 7C

Sedoheptulose 7–PO_4+Aldehyde⟶Xylulose 5–PO_4+Ribose 5–PO_4
7C 3C 5C 5C

Products : Xylulose 5–PO_4 ⟶ Two molecules
Ribose 5–PO_4 ⟶ One molecule

Ribose 5–PO_4

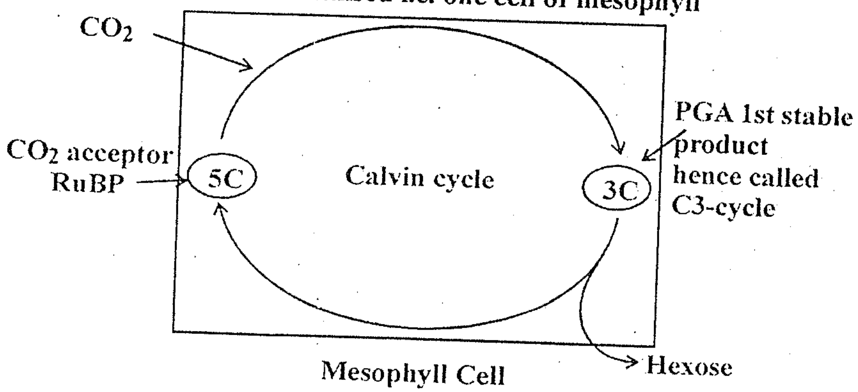
↓ Isomeric modification

Ribulose 5-PO_4 (Ribulose Monophosphate = RuMP)

↓ E (ATP → ADP)

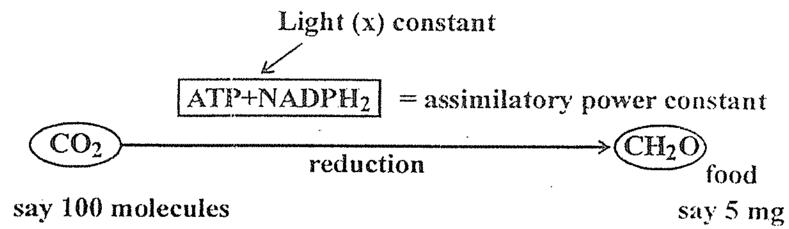
Ribulose 1, 5-biphosphate (RuBP)

Reaction Centre : localised i.e. one cell of mesophyll



Blackman's Law : Law of Minimum or Law of limiting factor:

a)



If light intensity is increased by twice but CO_2 -Concentration is constant, there will be no increase in photosynthetic rate. It means CO_2 acts as a limiting factor because it's concentration is available in minimum quantity.

Inferences :

1) The law is applicable to only those reactions where the rate is governed by multiple factors like photosynthesis.
2) The rate of such reaction is dependent on any one factor at specific time – Limiting factor or governing factor.
3) The limiting factor will be that one which is available in minimum quantity i.e. Law of Minimum.

Hatch & Slack cycle/C_4 cycle

1) It is found in Sugarcane, maize, sorghum, bajra etc. such plants are called C_4-plants.
2) In 1965 Kortschak, Hartt & Burr working with $C^{14}O_2$ on sugarcane leaves found C_4 dicarboxylic acid, malate & aspartate to be the major labelled products in very short periods of photosynthesis. This observation was confirmed by M.D. Hatch & C.R. Slack in 1967 in Queensland Australia.
3) a sub-tropical species of **Atriplex rosea** exhibits C_4-cycle whereas the temperate species of the same genus Atriplex rosea has only the calvin cycle.
4) C_4-Plants have 'Kranz anatomy' in leaves.
There are two types of chloroplasts – (i) Normal or isomorphic chloroplast & (ii) Karnz type of chloroplast.
5) 1st stable product is 4-carbon compound oxalo-acetic acid hence the name C_4-cycle.

6) PEP carboxylase has high affinity for CO_2 and hence C_4 plants are able to absorb CO_2 strongly from a much lower CO_2 -concentration than the C_3-plants. Thereby resulting higher rate of photosynthesis.

7) Most of the bad weeds of the world are C_4-plant.

Normal Chloroplast	'Kranz' type Chloroplast
1) Such chloroplasts are normal & isomorphic having grana,stroma & frets distinctly. Grana are double membraned closed vesicles called thylacoids. The grana contains the chlorophyll a & b in the ratio of 3:1 along with carotenoids & xanthophyll. The large thylacoids extend to one end to the other end of the chloroplasts called 'stroma thylacoids' whereas the small thylacoids are alternately arranged & fused with the large ones in the granum region only called 'grana thylacoids.'	1) Such chloroplast are dimorphic. It is undifferentiated. These chloroplast lack grana and contain starch grains. These are arranged centripetally within the cells of the bundle sheath.Such chloroplasts are very large.
2) Stromal thylacoids contain PSI means carry out only cyclic photophosphorylation while granal thylacoids contain both PSI & PSII means carry out both Non-cyclic & cyclic photophosphorylation.	2) Such chloroplast lack PSII and hence are dependent on the chloroplasts of mesophyll for the supply of $NADPH_2$.
3) The chloroplasts in all the green cells of the leaves are alike and found in C3 & C4 plants both.	3) Such chloroplasts are found in the bundle-sheath cells of C_4-plant.

4)

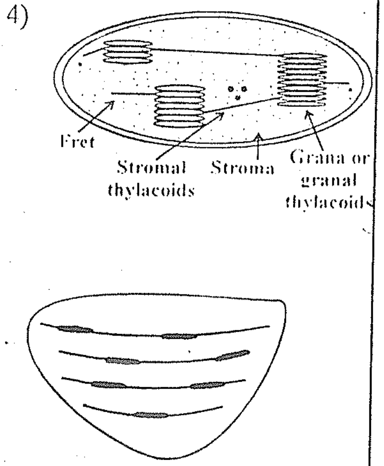


Fig. granal chloroplast

4)

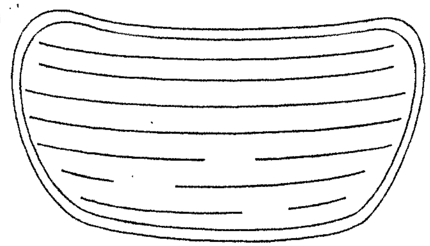
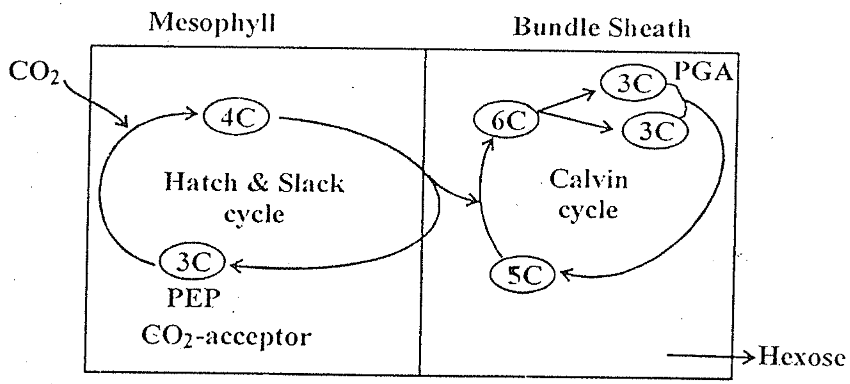


Fig Kranz anatomy (agranal chloroplast)

Reaction centre : Division of labour :



Here CO_2 - acceptor is PEP i.e. phosphoenol pyruvate which is the substitute of RuBP of C_3 plant.

Plasmodesmata is the channel for the transfer of 4C compound from mesophyll to Bundle-sheath.Depending on the process of decarboxylation of C_4-acids within the bundle-sheath, C_4 plant species are divided into three sub-groups viz. NADP-ME type; PCK type & NAD-ME type.

a) NADP-ME type : Malate formed within the chloroplast of bundle dheath is decarboxylated via NADP-malic enzyme, hence called NADP-ME type. Here **only chloroplast** is involved.

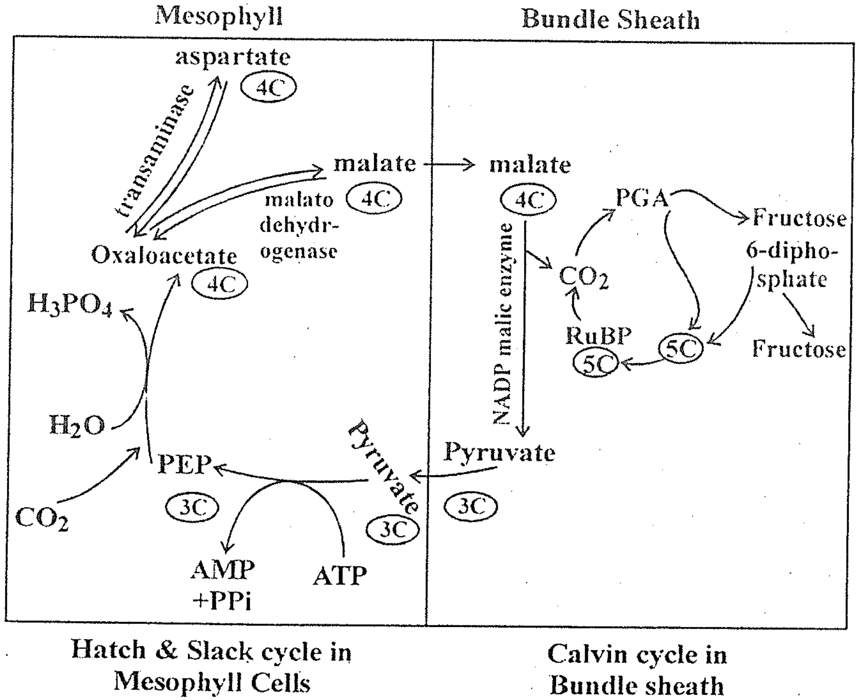
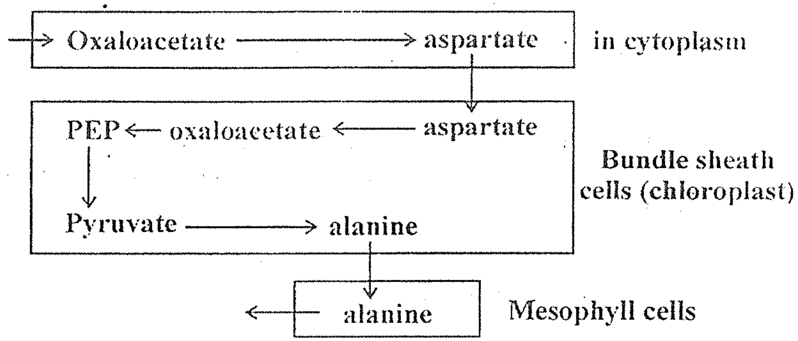
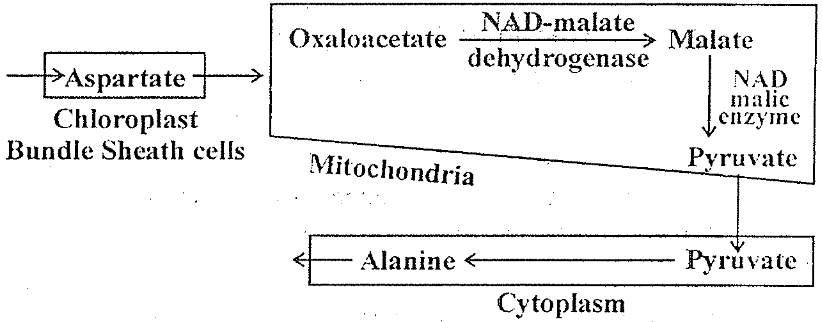


Fig. : NADP-ME type

b) **PCK-type :** Oxaloacetate is converted to aspartate by aspartate aminotransferase within cytoplasm. Then aspartate is transported to Bundle sheath cells. In Bundle sheath, aspartate is converted back to oxalo-acetate and oxaloacetate is decarboxylated to form PEP which yields pyruvate. Pyruvate is converted to Alanine and diffuses into mesophyll cells. It involves **Chloroplast & cytoplasm**.



c) NAD-ME type : Like PCK type, aspartate enters into the bundle sheath cells. It diffuses into mito-chondria where it is converted to oxaloacetate and oxaloacetate is reduced to malate which is decarboxylated to pyruvate. Pyruvate diffuses out of mitochondria & enters into cytoplasm where it is converted to alanine. It involves *Mitochondria, Cytoplasm & Chloroplast.*



Physiological Differences in relation to dry matter production between C_3 & C_4 plants:

1) The PEP carboxylase enzyme present in C_4 cycle has a very strong affinity for CO_2 as compared to RuBP carboxylase. Hence law of Minimum regarding the CO_2 -concentration is not in operation for C_4-plants.

2) PEP carboxylase is not sensitive to O_2 which has a cometitivè effect on RuBP carboxylase.

3) C_4 plants lack photo respiration, hence photosynthetic rate is higher.

4) In Mesophyll cells of C_3, Nitrogen (N) & Sulphure (S) reduction occur and so they compete for reducing power with photosynthesis.

5) In mesophyll cells of C_4, N & S-reduction occur but calvin cycle is in Bundle sheath, therefore competition for reducing power is low.

6) Photosynthates made in C_4 plants are readily transported to other parts.

7) High temperature is optimum in C_4 plants for enzyme thereby increasing the photosynthetic turn over rate higher.

8) High light saturation point (in C_4) coming higher electron transport and more generation of reducing power ($NADPH_2$) & ATP.

Crassulacean Acid Metabolism (CAM)

1) Occurence : Certain succulent plants of the family crassulaceae like cactus (cacti); pineapple, Onion, garlic, lilli, sisal etc. All CAM-plants have succulent habit.

2) Adaptability : Extreme dessication, such plants posses xerophytic characteristics like reduced leaves, thick cuticle, sunken stomata etc.

3) Special feature : Such plants have also the capability of fixing the CO_2 lost in respiration. Such plants behave like C_4-plants during the night and as C_3-plants during the day. These have slowest photosynthetic rates.

4) Biochemical reactions :

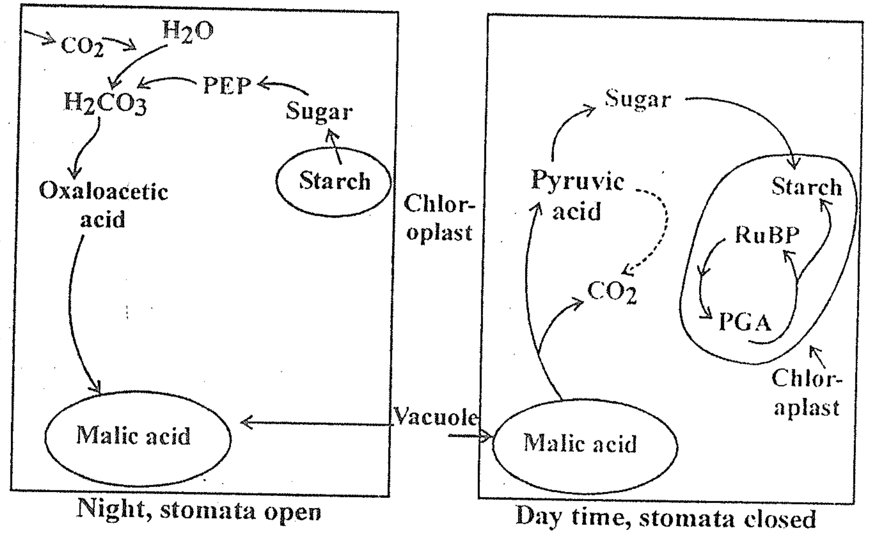


Fig. : Cam Cycle

In xerophytic plants, stomata open during the night & close during the day. When stomata are open, CO_2 is fixed by enzyme PEP-carboxylase to oxaloacetic acid and are stored as malic acid in the vacuole which breaks down in day time to release CO_2 for photosynthesis.

Difference between C_3, C_4 & CAM cycle/plant

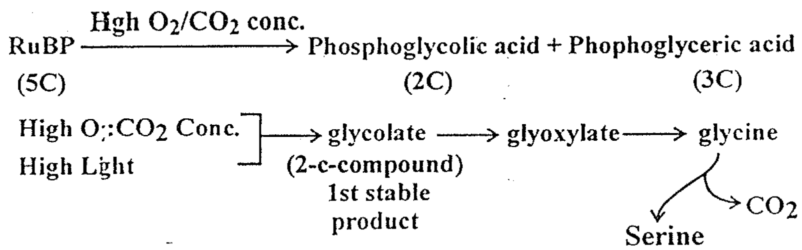
	Particulars	**C_3-plant (cycle)**	**C_4-plant (cycle)**	**CAM plant (cycle)**
1)	Site of the cycle i.e. leaf structure (Morphology)	Mesophyll	Mesophyll + bundle sheath i.e. Kranz anatomy	Mesophyll + vacuole
2)	1st stable compound	PGA 3-carbon compound	Oxaloacetic acid (or malic acid) C_4-compound	C_3 & C_4-compound in day C_4 in night
3)	CO_2 -fixing enzyme	RuBP carboxylase	PEP carboxylase and RuBP-Co (i.e. RuBP Carboxylase)	RuBPCo and PEPCo

4)	CO_2-acceptor	RuBP	PEP	PEP
5)	Dark reaction through	Calvin cycle	a) Hatch & slack cycle b) Calvin cycle	–
6)	Chlorophyll a: chl. b ratio	3:1	4:1	≥ 3:1
7)	Isotopic discrimination 13_C (1.1% in atm.)	–20 to 40%	–10 to– 20%	–11%
8)	CO_2-concentration (compensation point)	30-70 ul/lit. air 50 ppm CO_2	<10ul/lit.air 1-5 ppm CO_2	0.2ul/lit. air to <5ul/lit. air
9)	Internal concentration of CO_2 in illuminated leaves.	High 200 ppm	low 100 ppm	medium
10)	Saturation point for CO_2 fixation	500 ppm	lower conc.	medium
11)	Light saturation point	Low	High	Medium
12)	Habital	Mesophytes	Arid	Xeric
13)	Example	Wheat	Sugarcane	Cactus
14)	Photosynthetic rate	Medium	High	Variable and slow
15)	Biomas production	Medium	High	Low
16)	Pigment system (PS) present in chloroplast	Both PSI & PSII are present in all chloroplast	In chloroplast of B.S. cells PSII is absent and hence dependent on mesophyll chloroplast for the supply of $NADPH_2$	–
17)	Presence of calvin cycle enzymes	Mesophyll's chloroplast	Absent in meso phyll's chloroplast	–

18)	Presence of Photorespiration	High	Low	Low
19)	Sensitivity to oxygen	High	Low or negligible	Yes
20)	Water use Efficiency	Low	High	Medium
21)	Optimum temperature	10-25⁰C	30-45⁰C	–
22)	Response to CO_2 enrichment	High	Negligible	–
23)	Net rate of CO_2 fixation	15-35 mg. of CO_2 per dm² of leaf area per hour	40-80mg of CO_2 per dm² of leaf area per hour	–

Photorespiration/Glycolate metabolism/C_2-cycle

1) The term 'photorespiration' was firstly used by Decker and reported in tobacco plant.
2) RuBP-carboxylase normally fix CO_2 and forms 2 molecules of PGA (Phosphoglyceric acid). But under High concentration of O_2 (i.e. high O_2/CO_2 ratio) induced by high light checks the production of two molecules of PGA and forms Glycolate (or phosphoglycolic acid) instead of one molecule of PGA. Phosphoglycolic acid or Glycolate is 2-carbon-compound which is the first stable compound hence the name Glycolate metabolism or C_2 cycle. In this process H_2O_2 (Hydrogen Peroxide) is formed which may be dissociated by the enzymes present in peroxisomes.



a) High light level : It is a cause for increased photolysis of water (H_2O) which liberates O_2.

b) High O_2 level.

c) Low CO_2 level.

d) High Temperature.

4) Otto warburg in 1920 found that photosynthesis in algae was inhibited by O_2. This occurs in all C_3-plants. This effect is known as **Warburg Effect.**

5) Site of reactions in Respiration : Cytosol & Mitochondria but site in photorespiration are three. Here three organelles are involved viz. a) Chloroplast. b) Peroxisome and c) Mitochondria.

6) Phosphoglycolic acid is dephosphorylated into glycolate which forms the substrate for photorespiration. Photorespiration of glycolate results in uptake of O_2 and release of CO_2.

7) Photorespiration is light dependent because :

a) RuBP formation occurs much faster in light than in darkness because operation of calvin cycle needs to form RuBP, requires ATP and $NADPH_2$ (both light dependent products).

b) Chloroplastic O_2 is more abundant in light due tophotolysis of H_2O.

8) Photorespiration is essentially absent in C_4-plants because-

a) Rubisco (RuBP carboxylase) and other calvin cycle enzymes are present only in bundle sheath cells.

b) CO_2 concentration of Bundle sheath cells is maintained too high for O_2 to compete with CO_2 due to rapid decarboxylation of malate and aspartate transferred to Bundle sheath from mesophyll cells.

9) Amino acids viz. serine and glycine produced in theglycolate pathway are useful for protein synthesis.

10) Reactions :

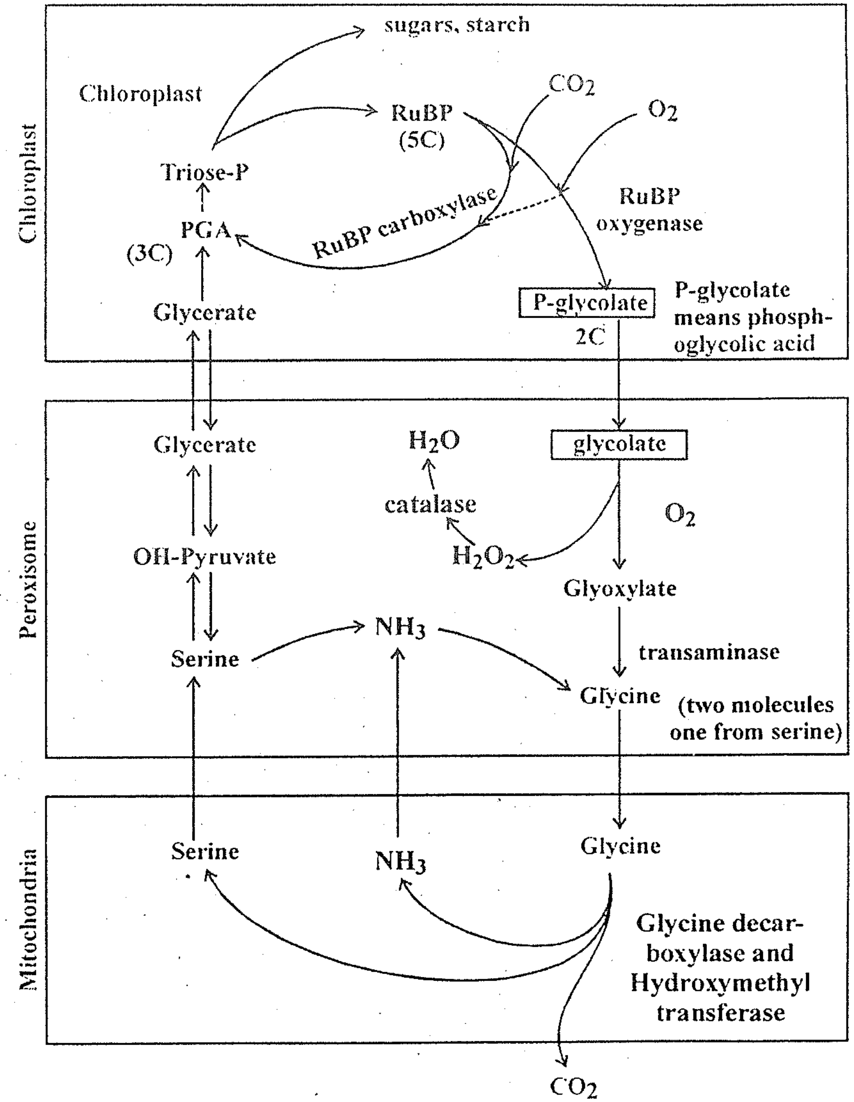


Fig. Glycolate Pathway

Factors Affecting Photosynthesis:

1) **Light :** It is the most important factor of photosynthesis. Light affects through its intensity, quality and duration.The amount of light received by the plant depends on its morphology. The actual requirement of the light intensity depends upon the type of plant and its habitat. Generally average sunlight is sufficient except on rainy or cloudy days. The rate of photosynthesis increases with the increase in light intensity until law of minimum operates. Extremely high light intensity has an inhibitory effect on the photosynthesis and this phenomenon is called **solarization.** During solarization, photo-oxidation occurs in which certain cell constituents are oxidized by O_2 into CO_2. High light intensity also increases the transpiration rate, consequently reducing the water content of mesophyll cells which has also an inhibitory effect on photosynthesis. Low intensity causes stomatal closure which restricts the entry of CO_2.

The light intensity at which the photosynthetic intake of CO_2 is equal to the respiratory output of CO_2, is called **compensation point**. Therefore net photosynthesis is zero at the compensation point.

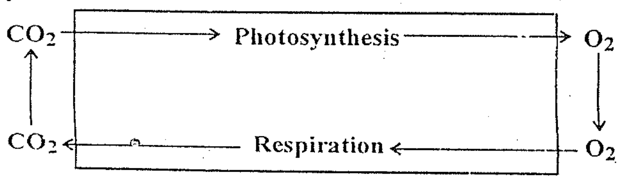


Fig. : Equilibrium is called compensation Point

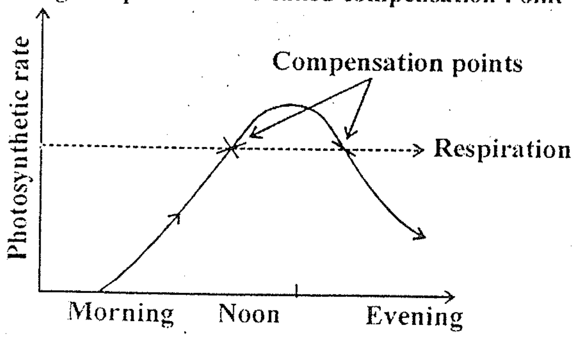


Fig. : Compensation Point Time

Visible part of the light spectrum i.e. wavelength between 400 nm to 750 nm is the only need for photosynthesis. Heavy absorption of light takes place in the red and next in the blue & violet. Continuous illumination of light also affects the photosynthesis.

2) **CO_2 :** The percentage of CO_2 in the air is 0.03% by volume. At optimum temperature and light intensity, photosynthesis is markedly increased with the increase in CO_2 concentration. But relatively high conc. of CO_2 reduces the photosynthetic rate.

3) **Temperature :** There is a rapid increase in photosynthesis if temp. increases from 10°C-35°C, provided other factors are not limiting. Photosynthetic rate declines with the higher temp. beyond the maximum limit.

4) **Water :** It has no direct effect. The decrease in water content of leaves may cause partial or complete closure of stomatal openings which reduces the diffusion of CO_2.

5) **O_2 :** Oxygen accumulation may retard the photosynthesis. It is a competitive inhibitor of carboxylase thus inhibits photosynthesis in C_3-plants.

6) **Mineral Nutrients :** Magnesium is a part of chlorophyll molecule and other nutrients are necessary for enzymic action and plant metabolism.

All the above factors are external but some internal factors like chlorophyll content; protoplasmic factors & hydration, end product of photosynthesis may also affect the photosynthesis.

***

3. Respiration

Introduction:

Respiration is the breaking down of organic substances viz. carbohydrates, fats and proteins into carbon dioxide, water & energy.

Energy output is the chief product of respiration.

Energy output- through-

a) Slow oxidation of organic food.

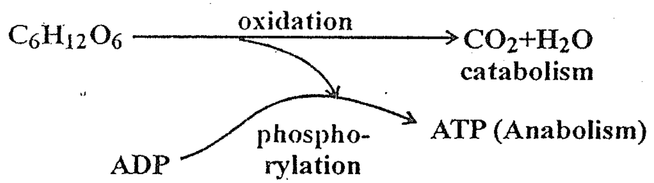
b) Exothermic

c) Release of energy = conserved in chemical energy.

Thus,

Respiration = oxidation of foods in living cells.

Nature of respiration : Amphibolic means both catabolic and anabolic.



Fast Oxidation	Slow Oxidation
1) $C_6H_{12}O_6$ → Fast release of energy → 673 K.cal. lost as heat or/and light; ↓ release of hydrogen at a time 12 H	1) $C_6H_{12}O_6$ → Slow release of energy → 673 K.cal.; ↓ release of hydrogen in the phases i.e. 6 oxidation steps = 2 H in each step
2) At high temp.	2) At low temp.

3) Non-catalytic	3) Catalytic (enzyme)
4) Example : Burning	4) Example : Respiration

Conclusion : Respiration is a special type of combustion.

Respiration Means-

1) Oxidation of food
2) Complex compound to simple compound
3) Exothermic (Release of heat)
4) Release of Hydrogen
5) Output of H in phases
6) Energy conserved
7) Enzymatically controlled
8) At low temp
9) In living cells.

Respiratory substrate may be carbohydrates, fats and in certain condition protiens.

$$\text{Complex carbohydrate} \xrightarrow[\text{enzyme systems}]{\text{hydrolysis by}} \text{Hexose sugar}$$

$$\text{Fats} \xrightarrow[\text{lipase}]{\text{hydrolysis by}} \text{fatty acids}$$

★ Proteins are utilised only when carbohydrates or fats are not available

★ The first phase of respiration during which carbohydrates were used up had been termed by **Blackman** as the **Floating respiration.**

★ The second phase of respiration in which protoplasmic proteins were used up had been termed by Blackman as the **Protoplasmic respiration.**

★ Most common respiratory substrate is glucose $C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 6CO_2 + 12H_2O + \text{energy}$.

Types of Respiration :

- Aerobic
- Anaerobic ≡ Fermentation

(Animal respiration is **essentially aerobic process** and ceases altogether if oxygen is absent).

* Fermentation is the form of anaerobic respiration carried on by some fungi and bacteria. Substrate of fermentation is present outside the cell and is in the liquid medium.

According to pfeffer, ordinary aerobic respiration occurs in two stages-

a) Splitting of sugar by a no. of steps into alcohol and CO_2.

Sugar $\rightarrow \rightarrow \rightarrow \rightarrow$ Alcohol + CO_2

b) Oxidation of alcohol or some intermediate product by atmospheric oxygen into CO_2 and H_2O.

$$\text{Alcohol/other} \xrightarrow[O_2]{\text{oxidation}} CO_2 + H_2O$$

Here, first stage is independent of O_2 and in fact it is Anaerobic respiration. It means Anaerobic respiration is the first part of aerobic respiration.

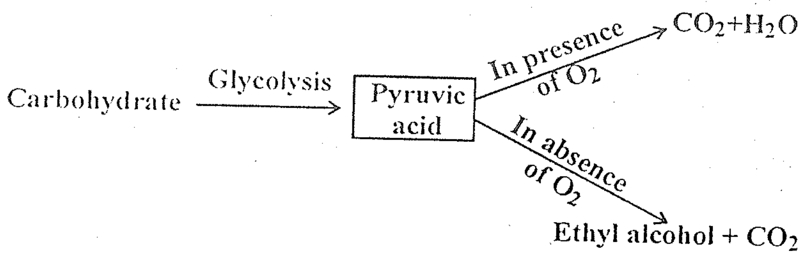


Fig. : Pfeffer - Kostychev Scheme

Mechanism of Respiration :

1) 1st and common stage in respiration in called Glycolysis or EMP Pathway (Embden–Meyerhoff-Parnass) after the name of Germar scientists who traced the reaction steps.
2) EMP pathway results in two molecules of Pyruvic acid.
3) Second stage is different in the two types of respiration.

I Glycolysis : or EMP Pathway:

Glycolysis has two phases :

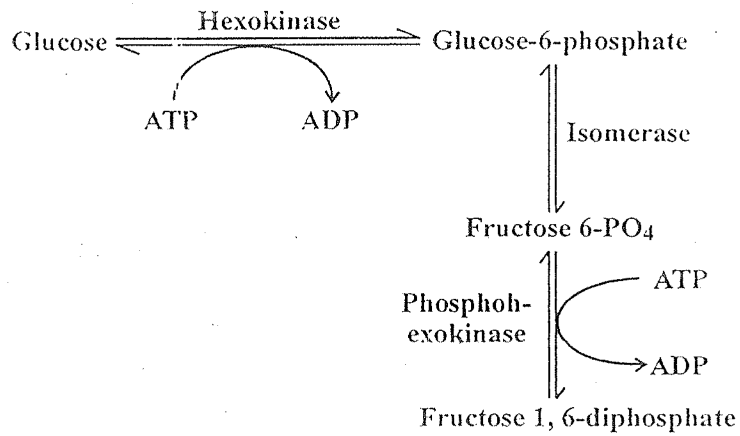
1st Phase : Consumption of ATP (2) i.e. Endothermic

2nd Phase : Production of ATP (4) i.e. Exothermic.

1st Phase of Glycolysis

1) Purpose : Phosphorylation of Glucose (i.e. addition of Phosphate PO_4)

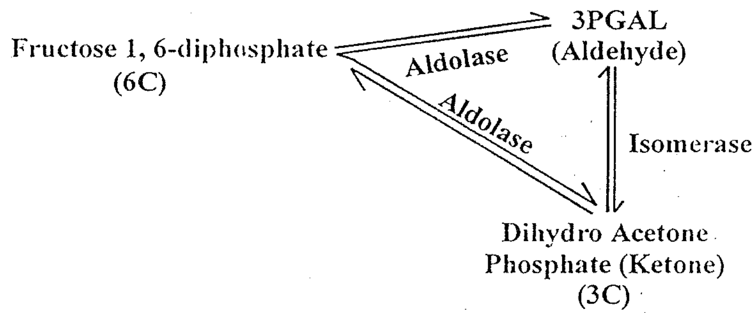
2) Requirements : Enzyme (3) + ATP (2)
3) Reactions.



In the first phase, there is loss of two ATP (2AP).

2nd Phase of Glycolysis :

Here hexose is broken down and reaction are the opposite of calvin cycle.

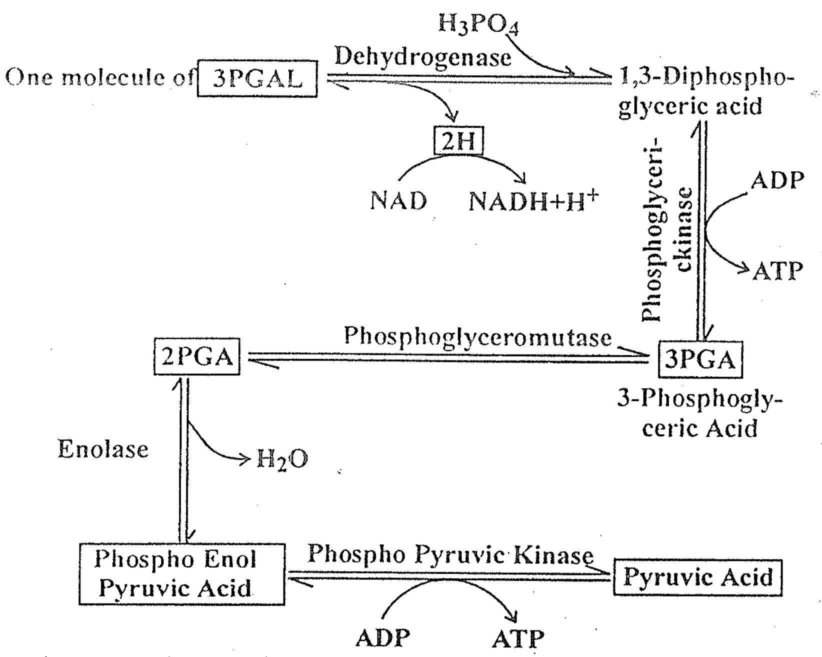


3PGAL : 3-phospho Glyceraldehyde

Products : 3PGAL : One molecule

Ketone : One molecule

But due to isomerase, ketone is converted to aldehyde i.e. 3PGAL, therefore two molecule of 3PGAL are obtained.

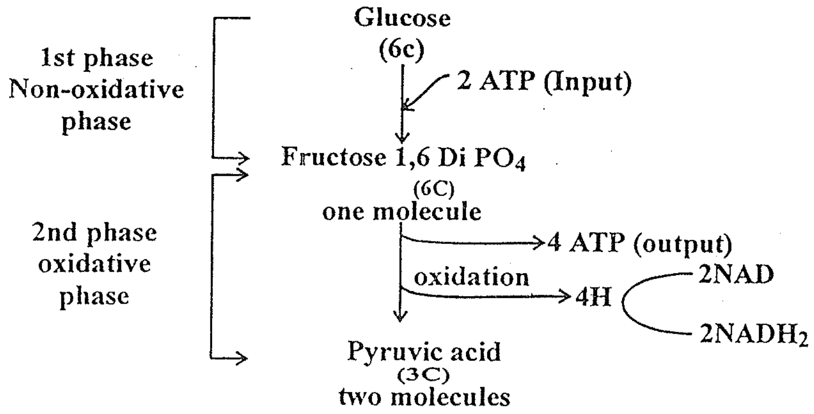


From 1 molecule of PGAL – 2ATP and 1 $NADH_2$ products

From 2 molecule of PGAL – 4ATP and 2 $NADH_2$ products

Note : All reactions of glycolytic pathway are reversible.

Summary of Glycolysis :



Products of Glycolysis :

1) 2 molecules of pyruvic acid (partially oxidised) and further will be oxidised through Link and Krebs cycle.
2) 2 molecule of $NADH_2$: Further will be used for electron transport system to release H_2O.
3) ATP : Energy for any cell work.

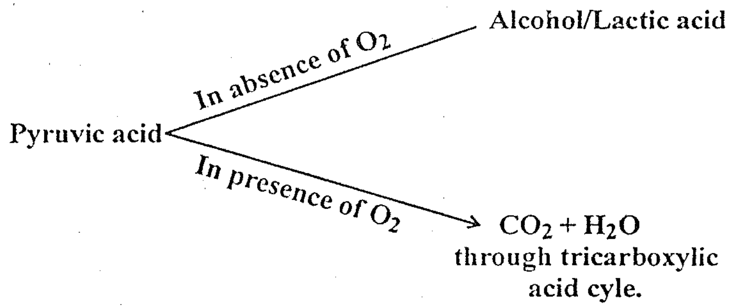
Production – 4ATP

Consumption – 2ATP

Net Production : **2 ATP in glycolysis.**

But 2 molecules of $NADH_2$ will be oxidised aerobically to yield 6 molecules of ATP. Thus total molecules of ATP through glycolysis in presence of O_2 will be 8 instead of 2.

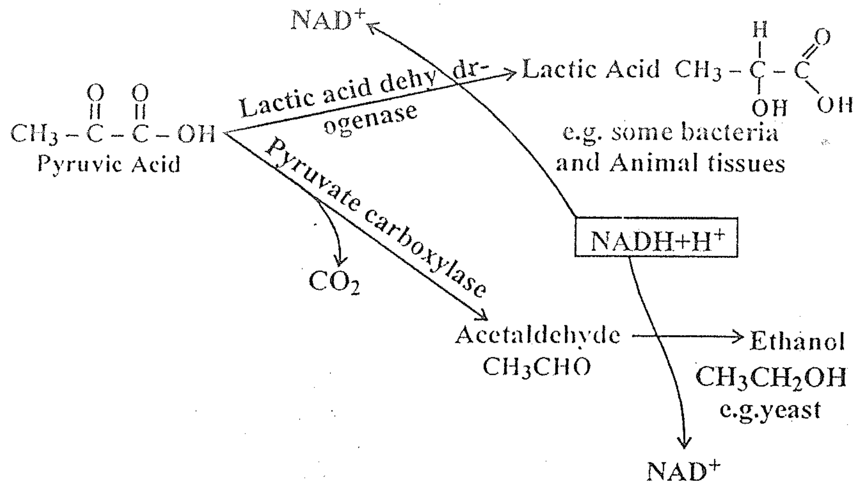
Pyruvic acid are obtained through partial oxidation of glycolytic pathway have two fates:



The first fate, which occurs in the absence of oxygen is called Anaerobic respiration (Fermentation) and the 2nd fate which occurs in the presence of oxygen is called aerobic respiration or simply respiration.

Anaerobic respiration = Fermentation:

In the absence of O_2, $NADH_2$ formed during glycolysis can't be reoxidised by O_2, hence for continuous supply of NAD is required for operation of glycolysis. There are two important ways:



The formation of ethanol (Ethyl alcohal) in the absence of O_2 is called Fermentation. The example is yeast. But in muscle tissue of animal (man) and in some bacteria, lactic acid is formed. After excessive work, man is tired only due to the formation of lactic acid in the muscles.

Aerobic Respiration :

It is a slow oxidation and involves 6 oxidation steps.

How Respiration?

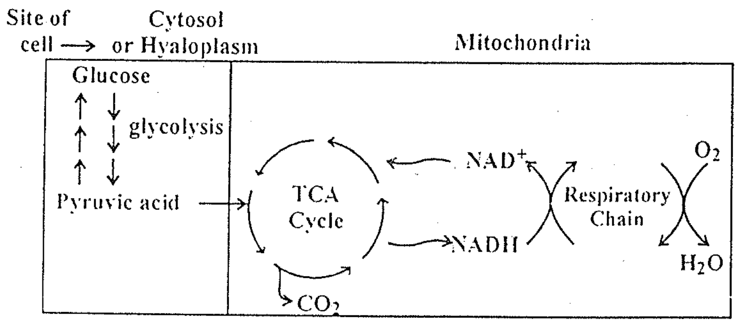
a) Breakdown of glucose (i.e. release of H) through glycolysis + Link + Krebs cycle

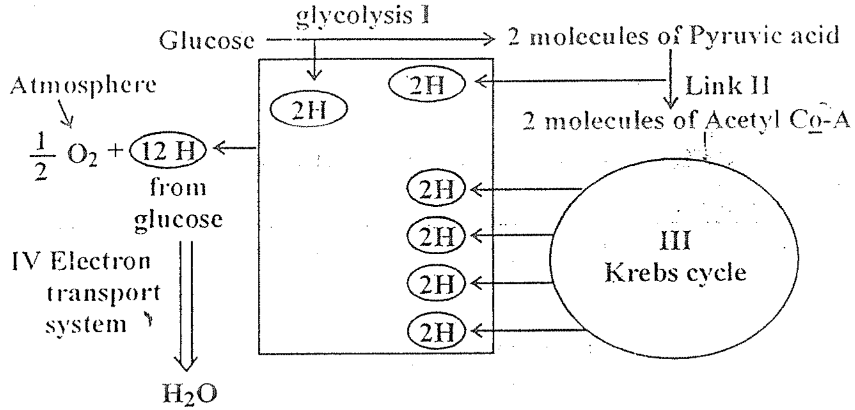
b) Union of all Hydrogen (from glucose) with atmospheric oxygen.

↓

Through Electron Transport System (ETS)

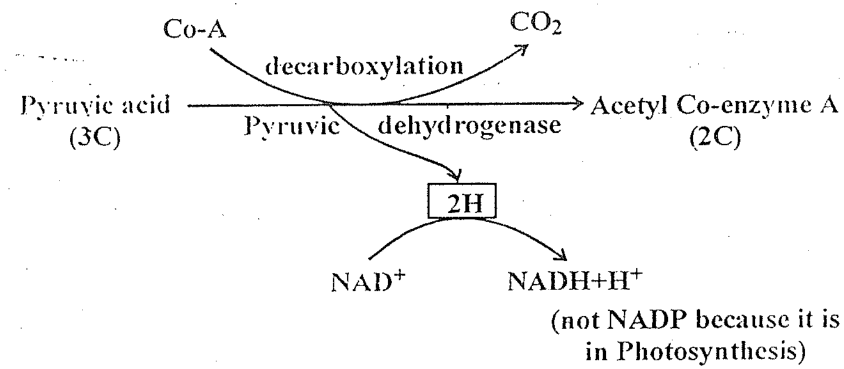
Outline :





II- Link :

Here Acetyle co-enzyme A is formed which is the connecting link betwen glycolysis and krebs cycle. Hence this stage is called link. There are three changes in the link-



Net result of the reaction :

[Pyruvate+Co–A+NAD+ → Acetyl Co–A + $NADH_2$ + CO_2]×2 molecules

Release : $2CO_2$ (two molecule of CO_2) + 4H

III. Krebs cycle/citric acid cycle/Tricarboxylic acid cycle

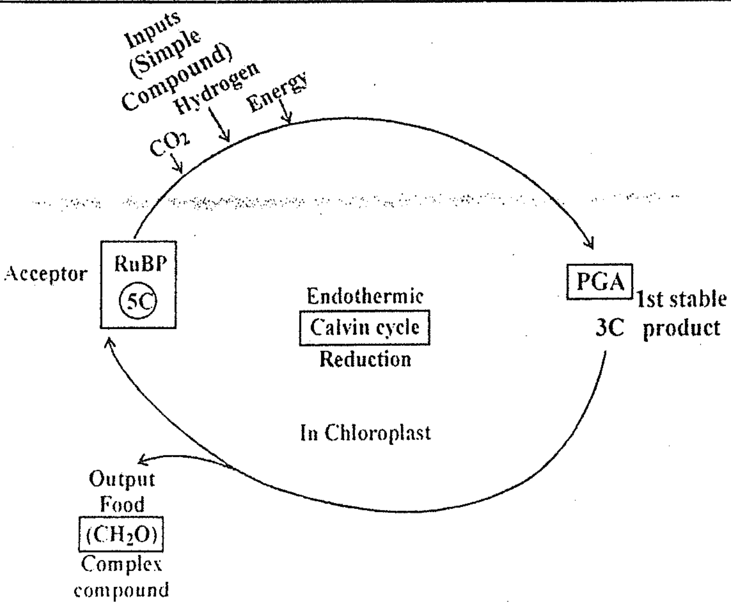
Krebs cycle	citric acid cycle	Tricarboxylic acid cycle
↑ Name of scientists	↑ First product of reaction	↑ Nature of organic acid produced in the reaction.

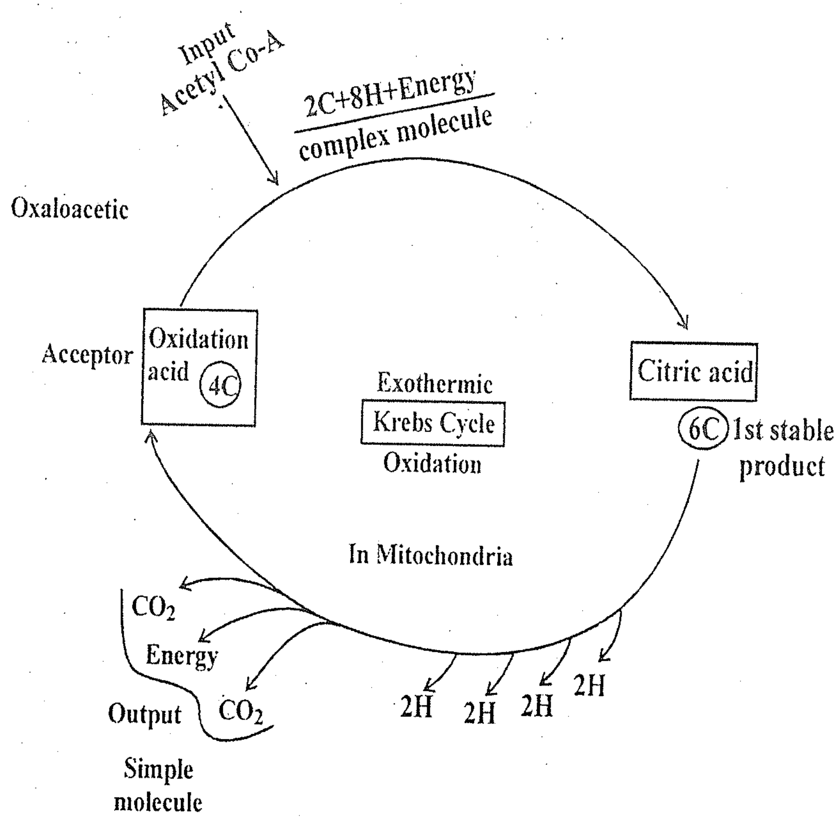
Under aerobic conditions pyruvic acid is oxidised through a 'Tricarboxylic acid cycle' given by **Wood** et al (1942) and **Krebs** (1943).

Energy is released due to breaking of bond of carbon-carbon into CO_2.

Difference between Calvin and Krebs Cycle

Calvin Cycle	Krebs Cycle
1) Initiator molecule : RuBP (5C) 5-carbon compound	1) Oxaloacetic acid (4C) 4-carbon compound
2) Raw materials : – CO_2 (atmosphere) – H_2 ($NADPH_2$) – Energy (ATP)	2) Acetyl Co-A Source : Oxidation product of glucose.
3) 1st stable product : PGA(3C)	3) Citric Acid (6C)
4) Product – Food (hexose)	4) Products – CO_2 – H_2 – Energy
5) Nature : Endothermic & Reduction	5) Exothermic and oxidation
6) Site : Chloroplast	6) Mitochondria.





Conclusion : Both calvin and Krebs Cycles are antiparrallel reactions.

Fig. : Calvin cycle & Krebs cycle.

Q. What happens during krebs cycle :

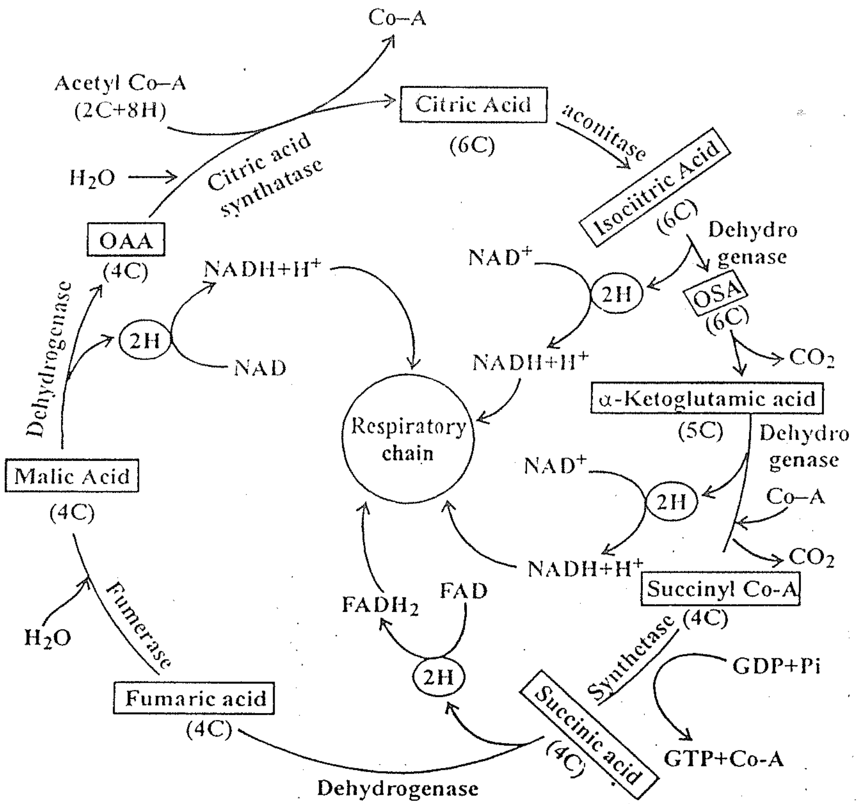
a) Decarboxylation (CO_2-removal)

b) Oxidation (H-removal)

c) Phosphorylation (Energy production)

d) All

Ans. (d)



OAA : Oxaloacetic acid
OSA : Oxalosuccinic acid
GTP : Guanosine Triphosphate
GDP : Guanosine Diphosphate
FAD : Flavin adenine dinucleotide

Fig. Krebs Cycle/TCA cycle

Note : All reactions of krebs cycle are reversible, but the reaction of link are not reversible.

No oxygen is taken up in the TCA cycle itself but is taken up in the respiratory chain.

★ Enzyme : Decarboxylase → For removal of CO_2
↓
acts twice; specific action on

i) Oxalo succinic acid] source of CO_2
ii) α-Ketoglutamic acid] in K.C. (Krebs cycle)

Total no. of CO_2 produced in K.C. from 2 molecule of Acetyl Co–A → $4CO_2$

★ Enzyme : Dehydrogenase → For removal of Hydrogen

Dehydrogenase = De + Hydrogenase
↓
means removal

It works 4 times specifically at :

H- donor in K.C.
i) Isocitric acid → 2H → NAD+
ii) a-Ketoglutamic acid → 2H → NAD+
iii) Succinic acid → 2H → FAD+
iv) Malic acid → 2H → NAD+
} H-acceptor in K.C.

Major acceptor of H → NAD
Minor acceptor of H → FAD
Total no. of 2H released in K.C. – 2H × 8 = **16H**

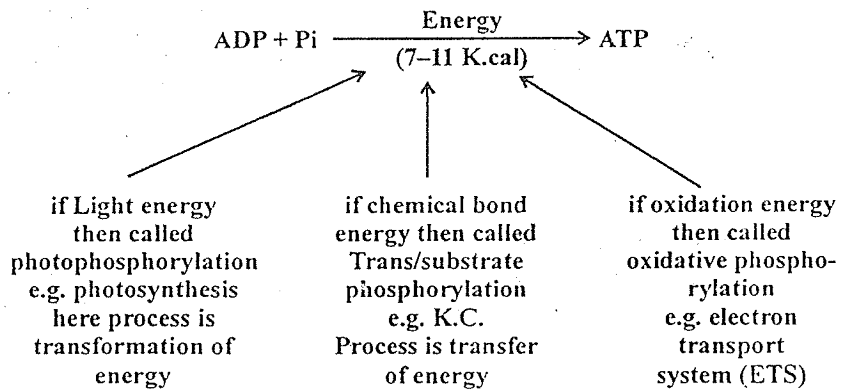
★ ATP production through K.C.

Breaking down of succinyl Co-A
↓
Releases chemical bond energy.
GDP + Pi → GTP; (Pi means inorganic phosphate)
GTP + ADP → GDP + ATP

Since one molecule of ATP is produced from one molecule of Acetyl Co-A

∴ two molecule of Acetyl Co-A → **2ATP**

Phosphorylation :



IV. Electron Transport System (ETS) / Respiratory Chain

Here oxidation of $NADH+H^+$ and $FADH+H^+$ occurs.

i) Electron donor is Hydrogen
ii) Electron carriers – Cytochrome (in F_1 particle of Mitochondria)
iii) Electron Acceptor – Oxygen (from atmosphere)
iv) Production of H_2O and ATP

$NADH_2$ & $FADH_2$ are the only temporary storage place for electrons.

Respiratory chain is the system of mitochondrial enzymes and electron carriers through which the re-oxidation of NADH to NAD^+ under aerobic conditions by transfer of electrons from NADH to O_2. Respiratory chain also transfer the electrons from succinic acid to O_2.

$$NADH + \frac{1}{2} O_2 + H^+ \longrightarrow H_2O + NAD^+$$

$$\underset{\text{succinic acid}}{COOHCH_2\ CH_2COOH} + \frac{1}{2} O_2 \longrightarrow H_2O + \underset{\text{Fumaric acid}}{\begin{matrix} CHCOOH \\ \| \\ CHCOOH \end{matrix}}$$

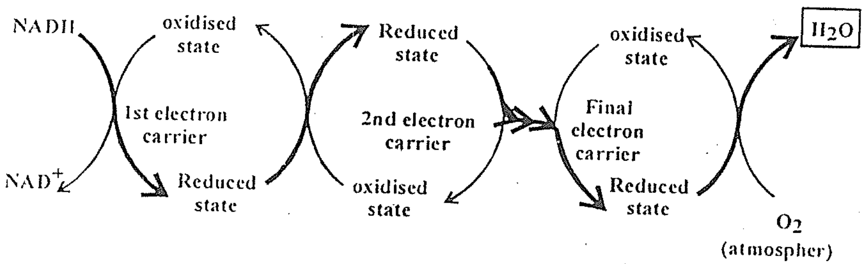


Fig. : Respiratory Chain
O_2 is the final electron acceptor

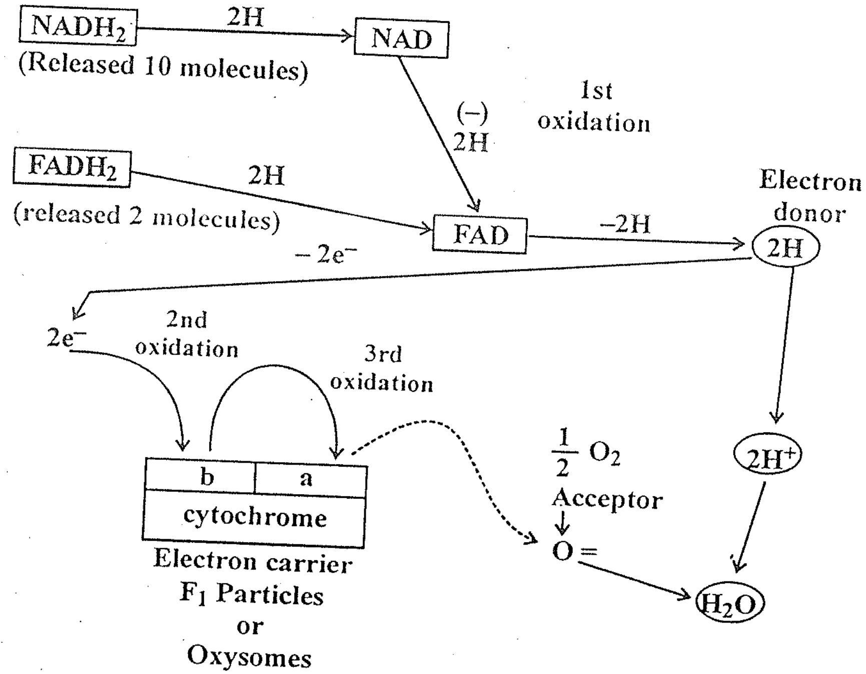
No. of released $NADH_2$ /$FADH_2$:

Released $NADH_2$ molecule :

Through Glycolysis	$= 1\times2$	$= 2\ NADH_2$
Link	$= 1\times2$	$= 2\ NADH_2$
K.C.	$= 3\times2$	$= 6\ NADH_2$
Total $NADH_2$	$= 5\times2$	$= 10$ molecule

Released $FADH_2$ molecule :
only through K.C. $= 1\times2 = 2\ FADH_2$

Oxidation Steps of $NADH_2$/$FADH_2$ in ETS



In the oxidation of one molecule of reduced NAD (i.e. $NADH_2$) to NAD^+, 3 molecules of ATP are released, one in the 1st oxidation step of $NADH_2$; one in the 2nd oxidn. step of reduced cytochrome b; and one in the 3rd oxidation step of reduced cytochrome a.

i.e. $NADH_2 \rightarrow NAD^+ + 2H + 1ATP$

$2H \rightarrow 2H^+ + 2e \mp 2ATP$

$NADH_2 \rightarrow NAD^+ + 2H^+ + 2e^- + 3ATP$

$\therefore$ 10 Molecules of $NADH_2$ released $3\times10=30$ ATP

In the case of succinic acid oxidation, NAD step (i.e. 1st oxidation step) is bypassed and therefore only 2 molecules of ATP are generated;

one in the oxidation of reduced cytochrome b; and one in the oxidation of reduced cytochrome a. According to Bidwell (1979) NAD^+ transfers 2H to FAD. It constitutes 1st oxidation step.

$$FADH_2 \rightarrow FAD^+ + 2H^+ + 2e^- + 2ATP$$

$\therefore$ 2 *molecules* of $FADH_2$ released $2 \times 2 = 4ATP$

$\therefore$ Total No. of ATP produced in ETS = 30ATP
4ATP
34ATP

Energy released during respiration:

1) On the basis of stages of respiration:
 a) glycolysis = 2ATP
 b) Krebs cycle = 2 ATP
 c) ETS = 34ATP
 38 ATP

2) On the basis of site:
 a) Enzyme of glycolysis : On cytosol (cytoplasmic soln) i.e. outside Mitochondria : **– 2ATP**
 b) Enzyme of K.C. : On Perimitochondrial space
 Enzyme of ETS : On cytochromes (oxysomes/F_1 Particles) i.e. Inner membrane of Mitochondria
 thus within Mitochondria = 2ATP of K.C.
 34 ATP of ETS
 36 ATP

3) On the basis of phosphorylation :
 a) Oxidative phosphorylation = 34 ATP
 b) Substrate/Trans phosphorylation = 4ATP
 (i.e. direct oxidation of substrate) = 38ATP
 2 ATP in glycolysis + 2ATP in K.C.

4) On the basis of 3 stages excluding ETS :
 a) Glycolysis = 8 ATP
 b) Link = 6 ATP
 c) K.C. = 24 ATP
 38 ATP
 (through respiratory chain) **in presence of O_2**

5) On the basis of two stages excluding link and ETS:
 a) Glycolysis = 8 ATP
 b) Krebs cycle = 30 ATP
 38 ATP
 (in presence of O_2 through ETS)

6) On the basis of reactions:

S.No.	Compound to be oxidised	Compound formed after oxidation	H-acceptor	No. of ATP
1.	3-Phosphoglyceraldehyde	1,3-diphosphoglyceric acid	NAD+	$2\times3 = 6$ (2 means 2 molecules of NAD^+)
2.	1,3-diPGA	3-PGA	---	$2\times1 = 2$
3.	Phospho enol Pyruvic acid	Pyruvic acid		$2\times1 = 2$
4.	Pyruvic acid	Acetyl Co-A	NAD^+	$2\times3 = 6$
5.	Isocitric acid	Oxalosuccinic acid	NAD^+	$2\times3 = 6$
6-	α-Ketoglutaric acid	Succinic acid	NAD^+ (+ATP)	$2\times3 = 6$, $2\times1 = 2$ } = 8
7.	Succinic acid	Fumaric acid	FAD^+	$2\times2 = 4$
8.	Malic acid	Oxaloacetic acid	NAD^+	$2\times3 = 6$

Total no. of produced ATP = 40 ATP
Total no. of Consumed ATP = 2 ATP
Net gain of ATP = 38 ATP

Reaction Formula of Respiration :

Outputs :
 a) No. of CO_2 molecule through Link = 2
 K.C = 4
 Total molecules released during respiration = **$6CO_2$**
 b) No. of H_2O molecule through ETS = $(1\times10)+(1\times2)$ = **$12H_2O$**
 [10 means 10 molecules of $NADH_2$
 2 means 2 molecules of $FADH_2$]

c) No. of net ATP produced = 38ATP

Inputs :

a) Glucose : $C_6H_{12}O_6$

b) Oxygen : $\frac{1}{2}O_2$

∴ Formula : After balancing the above inputs & outputs :

$$C_6H_{12}O_6 + 6O_2 + 6H_2O = 6CO_2 + 12H_2O + 38ATP$$

or $C_6H_{12}O_6 + 6O_2 + 6H_2O = 6CO_2 + 12H_2O + 686$ K.cal

Efficiency of respiration:

When glucose is a respiratory substrate, 686 K.cal. is released where some energy is conserved as 38ATP molecules. When one ATP molecule is hydrolysed, the energy released is about 7.6 K.cal per mole of the terminal phosphate group in ATP.

$$\therefore \text{Efficiency} = \frac{38 \times 7.6}{686} = 42\%$$

Thus the efficiency of respiration is 40-50%. It means respiration is partially efficient and rest energy is lost as heat energy. The temp. of the test tube containing germinating seed is increased only due to fast respiration. In the dormant seed, respiration is slow.

Q. During aerobic respiration of glucose, a plant cell released 42 molecules of CO_2. How many ATP will be produced?

Soln: Eqn : $C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 6CO_2 + 12H_2O + 38ATP$

6 molecules of CO_2 produced when 38 ATP are released

∴ 42 molecules of CO_2 produced are $\frac{38}{6} \times 42 = 266$ ATP.

Respiratory Quotient/Respiratory Ratio:

R.Q. is the ratio of the volume of CO_2 released to the volume of O_2 absorbed in the respiration. It is also called respiratory ratio(RR).

$$R.Q. = \frac{\text{Volume of released } CO_2}{\text{Volume of absorbed } O_2}$$

a) R.Q. = 1, when substrate is carbohydrate (hexose)

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 686\text{K.cal}$$

b) R.Q. < 1 i.e. R.Q. is less than unity. when respiratory substrate is highly reduced food.

i) respiration of fats & protein :

$$2C_{51}H_{58}O_6 + 145O_2 \rightarrow 102CO_2 + 98H_2O$$

(fat)

When substrate is **Fat**, R.Q. = **0.7**

when substrate is **Protein**, R.Q. = **0.8 – 0.9**

Respiration of Protein:
- with amide formation, RQ = 0.8
- With ammonia formation, RQ = 0.99

ii) Respiration in succulent plants and red leaves (i.e. xerophytes e.g. opuntia)

Here oxidation is incomplete.

$$2C_6H_{12}O_6 + 3O_2 \xrightarrow[\text{Oxidation}]{\text{Partial}} \text{Malic acid} + 3H_2O + 386\text{K.cal}$$

$$R.Q. = \frac{CO_2}{O_2} = \frac{0}{3} = 0$$

c) R.Q. > 1 i.e. R.Q. is more than unity when respiratory substrate is highly oxidised food.

i) Organic adds :

$$2(COOH)_2 + O_2 \rightarrow 4CO_2 + 2H_2O + 60.2 \text{ K.cal}$$

oxalic acid

$$R.Q. = \frac{CO_2}{O_2} = \frac{4}{1} = 4$$

$$C_4H_6O_5 + 3O_2 \rightarrow 4CO_2 + 3H_2O$$

malic acid

$$R.Q. = \frac{CO_2}{O_2} = \frac{4}{3} = 1.3$$

ii) Anaerobic respiration :

$$C_6H_{12}O_6 \xrightarrow{\text{Zymase}} 2C_2H_5OH + 2CO_2 + 21 \text{ K.cal}$$

$$R.Q. = \frac{CO_2}{O_2} = \frac{2}{0} = \infty \text{ (infinity)}$$

The R.Q. of a plant material is measured by Ganong's Respirometer.

Difference between-

Aerobic respiration	Anaerobic respiration
1) Oxidation of substrate in presence of O_2.	1) Oxidation in absence of O_2
2) Intermolecular respiration $C_6H_{12}O_6 + O_2$	2) Intramolecular respiration
3) Complete oxidation	3) Partial oxidation
4) Energy output → higher glucose → 38ATP	4) Energy output → lower Glucose → 2ATP
5) End product $C_6H_{12}O_6+6O_2 \Rightarrow 6CO_2+6H_2O+38ATP$	5) End product $C_6H_{12}O_6 \Rightarrow 2CO_2+2C_2H_5OH+2ATP$ or $C_6H_{12}O_6 \rightarrow 2C_3H_6O_3+2ATP$ lactic acid
6) Oxidation steps → 6 (six)	6) Oxidation step → 1 (one)
7) Dependent on mitochondria	7) Independent of mitochondria
8) Hydrogen acceptors → NAD^+ + FAD^+	8) Hydrogen acceptor → NAD^+ only
9) Phosphorylation : a) Oxidative and b) Substrate	9) Phosphorylation → Trans (substrate) only.
10) R.Q. → 1, >1, <1, or 0	10) R.Q. : Infinity (∞)

Difference between Respiration and Photorespiration

Respiration	Photorespiration
1) Respiratory substrate : carbohydrate, fat or protein	1) Glycolate
2) Substrate maybe recently formed or stored one	2) Substrate is always recently formed
3) Process of respiration occurs in cytoplasm + Mitochondria	3) Process occurs in chloroplast + Peroxisomes + mitochondria
4) Hydrogen peroxide (H_2O_2) is not formed	4) H_2O_2 is certainly formed
5) Several ATPs are produced	5) No ATP
6) It occurs in light and Dark both.	6) Only in light
7) Occurs in all living cells.	7) Only in chlorophyllous cells.
8) Not sensitive to rise in temperature	8) Photorespiration is high at 25°-35°C.
9) No Transamination Occurs	9) Transamination occurs.

Factors affecting respiration (aerobic) :

External Factors :

1) Temperature : The increase in temperature increases the rate of respiration following the vant **Hoff's law**. (vant Hoff's law – the respiration rate increases two or three times for every rise of 10°C i.e. Q_{10}=2 or Q_{10}=3). This marked increase in respiration rate is only in between the range of 0°-45°C. The optimum temp. of respiration is 30°C. At high temperature, there is a decrease in respiration rate and the responsible factor is called Time Factor. At very low temp., the respiration rate is very low i.e. insignificant. Therefore vegetables and fruits are generally stored at very low temperature just to minimise the catabolic effects of respiration.
2) Light : The effect of light is indirect on respiration rate. Light increases the respirable material by increasing photosynthesis. Light also increases the temperature. Light affects the opening and closing of stomata also.
3) Concentration of O_2 in the atmosphere : Oxygen is essential for aerobic respiration but its concentration in the atmosphere is almost constant thereby not affecting the rate.
4) CO_2 concentration : Since its concentration in the atmosphere is also constant, therefore it has no effect on respiration rate. But its concentration is variable in the soil air, therefore its high concentration in the soil air, inhibits all those activities of plant which require energy.
5) Water : The slight change in the water content does not affect the respiration rate. The shortage of water may increase the respiration rate but the very low content of water (e.g. dry seeds and stored tubers) minimises the respiration rate.

6) Injury : The sugar content of the injured or wounded portion of the plant is suddenly increased because the conversion of starch to sugar is increased due to the increase in the rate of respiration.

7) Certain chemical compounds : Certain enzymatic inhibitors like cyanides, azides, carbon monoxide, iodoacetate chloroform, ether etc. reduces the rate of respiration.

8) Mechanical effects: The gentle rubbing or bending of the leaf blade increases the respiration rate but high wind or storm closes the stomata to cut off the O_2 supply.

Internal Factor:

9) Protoplasmic factors : Younger cells which have more of active protoplasm respire more rapidly than older cells. The older cells have less protoplasm due to larger vacuoles. The rate is also affected by the quantities of respiratory enzymes present in the protoplasm. In the old age (i.e. senescence), the respiration rate declines.

10) Concentration of respiratory material : If other factors are not limiting, the respiration rate increases with the increase in the respiratory substrate.

Pasteur Effect :

Generally the increase in respiratory substrate or oxygen, increases the rate of respiration.

But there are many cases where oxygen reduces the rate of sugar breakdown and even conserve it, is called Pasteur Effect.

Climacteric Rise :

The rate of respiration varies with the age of respirable cell. In merismatic cells respiration is high and becomes steady in the growing stages. In the maturing fruit or in the ripening of fruits, there is the production of ethylene which increases the respiration rate. This rise in the rate of respiration is called the climacteric rise.

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4. Enzymes

Meaning :

Enzyme = En + Zyme = Greek words

means

En → In, Zyme → Living

The word 'enzyme' was coined by W.kuhne (1878) while working on fermentation. Enzymes may be defined as organic substances capable of catalysing chemical reactions in the living systems. These are the following points necessary for to be the enzyme :-

a) proteinaceous substance
b) Biological and organic catalysts.
c) required in small quantity.
d) Specific in nature.

Thus enzymes alter the rate of reaction without affecting the equilibrium.

Types :

(a) On the basis of structure :

1) Simple protein enzymes : such enzymes are wholly made up of proteins e.g. trypsin, pepsin, amylase, urease etc.

2) Conjugated enzymes : In such enzymes, non-protein parts are also the structural components. The protein part is called **Apoenzyme** and non-protein component is called **cofactor**.

Conjugated enzymes = Protein component + Non-protein component

↓ Apoenzyme ↓ Cofactor

Cofactor → (I) Coenzymes, (II) Prosthetic group, (III) Metal activators

(I) Coenzymes organic part and easily separable from apoenzyme e.g. NAD,NADP, Co-A, ATP

(II) Prosthetic group Firmly adhered to the apoenzyme e.g. FAD

(III) Metal activators e.g. Fe^{2+} Co^{2+},Mg^{2+},Zn^{2+} Fe as in cytochrome

Isoenzymes : Such enzymes are different in moleculer structure but are similar in Function e.g. Lactic acid dehydrogenase (LDH).

(b) On the basis of presence :

1) Inducible enzyme : Such enzymes do not occur in the absence of substrate e.g. Nitrate Reductase (Nitrate reductase is found in the nodules of leguminous crop.)

2) Non-Inducible enzyme : Such enzymes are present at all the times e.g. mostly enzymes.

Mode of Action :

The action of the enzyme depends upon a combination of the enzyme and the substrate molecules to form an enzyme-substrate complex. The enzyme substrate relationship is often compared to as **'Lock and Key'** theory, proposed by Fischer (1894). Another theory called **Induced-Fit hypothesis** was proposed by **Koshland** (1959). According to the latter theory, the attachment of substrate to the enzyme brings about a three dimensional structural change in the enzyme.

Classification : The enzymes are broadly classified into six groups :

1) Transferases : Such enzymes catalyse the transfer of one carbon group to another molecule e.g. Hexokinases, transaminases etc.

2) Hydrolases : Such enzymes catalyse the hydrolysis of the compound. i.e. the addition of the water molecule e.g.
$C_6H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$
Invertase, amylase, esterase, phosphatase, etc.

3) Oxido-reductases :

3a) Oxidases : Such enzymes catalyse the oxidation with molecular oxygen e.g. cytochrome oxidase, peroxidase.

3b) Dehydrogenase : Catalyse the removal of 'H' through oxidation concerned with oxidative phosphorylation e.g. Alcohol dehydrogenase (i.e. for hydrogen transfer).

3c) Reductases : These enzymes cause addition of 'H' or electron (e^-) and the removal of O_2 e.g. Nitrate reductase.

4) Lyases : These enzymes cause the removal of a group of atoms from the substrate and cause addition of 2nd group at this (double) bond without affecting hydrolysis, oxidation and reduction. e.g. carboxylase, Fumerase, adolase.

5) Isomerases : These enzymes are the responsible for the isomeric changes through rearrangement.

6) Ligases or Synthatases : These catalyze the synthesis of different types of bonds e.g. polymerase, RNA synthatase.

Nature and Properties of Enzymes

1) Enzymes **are specific** in nature means specific in reaction with substrate.
2) Enzymes are **colloidal** in nature and thus provide large surface area for reaction.
3) Enzymes are made up of either only Apoenzyme or Apoenzyme + Co-Factor.
4) are required in extremely small amounts.
5) remain unaffected in the reaction:
6) Organic catalyst.
7) are pH regulated.
8) Enzymes are amphoteric protein (means react with acidic and alkaline both substances)
9) Thermolabile (means heat sensitive)
10) Enzymic activity can be inhibited.
11) Enzymic reactions are reversible but forward reaction is more.

Factors affecting Enzymic reactions :

1) **Substrate Concentration :** An increase in the concentration of the substrate firstly increases the rate of the reaction but when all the active sites of the enzyme surface are occupied by the substrate moleucle, the increase is stopped. And there is no effect of the further increase in

substrate conc. on the rate of reaction. This is because of the limiting effects of the enzyme concentration.

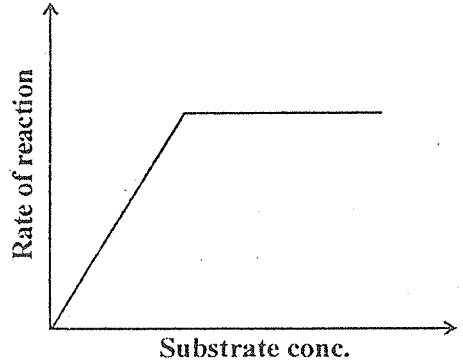

Fig. : Relationship between the substrate conc. and the rate of reaction.

2) **Enzyme concentration :** Firstly there is an increase in the rate of reaction with the increase in enzyme concentration but the rate of reaction stops at a point and becomes constant when substrate conc. becomes the limiting factor.

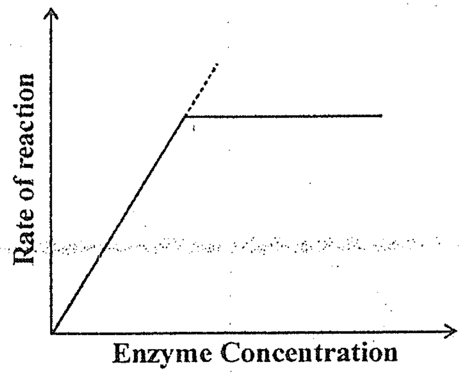

fig. Effect of enzyme conc. on the rate of reaction.

3) **Temperature :** The enzymic reaction rate increases twice (i.e. doubles) for every rise of 10°C within the certain limit. i.e. $Q_{10}=2$. At 0°C enzymatically active reaction rate becomes zero and at higher temperature i.e. 55°–60°C, the Denaturation of enzyme takes place (i.e. the loss of natural properties). However, the optimum temp is 30°C.

4) **Hydrogen ion concentration (pH) :** The pH between 7–7.5 is

ideal for the normal enzymic activity but there are certain enzymes like pepsin requires very low pH i.e. 1.5–3.0 whereas enzymes like Trypsin are active even at high pH.

5) **Hydration :** In the seeds, the amount of water is too less so no enzymic activity is observed. With the increase in the amount of water, enzymes become active and seed starts to germinate.

6) **Concentration of the End product :** Enzymic reactions are reversible in nature and acts on the 'Mass action' principle. Therefore the accumulation of the end products results in an increase in the rate of the reverse reaction.

7) **Inhibitors :** Enzyme inhibitors are of two types :

Enzyme Inhibitor

- **Reversible** — such inhibitors are removed by dialysis
  - Competitive inhibitors : Such inhibitors are structurally similar to the substrate molecule e.g. Malonic acid resembles with succinic acid. This effect is overcome by increasing the concentration of sucinic acid.
  - Non-competitive inhibitors : such inhibitors reacts with either enzyme or enzyme-substrate complex e.g. cyanides, azides
- **Irreversible** — Such inhibitors can not be removed because they probably alter or destruct the active sites of the enzymes.

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5. Growth, Harmones & Growth regulators

Growth and Development:

Growth may be defined as a dynamic vital process which brings about a permanent change in any plant or its parts with respect to size, form, weight and volume. The permanent change may be either in positive direction or negative direction. For example, the dry weight in the sprouting potato tubers decreases during the early phase of the growth. Therefore the main points of growth are :

a) It is dynamic **vital process.**

b) It brings about a **permanent change.**

Growth

- **Primary Growth is due to**
  - **Apical meristems responsible for**
    - → **Formation of Tissues**
    - → **Increase in length**
    - → **Differentiation of various appendages**
  - **Temporary apical meristems called Intercalary meristems responsible for increase in length in bamboo, mint etc.**
- **Secondary Growth is due to**
  - **Lateral meristems responsible for the thickness.**

Development : Development is the process of growth and

differentiation of individual cells into tissues, organs and organisms. It is the resultant of growth.

Phases of Growth :

Broadly there are three phases of growth :

a) The phase of cell **Division/Cell Formation**. It is also called **Logrithmic** or **Exponential** phase.

b) The phase of **Cell Enlargement**. It is called **linear phase**.

c) The phase of **cellural differentiation** or **cell maturation**. It is also called **senscence phase.** But there are five distinct phases of growth.

1) **Lag phase** : It is the initial lag period where internal changes in the cell occur which are the preparatory to gtowth. Here the increase in size or weight is very slow or negligible.
2) **Log Phase** : It is the grand period of growth. Here growth is very fast.
3) **Third phase** : Here Growth rate gradually decreases.
4) **Fourth phase** : It is the phase where organism reaches to maturity and growth ceases.
5) Final phase : It is phase of sencence where death of organism sets in.

on the basis of the different phases of growth, a **sigmoid growth curve** (i.e. **'S' - shaped**) is obtained.

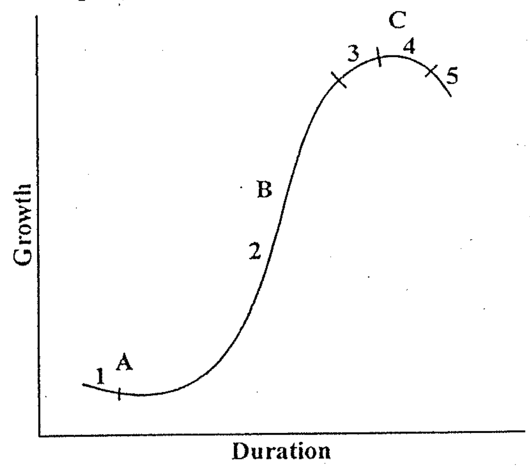

Fig. : Different Phases of Growth

The growth rate is measured in different ways by Auxanometer and crescograph (J.C. Bose).

Factors affecting Growth & Development :

Growth and Development is affected by physiological processes and environmental conditions. Absorption of water and minerals, photosynthesis, respiration etc. are the physiological processes which govern the growth and development to a very large extent. The environmental factors include the climatic factors and edaphic factors. The major two climatic factors viz Temp. and light are discussed here:

Temperature : There is a pronounced effect of temperature on the growth of the plant. Growth occurs in the range of 4°C to 45°C but the cardinal temperature range is 28-33°C. The low temperature at night reduces the rate of respiration but high temp. during the day time increases photosynthesis and accumulation of synthates which in turn increases growth. That is why **potato tubers** growing on **hills** are **much larger** than those of the plains.

The very high temperature generally stops the growth of plant by affecting many physiological processes. At high temperature, the **protein** component of the protoplasm is also **coagulated** and the protoplasm is killed. This effect of high temperature is called **heat injury.** But there are some plants which have some heat resistance mechanism like high sugar content, thick bark etc.

The very low temperature also generally stops the growth. There are three types of injuries caused by low temperature :

a) **Dessication** : The plant tissues become dessicated and injured when the rate of absorption is very slow due to low temperature but transpiration rate is rapid.

b) **Chilling Injury** : The plant of the hot climate when exposed to low temperature (above the freezing point) for some time is either killed or severely injured. This injury is called chilling injury. The ripe banana becomes black when is kept in refrigerator is only due to chilling injury.

c) **Freezing Injury** : When the plants is exposed to very low temperature (below the freezing point), the protoplasm of the plant cell is dehydrated resulting in its coagulation due to the formation of ice crystals of water. The high concentration of the cell sap aggravates the precipitation of protein and thus resulting into the death of the cell. But there are many

perennial plants which withstand the freezing injury because of the high osmotic concentration of the cell sap. Such foost resistance (or hardiness) nature of the plant lower the freezing point and reduces the amount of water.

Light : The intensity, quality and duration of light affect the growth. The weak intensity of light promotes shortening of internodes and expansion of leaves. Very weak intensity reduces the rate of overall growth. Very high intensity reduces the growth rate indirectly, increasing the water loss. Blue violet light enhances internodal growth whereas green light reduces expansion of leaves. Red colour is the most Favourable light quality for growth. Beyond the visible spectrum i.e. infrared and uv-rays are detrimental for growth. The duration of light has pronounced effect on the vegetative and reproductive growth of plant. This phenomenon is called Photoperiodism which is described in the next chapter. Longer periods of light causes luxuriant vegetative growth in most of the plants. Garner and his co-workers found that the amount of vegetative growth was proportional to the duration of day light.

Growth Harmones & Growth Regulators

Growth Harmones : Growth Harmones are the such organic substances which are produced generally in meristematic tissues of the plant and translocated towards the site of action inducing a physiological process or response and can work in extremly munute quantities. Thimann (1948) suggested the term **Phytoharmone** for hormones of plants.

Plant Growth Regulators (PGR) : Such organic compounds occuring naturally in plants as well as synthetic other than nutrients which in small amounts promote, inhibit or modify any physiological process are called PGR. The PGR are of two types :

i) Growth promotor e.g. auxins, gibberellins & cytokinin.

ii) Growth inhibitors e.g. abscisic acid and ethylene.

Ausins :

1) F.W. Went (1928) isolated the growth substance which he named Auxin.
2) The plant **Avena sativa** (i.e. Oat) was used by Went for the bioassay henca the test is known as **Avena Curvature test** or **Avena Coleoptile test**. It was found that Auxin was respon-

sible for curvature in Avena Coleoptile.

3) Thimann (1934) found that the highest concentration of auxin was occured in the coleoptile tip and a gradual decrease from the tip to the base of the coleoptile. He also noticed that the concentration of auxin was much less in the root tip than that of the coleoptile tip.

4) Auxin was a general term used to denote for such substance which promote the elongation of the coleoptile tissues.

5) Indole acetic acid (IAA) is a endogenous auxin occuring naturally in plants.

6) Synthetic auxins : Examples are -
   a) Indole – 3 – butyric acid (IBA)
   b) Indole – 3 – Propionic acid (IPA)
   c) Napthalene acetic acid (NAA)
   d) Dichlorophenoxy acetic acid (2, 4–D)
   e) Malic Hydrazide (MH)

7) MH and Acid paracoumaric have the property of anti-auxins.

8) Precursor of IAA is **Tryptophane** (produced from SKIMMIC pathway of respiration)

9) Two types of endogenous Auxin :
   a) Free Auxins : Such are utilised in various metabolism.
   b) Bound Auxins : Such auxins are attached with enzyme and/ or antiauxins and therefore such are not utilised in the various metabolism. In Mango, there is no rooting even after the use of NAA. It means it is due to the presence of bound auxin.

Bound auxin means : Auxin + enzyme / Auxin + antiauxin } checks the activity of auxin.

10) Non-Indole auxin : Example is Phenyl acetic acid found in tomato.

11) **Polar transport of Auxin** : Auxin is known for polar transport:

a) Poar transport means the movement of auxins from the morphological apex towards the base of the plant.

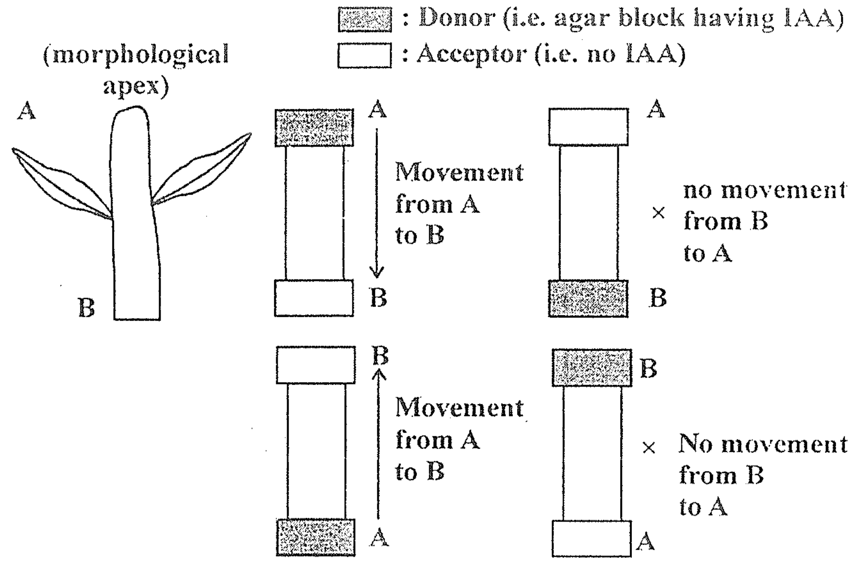

Fig. : Movement of auxin against the gradient.

b) Polar transport of IAA is strongly developed in monocot coleoptiles.

c) Polar transport is negated if anaerobic condition is maintained or treated with respiratory inhibitors. It means the movement of IAA is not polar and becomes free to move irrespective of morphological apex.

12) **Apical dominance of auxin** : The growth of the apical bud suppresses the growth of the lower axillary buds in many plants. It means the terminal (apical) bud dominants over the lateral buds by inhibiting their development. Such dominancy is called apical dominance. the development of lateral shoots or buds is inhibited by a substance which arises from the apex. When the tip of the main shoot is removed, the side shoots or buds start to develop. Thimann and Skoog (1934) found that the dominance of the terminal bud was due to the auxin.

13) Physiological Effects (Practical application) :

i) **Cell division** : Auxin is responsible for promoting cell division in certain tissues like cambium. The cambial activity and callus formation at the wounded site is stimulated by auxin. The formation of callus has practical use in grafting which strengthens the union of stock and scion. The cell division of tissue culture is entirely dependent on auxin.

ii) Cell Elongation : The primary physiological effect of auxin on growth of a plant is the elongation of cells. The cell elongation is activated by auxin in three ways:

a) by increasing osmotic solutes

b) by decreasing wall pressure

c) by increasing permeability of cytoplasm to water.

The avena curvature test was the bioassay for cell elongation test. But Auxin has **inhibitory** effect on **root elongation** due to the auxin-induced production of ethylene.

iii) Inhibition of Lateral buds : The sprouting of lateral buds i.e. eyes in potato tuber is checked by applying synthetic auxins. Therefore the dormancy period of tubers is increased by using IBA, NAA and MH. The opening of flower bud on fruit trees is also delayed by using synthetic auxins to avoid the damage caused by late frost.

iv) Shortening of Internodes : High concentration of α-NAA prevents, the elongation of inter nodes and the plant becomes dwarf.

v) Root Initiation : Due to the polar transport of auxin, rooting starts at the morphologically lower end. Thimann & Went (1930) found that the indole acetic acid and outer growth substances were essential for initiating adventitious root formation in cuttings. For commercial use α-IBA and NAA are markedly superior to IAA.

vi) Prevention of abscission layer : The formation of abscission layers at the bases of petiole, pedicel or peduncle results into the separation of leaves, flowers and fruits from the plant. The premature drop of fruits may be stopped by spraying 2, 4-D; IAA, NAA etc.

vii) Flower initiation : Auxin generally inhibits flowering and thus is helpful in delaying the flowering in lettuce.

viii) Production of Parthenocarpic fruits : Seedless fruits are being developed by horticulturists by spraying synthetic auxins.

ix) Weed control : The roots are extremely sensitive to auxins. Auxin distorts the roots, blocks the sieve tubes and disturbs the cell division of roots. 2, 4-D is used for weed control.

Gibberellins

1) The name 'gibberellin' was used by Yabuta and Sumiki (1938) for a pure crystalline chemical which was isolated from

'**Bakanae or Foolish seedling**' diseased **rice** plants. **Kurosawa** of Japan in 1926 confirmed that the disease was caused by a fungus '**Gibberella fujikoroi**' (Fusarium heterosporum). Due to this disease, rice plant grows abnormally thin and tall.

2) 6 gibberellins viz. GA_1, GA_2, GA_3, GA_4, GA7, & GA_9 were isolated from the fungus Gibberella by Cross et al (1961). 3 gibberellins viz. GA_5, GA_6 & GA_8 were isolated from bean seeds by Mac Millan et al (1961). Chemically gibberellins are known as **gibberellic acid.**

3) Most commonly available gibberellic acid is GA_3.

4) Gibberellins are common in higher plants but restricted to the only certain species of Fungi & bacteria. The conc. is higher in stem apex, young leaves and seeds.

5) Gibberellins are synthesised through the normal isoprenoid pathway of terpene biosynthesis.

6) Gibberellin promotes shoot growth by accelerating the cell elongation & cell division in the **sub-apical** meristem region which increases the length of **internodes**. Gibberellin regulates the mitotic activity of the sub apical meristem.

7) In certain cases it protects the apical meristem from the inhibitory effect of **dormin** (endogenous growth inhibitor)

8) Gibberellin induces the synthesis of hydrolytic enzymes especially **protease** and **α-amylase** which triggers **seed germination.** Gibberellin is released by the seed embryo and is transported the **aleurone** layer of endosperm where such enzymes are synthesized under its influence. This is the example of hormonal control of enzyme synthesis.

9) Gibberellin has **no effect** on root growth and the activity of apical meristem of stem apex.

10) Physiological effects :

   i) Stem Elongation : It increases the length of internodes. It speeds up RAN-synthesis.

   ii) It converts the dwarf plant into a plant of normal height. When 'Rosette' plant of sugarbeat (example of extreme dwarfism) is treated with gibberellins, it undergoes a rapid growth or bolting.

   iii) Substituting cold treatment : Many biennials complete their life cycle within a single year by treatment with GA.

iv) Partthenocarpic fruits : GA induces partheno carpic development of fruits in tomato, apple & pear more effectively than auxin.
v) Breaking dormancy : It is effective in breaking of dormancy in potato tubers and in tree buds in winter.
vi) It promots flowering in long day plants and induces maleness. GA introduces male flowers whereas Ethrel/Ethephon increases femaleness.
vii) It increases the size of leaves and fruits.
viii) It prevents senescence.
ix) It increases the cell division and cell size.

Cytokinin/Kinetin/Kinin

1) Jablonski and skoog (1954) reported that the cell division in the pitu cells was due to a substance present in vascular tissues. Miller et al (1956) showed that this substance was very effective in cell division. Such cell-division inducing substance is known as Kinetin and Letham (1963) used the term cytokinin (specific effect on cytokinesis) for kinetin like substances viz. Kinetenoid, Phytokinin, Phytocytomine.
2) Cytokinin is a derivative of the **purine** base **adenine** which has furfuryl substituent at the 9 position which changes to 6 position of the adenine ring during autoclaving of DNA.
3) At present it is clear that cytokinins are a part of t **RNA** (transfer RNA)
4) The chemical name of kinetin is N^6 furfuryl adenine or 6-furfurylamino purine.
5) Kinins promote cytokinesis in cells of various plant organs.
6) Kinetin alongwith auxin increases mitotic activity tremendously because division is promoted mainly by kinetin and auxin induces cell enlargement.
7) The endosperm of coconut (coconut milk) also contains endogenous (naturally occuring) cytokinin. **Zeatin** is endogenous cytokinin o Maize.
8) Physiological effects :
   i) It promotes cell division and the related DNA and RNA synthesis.
   ii) It has morphogenesis effect, that's why it is used for organ formation in a variety of tissue cultures.
   iii) It counteracts the apical dominance of auxin.
   iv) It is used in the breaking of dormancy. It also promotes the seed germination.
   v) It delays the phase of senescence. Senescence means the disappearance of chlorophyll and the degradation of protein. Richmond and Lang (1957) reported that the senescence was delayed in the detached xanthium leaves for several days when they were treated with kinetin. Such effect of Kinetin in retarding the senescence (ageing) is called **Richmond-Lang Effect.**

Abscisic Acid (ABA)

1) ABA is a common growth **Inhibitor.**
2) Robinson and P.F.Weiring (1963-64) extracted the inhibitory substance and called it '**dormin**' because it caused dormancy.
3) Okhuma et al (1963, 65) isolated the very active inhibitor from young cotton fruits and called it abscisin II. Abscisin I was isolated from the burrs of mature cotton fruits. Later on in 1967 it was realised that the dormin and abscisin II were the same and was named Abscisic acid (ABA).
4) Physiological Effects :
   i) It accelerates the senescence phase of growth.
   ii) It regulates the buds and seeds dormancy by inhibiting the growth processes.
   iii) It inhibits GA-induced α-amylase synthesis thus inhibiting germination of seeds.
   iv) It inhibits gibberllin - stimulated growth hence called **antigibberellin.**
   v) It causes abscission of leaves.
   vi) It inhibits RNA and Protein synthesis.
   vii) It causes the closure of stomata by interferring with the uptake of K^+ (Na^+) in guard cells.

Ethylene

1) Ethylene ($CH_2 = CH_2$) is a volatile gas which is included under Hormones in 1971.
2) It is synthesized in plant from the amino acid Methionine.

3) The most important effect is fruit **ripening (climacteric rise of respiration)**. The climacteric rise indicates the beginning of senescence and death.
4) Ethylene increase the cell permeability due of which the fruit becomes soft.
5) The inhibitory effect of auxin on root elongation and buds growth is due to auxin-induced production of ethylene.
6) High concentration of CO_2 i.e. 5-10% inhibits the effect of ethylene. Ag^+ is also the inhibitor of ethylene action.
7) According to D.N. Neljubow, ethylene caused triple response on Pea seedling :
   i) It inhibits stem elongation
   ii) It increased stem thickening.
   iii) It stimulated horizontal growth habit.
8) Ethrel/Ethephon : The chemical which releases ethylene.
9) **Physiological effects:**
   i) It induces climacteric rise and fruit ripening.
   ii) Induction of epinasty (leaf bending), leaf abscission and stem swelling.
   iii) Inhibition of stem and root growth.
   iv) Induction of flower petal discolouration.

Difference between Growth Inhibitor and Growth retardant

Growth Inhibitor	Growth Retardant
1) Such are the chemicals which inhibit or retard physiological or biochemical processes in plants.	1) Such chemicals retard cell-division and cell elongation in shoot tissues and thus regulate the plant height.
2) It causes malformation of leaves and stems.	2) There is no malformation.
3) It completly suppresses the plant growth.	3) Does not completely suppress.
4) It causes yellowing and abscission of leaves.	4) It intensifies the green colour of leaves.
5) It affects the vigour and rate of organ development.	5) There is no such effect.
6) Examples : i) **Malic Hydrazide (MH)** ii) ABA	6) Examples : i) Cycocel or CCC or chlormequat ii) Phosphon D iii) Amo-1618 etc.
7) It may be antigibberellin, antiauxin, antigermination	7) It is mainly antigibberellin.

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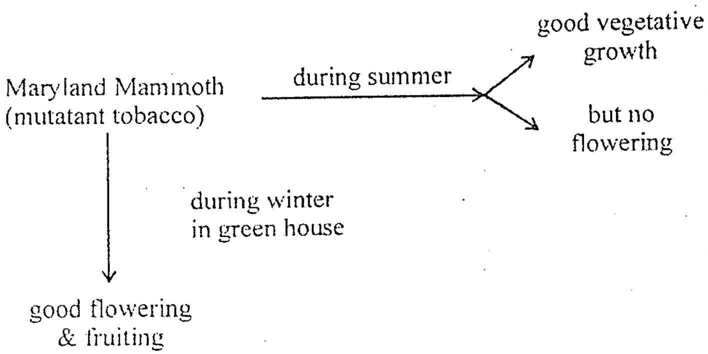
6. Photoperiodism and Vernalisation

The maturity of vegetative growth of the plant proceeds flower initiation. But the flower initiation of flowering depends on the environment specially light period (photo period) and temperature (vernalisation).

Photoperiodism

Photoperiodism is the physiological response of plants to relative length of light (day) and dark (night) periods. W.W. Garner and H.A. Allard (America, 1915-20) found that a newly developed ***tobacco mutant, Maryland Mammoth*** and Soybeans (*Glycine Max*) had strange seasonal pattern in flowering. Maryland Mammoth did not flower during summer but had good vegetative growth. When it was grown within a green-house during winter, it had excellent flowering and fruiting. Similarly soybean flowered only in the late summer irrespective of the sowing time in the previous spring.



The term 'photoperiodism' was coined by Garner and Allard (1920) to disignate the response of organisms to the relative length of the day and night and the 'photoperiod' to disignate the favourable length of day for

each plant. They classified the plants into three groups according to their photoperiods:

a) Short day plants : Such plants require to flower the day-length less than the certain critical day-length (for say 12 hours). Such plants are also called **Long night plants** because for its flowering a certain minimum uninterrupted dark period in 24 hours is necessary. If the dark period is less than a critical length, there will be no flowering. Short day plants will not flower if the dark period is interrupted by a flash of light during the continuous dark period but such light interruption is not very effective if it is given near the beginning or the end of the dark period. Such plants don't also flower if short dark and short light periods are provided alternatively. Examples of short day plants are **Maryland Mammoth tobacco, Soybean, Chrysanthemum Rice, Chenopodium album, Xanthium stumarium** (cocklebur), Generally Kharif crops and many tropical plants.

b) Long day Plants : Such plants which flower only when the day length is longer than a certain critical period. The ciritical length varies from 4 to over 18 hours. They require either a relatively small period of darkness or no darkness at all. A flash of light to long day plants during long dark period can induce flowering even during short day period. This is called **Night break**. Here, darkness has an inhibitory effect on flowering. The flowering in long-day plants is inhibited not because of the short light periods but because of too long dark period. That's why such plants are also called **short night plants**. e.g. Wheat, barley, oat, sugarbeet, spinach, lettuce, castor, generally rabi crops.

c) Day neutral plants : Such plants are unaffected by the day-length e.g. **Maize, tomato, sunflower, cotton**, cucumber, balsam etc.

Critical Period : It is the photoperiod required to induced flowering e.g. for M.M.tobacco, critical day period (CDP) is 12 hours and for xanthium it is 15.5 hours.

Photoperiodic Induction : In short day and long day plants, a continuous favourable photoperiod till blossoming is not essential but a few days' exposure to the appropriate photoperiod is enough to induce flowering. This photoperiodic influence persists even when a treated plant is kept in unfavourable photoperiods. This initial important effect on flowering is known as photoperiodic induction or photo-induction.

Flowering Stimulus : Cajlachjan (Cailakhyan) while working on chrysanthemum and perilla demonstrated that the photoperiodic stimulus was perceived by the leaves of a plant. Garner and Allard found that the stimulus was highly localised or systemic. Even if a single leaf of cocklebur was exposed to short days and the rest of the plant to long days, flowering was occured in the whole plant. It means that this stimulus is systemic.

Mature leaves are very sensitive to the photoperiodic stimulus while very young and old leaves are generally insensitive. Green colour of light spectrum is normally ineffective in inducing flowering whereas blue colour induces poor flowering. It is the red spectrum (wavelength of 580 nm to 680 nm) of light which is the most effective for inducing flowering in both short day and long day plants.

Cajlachjan (Chailakhyan) used the term **Florigen** for a flowering stimulus hormone. Formation of florigen is triggered by **phytochrome**.

Dr. S.M. Sircar (Bose Institute) induced flowering of a winter variety (Aman) of rice in 50 days against normal 140 days.

Vernalisation

In annual plants the flowering is primarily affected by the photo period but in biennials flowering requires prolonged periods of low temperature. The effect of temperature is secondary to light. Firstly G.Gassner of Germany (1918) reported the effect of temperature on reproductive development. 'Vernal' means spring.

The term 'Vernalisation' was coined by T.D. Lysenko (1920).

The Russian term 'Jarovizacija' means pre-sowing treatment.

Gassner demonstrated his experiment on winter Petkus rye (secale cereale cv. petkus). The low temperature requirement of winter petkus rye was given by chilling treatment. The imbibed seeds (water soaked were stored at 2-5°C for 5-6 weeks and then was sown in the spring season. Flowering was occured on the same schedule as on spring cultivar of petkus rye flowered.

Summary of Experiment :

$$\text{Winter Petkus rye} \xrightarrow{\text{Chilling treatment}} \text{Spring Petkus rye}$$

means winter variety is vernalised.

Cold treatment is quantitative or facultative (means low temp. results in faster flowering) but not qualitative or absolute (qualitative means flowering absolutely depends upon cold)

Vernalisation is the cold treatment to a plant bud or seedling in order to fulfil a specific low temperature rquirement for accelerating the flowering. In other words the acquisition or hastening of the ability to flower by chilling treatment is called vernalization or yarovization (Russian term)

Site of Vernalisation : growing point (apical buds)/early stages of germination/embryo undergoing rapid cell division/initiating metabolic process in shoot/meristematic zones.

It means that dividing cells are the site of vernalisation.

Cause : The growth substance formed by low temp. induction was named 'vernalin' by G.Melchers (1939).

According to Mikhail Chailakhyan (1968) there were two substances responsible for vernalisation :

i) Gibberellin or gibberellin like substances

ii) Anthesin.

Devernalization : Vernalization effect is reversible. If the vernalized seed or plant is kept at high temperature just after vernalisation, the effect of the low temp. treatment is compeletely removed. This process is called devernalisation.

$$\text{Vernalised seeds or plants} \xrightarrow[(\geq 30^{\circ}C)]{\text{High temp.}} \text{Normal or Original seeds/plants}$$

Factors of Devernalization :

a) High temp. } just after vernalization
b) Anaerobic condition }

Pratical benefits :

1) To induce earlier flowering and earlier maturity of crop.

2) To escape frost, drought and flood.

3) To extend cultivation to the region with very low temp.

with very low temperature (extensively used in Russia i.e. siberia where only 2 months are ice free for growing early crops.)

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7. Agricultural Entomology
An Introduction

1. INSECT–PEST : Pest is a Latin and French word meaning plague or infectious disease. Earlier the term 'pest' was used for devastating infectious disease. But today the 'pest' is defined as "such an insect or any other living being whose population increases to such an extent to cause economic losses to crops or a nuisance and health hazard to man and his livestock."

Criteria of to be pest : From the above definition we derive three criteria of pest –

(a) Insect or any other living organism
(b) Economic losses to crop or human health.
(c) A minimum population level i.e. Threshold level of population.

It means to control insect-pest below the threshold level of population has no significance. Therefore pest control measures are to be adopted at threshold level (or economic level) i.e. before the Economic Injury Level.

Threshold Level ⟶ Control ⟶ Economy Injury
Or (TL) Level
Economy Level (EIL)
(EL or ETL)

Economic Threshold Level (ETL or TL) : Economic Threshold (ET) is the density of the pest population which needs control measures. According to Stern et. al (1959) : ETL is the pest density at which control measures should be applied to prevent an increasing pest population from reaching the economic injury level (EIL).

Economic Injury Level (EIL) : Stern et. al (1959) defined it as the 'Lowest population density that will cause economic damage." Headley (1972) defined as the "pest population that produces incremental damage equal to the cost of preventing damage."

Conclusion : (1) All insects are not Pests.

(2) All pests are not insects.
(3) Pest may be insect, nematode, mite, fungus, bacterium, virus, rodent etc.

2. Entomology :

Entomo + Logos ⟶ Greek words
↓ Means ↓ Means
Insect discourse
↓ Means
Cut into (Section)

3. Phyllum : Arthropoda

Anthros + Podus ⟶ Greek words
↓ ↓
Segmented Leg

Class : Hexapoda : Body is divided into three parts viz. Head, Thorax and Abdomen. It has three (3) pairs (i.e. 6 legs) of legs. Wings are present. Examples are Insects, Bugs, Beetles Insects are 97% of total population of Arthropoda. Arthropoda having 94000 species is the largest group.

Class : Arachnida : Head and Thorax are fused and known as cephalothorax. Four (4) pairs (i.e. 8 legs) of walking legs are present and Legs are unsegmented. Abodoment is distinct. It has ***no*** antenna. Examples : Mites, Ticks, Ked spider.

4. Insects :

Insects are :

(a) Tracheate Arthrophods means having trachea for respiration.
(b) Head, Thorax and abdomen are distinctly present.

Insect = Head + Thorax + Abdomen
↓ ↓ ↓
Usually 6 segments **Fused** | 3 segment distinct | 11 segments distinct

Abdomen has main function of ***Respiration*** and ***Reproduction.***

(c) 3 Pairs of working legs are present on Thorax. It means Thorax has main function of Locomotion But one pair (2 only) of trachea also on thorax therefore it has minor function of respiration. Remaining trachea are on Abdomen.

(d) 1-2 pairs of wings are present.

(e) One pair of antennae present.

5. Ticks/Mites :

Acarina; no antenna; no wing; 4 pairs (8) of legs; Number of spiracles → 4 (maximum); Mouth parts → Piercing type; Head and thorax are fused and fixed. Killing substance of Acarina is called acaricide.

6. Metamorphosis :

Metamorphosis is the radial changes in morphology during development. It may be incomplete or complete.

(a) Incomplete/Direct/Gradual/Hemi-Metamorphosis : Here metamorphosis occurs in three stages :

Egg → Nymph → Adult

Here Egg is turned into nymph during the development but nymph is the smallest form of an adult; therefore such metamorphosis is called Direct metamorphosis. Such types of gradual metamorphosis are present in following orders:

(i) Orthoptera : e.g. Locust, Grasshopper, Cockroach

(ii) Thysanoptera : e.g. Thrips

(iii) Isoptera : e.g. Termites

(iv) Heteroptera : e.g. True bugs

(v) Homoptera : e.g. Aphids, Leaf hoppers.

(b) Complete/Complex/indirect/Holometamorphosis : Here radial changes in morphology occur in four phases i.e.

Egg ⟶ Larva ⟶ Pupa (Cocoon) ⟶ Adult

Examples of such complete metamorphosis are in :

(i) Coleoptera : e.g. Beetles, Weevils. This order is most damaging.

(ii) Lepidoptera : e.g. Moths, Butterflies, Silkworm

(iii) Diptera : e.g. Flies.

(iv) Hymenoptera : e.g. Sawflies, Bees, Ants, Wasps, (Mostly insects are used as Predators)

Some early order i.e. Protura & Thysanura of class Insecta have no any metamorphosis and are characterized as **Ametabola** e.g. Apterigola.

Types of Larvae : Larva is of 4 types :

(a) Nymph : e.g. Order-Hemiptera ; Bugs, Hoppers, Whiteflies, Aphids, Jassids.

(b) Caterpillar : e.g. Lepidoptera; Moth, Bollworm, Borer (Except lesser grain borer)

(c) Grub : e.g. Coleoptera and Mustard Sawfly (Hymenoptera)

(d) Maggot : e.g. Diptera [all flies except white fly and mustard Sawfly (MSF)]

7. Mouth Parts and its types :

Mouth parts of an insect :

(a) Maxilla : It cuts the food material i.e. cutting of Food.

(b) Mandible : It crushes the food material i.e. crushing of food.

(c) Labium : It acts like lower lip.

(d) Labrum : It acts like upper lip.

Labium and Labrum saves the food material from to come out from mouth.

(e) Hypopharynx : It works like Tongue. It mixes the crushed and cut food material.

Types of mouth parts :

(i) Piercing and sucking Type : e.g. Mosquito, aphids, bugs, Leafhoppers.

(ii) Sponging Type : e.g. Housefly.

(iii) Siphoning Type : e.g. Butterfly, Moth (simple sucking type)

(iv) Rasping and Lapping Type : e.g. Honey bee or chewing and lapping type)

According to agricultural purpose, there are two types of month parts of insect :

(a) Chewing/Biting and cutting type : Insects having such type of month parts are controlled by stomach poison. Such pests are generally called chewing pests. Examples are : Grasshoppers, Larvae (all), Locust, Cricket, Beetles & Weevils.

(b) **Piercing and sucking type :** It is also of two types viz. Bug type and (ii) Mosquito type. Such insects are controlled by systemic or contact poison and are generally called piercing and sucking pests. Examples : Bugs, Plant hoppers (except grass hopper), Aphids, Jassids, Thrips.

8. Damaging Stages :

Insect-pests have some damaging stages in its life cycle which cause losses to plants and trees :

Orders		Damaging stage
(a) Coleoptera	:	Larvae (grub) + Adult both stages
(b) Lepidoptera	:	Only Larvae (Caterpillar) Except Fruit sucking moth (FSM). Adult stage of Fruit sucking moth causes damage.
(c) Hemiptera	:	Nymph + Adult both stages
(d) Diptera :		Generally parasites
(e) Hymenoptera	:	Except Mustard Sawfly, all others are beneficial and used as biological control agents.

9. Bhopal Gas Tragedy :

This mishappening was occurred on 3rd Dec. 1984 in Union Carbide of India at Bhopal. This company manufactures Methyl Isocyanate which is used in the production of Carbaryl.

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8. Insecticides

The Chemical or poison used to kill the insect is known as Insecticide. To control the harmful effect of Insecticides on human and other living beings, a regulatory act was enacted on 2nd September 1968 by Govt. of India. This Insecticide Act regulates the use, production, sale, import, transportation and distribution of insecticides.

1. Mode of Action of Insecticides : Broadly four types of insecticides are characterized on the basis of the effect of insecticides :

(a) Systemic poison : Such type of chemicals or poisons are absorbed into plants and translocated to whole plant system internally. Such poisons are translocated and concentrated more in the aerial part of plant. Insect Pest starts dieing when it sucks the affected plant juice. This poison affects the metabolism of sucking insect pests. It means systemic insecticides are used to control sucking pests. Examples of systemic insecticides are : DRM^2 PACT^2

Where,

D → Dicrotophos
R → Rogor (Dimethoate)
M → Metasystox and Systox (Methyl demeton and demeton)
M → Monocrotophos (Nuvacron)
P → Phosphomidon (Dimecron)
A → Aldicarb (Temik)
C → Carbofuran (Furadan)
T → Thimet (Phorate)
T → Thionazin (Zinophos)

All the above systemic insecticides are either organo-phosphates or carbamates.

(b) Contact poison : The poison brings about death of the insect pest by means of contact, is called contact poison. When such chemical comes in contact with the pest, it penetrates into the body through the vulnerable sites, viz. sutures, trachea. Examples:

Malathion (Organophosphate), Monocrotophos (Organophosphate), Diazinon (Organophosphate), Thiodan (chlorinated), carbaryl (carbamate) Baygon (Carbamate)

(c) **Stomach poison** : Such chemical causes the death of insect only when the insect feeds on the treated plant. This poison acts on the digestive system of insect when ingested. Stomach poison is used mainly to control chewing type insects. Toxaphene is basically a stomach poison.

Cholorinated Insecticides are generally both stomach + contact poisons. Examples :

HECDAQ

Where,

H → Heptachlor
E → Endosulfan (Thiodan)
C → Chlordane
D → DDT
A → Aldrin
Q → Quinolphos (Organophosphate group)

(d) **Fumigant** : Such chemical enters in gaseous form through respiratory system (trachea) and kills the pest. It is used to control all types of insects irrespective of its feeding habits. E.g. Aluminium phosphide.

Table : Insecticides and their trade names

Insecticides	**Trade names**
Organochlorines	
Dicofol 18.5 EC (miticide)	Kelthane
Endosulfan 35EC	Thiodan
Organophosphates	
Acephate 75% SP	Asataf, Orthene and Starthene
Chlorpyrifos 20EC	Dursban
Dimethoate 30EC	Rogor
Dichlorvos 76EC	Nuvan, Vapona
Ethion 50EC	Fosmite

Fenitrothion 50EC	Sumithion
Monocrotophos 36SL	Nuvacron
Malathion 50EC	Cythion, Hilthion
Methyl parathion 50EC	Metacid
Oxydemeton-methyl 25EC	Metasystox
Phorate 10G	Thimet
Phosphamidon 40SL	Dimecron
Phosalone 35EC	Zolone
Profenophos 50EC	Curacron
Triazophos 40EC and 20EC	Hostathion
Quinalphos 25EC	Ekalux
Carbamates	
Aldicarb 10CG	Temik
Carbufuran 3G	Furadan
Carbaryl 75WP	Sevin
Methomyl 40SP	Lannate
Propoxur 1% Aerosol	Baygon
Thiodicarb 75WP	Larvin
Synthetic pyrethroids	
Betacyfluthrin 2.45 SC	Bulldock
Bifenthrin 10EC	Talstar
Cypermethrin 10EC & 25EC	Cymbush, Bilcyp
Deltamethrin	Decis 2.8EC, K-Obiol 2.5 WP
Etofenprox 10EC	Trebon
Fenpropathrin 10EC	Meothrin
Fenvaleratre 20EC and 0.4% DP	Parafen
Alphamethrin 10EC	Alphaguard
Fumigant	
Aluminium phosphide (Tablets or pellets)	Celphos
New insecticides group	
Neonicotinoids	
Imidacloprid As spray liquid	Confidor 17.8 SL

WP formulation (Seed treatment)	Gaucho 70WS
Thiamethoxam	
Wettable Powder	Cruiser 25WG
Spray liquid	Actara 70 WS
Acetmiprid 20 SP	Pride
Pyyrole insecticides	
Fipronil 5 SC	Regent
Avermectins	
Emamectin benzoate	Proclaim
Spinosyns	
Spinosad 45% SC and 2.5% SC	Tracer, Naturalyte
Chitin synthesis inhibitors	
Diflubenzuron 25WP	Dimilin
Biopesticides	
Bacillus thuringiensis (Liquid and WP formulations)	Dipel, Delfin, Halt, Spicturin, Biolep, Biobit
Verticillium lecanii	Vertilec
Beauveria bassiana	Larvocel, Boverin
Hirsutella thompsoni	Mycar
Metarrhizium anisopliae	Biomax
NPV	Elcar
Miscellaneous	
Cartap hydrochloride 4% Granules and 50SP	Padan, Caldan

[A] Inorganic Compounds :

(i) Paris green (double salt of copper arsenite and copper acetate) was firstly used as insecticide by about 1867 to control colorado potato beetle.

(ii) Lead arsenate was used first in 1832 by Moulton to control gypsy moth in Massachusetts.

(iii) Calcium arseinate was first used by about 1906 to control leaf eating insects.

(iv) Sodium fluoaluminate (sodium aluminium fluoride) was used first in 1929 by Marcovitch and Stanely to control

chewing insects.

(v) Lime sulphur was used first as a fungicide in 1852 by Grison and later in 1886 by Dusey to control San Jose Scale. Sulphur is primarily a fungicide and acaricide.

(vi) Borax (sodium tetraborate) is used to control fly maggot in manure pits and animal wounds infested by maggots.

(vii) Zinc phosphide (Zn_3P_2) is a well known rat poison. Zinc phosphide when ingested into the rodent's stomach, reacts with hydrochloric acid of stomach and releases phosphine gas which is extremely reactive and poisonous.

Other inorganics used as insecticides and pesticides are sodium fluoride, white arsenic, Barium carbonate, Thallium sulphate etc. Inorganics are stomach poison.

[B] Organic Compounds :

I. Hydrocarbon Oils : e.g. coal tar oil, mineral oil. Anthracnose oil is used for wood preservation. The phytotoxic nature of oils is due to presence of unstable unsaturated compounds. The mineral oils or the petroleum oils are derived from sedimentary rocks.

II. Animal origin compounds : The insecticide Nereistoxin is obtained from marine annelids *Lumbrineris* (Lumbriconeris) *heteropoda* and *L. brevicirra.*

III. Plant Origin Compounds/Botanical Compounds :

(i) **Nicotinoid/Nicotine** : It's main source is *Tobacco.* Nicotine shares 0.5 – 5.5% and 3.5 – 8.0% in the leaves of *Nicotiana tabacum* and *N. rustica* respectively. The scientific study of insecticidal property of Nicotine alkaloid present in tobacco leaves was made first time in 1828 by Passlet and Reimann. The structure of Nicotine was confirmed in 1893 – 1-3 (1-methyl – 2- Pyrrolidyl) pyridine. Nicotine is a contact and nerve poison which affects especially soft bodied insects. It's main effect is on aphids and thus prior to the use of synthetic insecticides it was known as *aphicide*. It has no phyto-toxic and residuary effect, that's why the sprayed crops may be harvested just after two days. But for the mammals, it is highly toxic. It is marketed in the name of Nicotine sulphate. Due to high volatization rate, it may be used as fumigation in the glass-house. Dust formulation of nicotine sulphate releases nicotine in the presence of moisture.

(ii) **Pyrethroids/Pyrethrins/Pyrethrum :** Source : White flowers of *Chrysanthemum cinerariefolium* (Guldaodi)

In the beginning of the 19th centuary (1800-1899) Jumtikoff of Armenia found that the tribals of the Caucasus (the area between the Caspian sea and black sea) were using the flower dust of chrysanthemum spp. Generally the mixed esters of pyrethrolone and Cinerolone are called pyrethroids/Pyrethrins in which 0.7 to 3% is chrysanthemic and Pyrethric acids. Since these esters can't be separated, therefore it is collectively called Pyrethrins. Pyrethrins are powerful contact insecticides which rapidly paralysed the housefly. This characteristic action is known as ***"knock down"*** effect. It is extremely unstable hence it is of little value for field crops. Pyrethrum is used with the solvent of DDT e.g. Flint. Here DDT acts like synergist which increases the action of pyrethrins. The equivalent synthesized compounds of pyrethrins are Allethrin, Cypermethrin, Dimethrin and Barthrin which are harmless to man.

(iii) **Rotenoids/Rotenone :**

Source : Roots of leguminous plants *Lonchocarpus* spp (South American plant) and *Derris eliptica* (Malaysia). Insects poisoned with rotenone show a steady decline in oxygen consumption followed by paralysis and death. It is well known contact fish poison. It was first used in 1848 against leaf eating caterpillars. However rotenone was first isolated in 1895 by Geoffrey. It is used as dust containing 0.75 – 1.5% rotenone and effective against beetle and caterpillars.

(iv) **Raynia/Ryanodine :** It is an alkaloid derived from ground roots and woody stems of south American shrub. *Ryania spaciosa* (family–Flacourtaceae). It is a stomach and contact poison and effective against Lepidopterous pests. It is a muscular poison and known for blocking the conversion of ADP to ATP in striated muscles. It is used as dust (20-40%).

(v) **Sabadilla :** It is an alkaloid derived from seeds of tropical lily *Schoenocaulon officinale* (Family : Liliaceae) found in South and Central America. The alkaloids mainly cevadine and veratridine are contact poison and used for the control of houseflies and domestic insects. It is harmful to pollinators honeybees.

(vi) **Margosa (Neem)/Azadirachta indica :** Kernels of the neem tree *(Azadirachta indica)* posses extraordinary gustatory repellant properties which are attributed to the active ingredients nimbidin-T, meliantriol and azadirachtin. The main a.i. azadirachtin is present in seeds and leaves and varies from 2-4 mg/g Kernel. Neem is known for various insecticidal properties e.g. antifeedant action, insect growth regulatory activity inhibits juvenile harmone synthesis, Oviposition deterrent, repellant action, reduction of life span of adults and intermediates. Insecticide vapacide is prepared from neem cake. The commercial neem insecticides available in market are based on neem seed kernel extract (NSKE). Some products are Gronim, Neemazal, Achook, Nimbecedine. Neem based products are sensitive to UV light i.e. it degrades when exposed to sunlight.

Some another botanicals are yet to be used on large scale :

(vii) Limonene and Linanool are citrus peal extracts which cause insect paralysis. They evaporates quickly in environment hence are used to control aphids, mites and fleas.

(viii) Garlic oil due to presence of diallyl disulfide and diallyl trisulfide shows larvicidal property and is fatal to larvae of mosquito *Culex pipiens quinquefasciatus*

(viii) Root diffusates of the crucifers *Brassica nigra* and *Sinapis alba* inhibit emergence of the golden cyst nematode of potato *(Globodera rostochiens)* due to the presence of isothiocyanates. Thiophenic compounds present in Tagetes sp. suppress the population of *Meloidogyne*, *Pratylenchus penetrans* etc. Root extracts of *Asparagus racemosus* inhibits hatching of eggs of *Meloidogyne javanica* and *M. arenaria.* Tannin and polyphenols found in aqueous extracts of raspberry roots and canes *(Rubus ideaus)* are poisonous to the nematode *Longidorus elongatus.*

IV. Synthetic Organic Compounds :

Such organic compounds may be broadly grouped into Organochlorines, organo-phosphorus compounds, Carbamates Dinitrophenols.

[A] Chlorinated Hydrocarbons :

(1) DDT : $C_{14}H_9Cl_5$

DDT → Dichloro Diphenyl Trichloroethane but chemical name of DDT is

p 2–bis (p-chlorophenyl) 1,1,1 – trichloroethane (old)

2,2–bis (p-chlorophenyl)–1,1 trichloroethane (new)

DDT is a mixture of two isomers viz pp'–DDT (>80%) and op'–DDT : DDT was first synthesized by Othmar ***Ziedler*** in 1874 but its insecticidal property was first discovered by **Paul Herman *Muller*** of Ciba Giegy Company in 1939. Muller obtained Swiss patent in 1942

for his discovery and awarded Nobel prize in Medicine in 1942. This Insecticide was used on the large scale first time during World War II in 1942 by the Allied Troops in Naples, Italy. It was discovered as first protective insecticide. It is a stomach and contact poison. It is one of the most apolar compounds and practically insoluble in water. pp' – DDT is more toxic than op' – DDT. DDT poisoned insects show tremors throughout the body and the appendages, characteristically called ***"DDT Jitters"***. Its use in agricultural sector has been withdrawn in India and permitted to be used only for mosquito control under public health programme as 50% WP or 75% WP.

DDT Analogs :

* Rhothane (trade name) is a contact & stomach poison.
* Methoxychlor is easily biodegradable and has faster knock down of houseflies.
* Dicofol (Kelthane) is effective as acaricide and used presently for control of mites. It is effective for all stages of mites, harmless of bees and possesses long residual effect. Its acaricidal properties were first discovered by J.S. Barker and F.B. Maugham in 1956.
* Acaricides like DMC (Dimite) and Chlorobenzilate are another DDT analogs.

3. BHC/HCH :

Benzene Hexachloride/666/Gammexane

Benzene Hexachloro Cyclohexane.

$C_6H_6Cl_6$: 1, 2, 3, 4, 5, 6 –hexachlorocyclohexane (i.e. HCH). The HCH compound was first synthesized in 1825 by Michael Faraday but its insecticidal properties were rediscovered between 1940-1942. HCH has 6-isomers but γ–isomer (Gamma-BHC) is highly active for insecticidal property. The composition of isomers in BHC :

(i)	alpha	(α)	–	55-70%
(ii)	Beta	(β)	–	5 – 14%
(iii)	Gamma	(γ)	–	10-18%
(iv)	Delta	(δ)	–	6% - 7%
(v)	Epsilon		–	3-4%
(vi)	Eta		–	in trace

A German chemist Van der Linden discovered four isomers of BHC in 1912. The toxic r-isomer was isolated by British group of scientists and named it *Lindane (Gammexane)* in honour of van der Linden. Toxicity of BHC is proportional to the toxic content of γ-isomer. The prepared product Lindanc contains *at least* i.e. a minimum of *99% γ-isomers*. It is a stomach and contact poison and has fumigant action.

Since Lindane dechlorinates in normal alkali candition, therefore it is not used in alkali soil. It should not be sprayed on vegetable, roots, tubercrops and fruits otherwise it may have harmful effect. Hovever it is not harmful for the crops but may damage the primary growth stage of cucurbits. There must be a gap of two weeks between harvesting and spraying on crops. It is used to control soil insects and ectoparasites and it has long residue in the soil.

3. Cyclodiene Insecticides : Such are highly chlorinated cyclic hydrocarbons having 'endomethylene bridged' structure. The toxicity of these insecticides is due to its high lipoid solubility such insecticides are :

3a. Chlordane : $C_{10}H_6Cl_3$ – Its insecticidal property was described firstly in 1945 by Kearns et al. It is a presitent (stomch + contact) poison and light fumigant. It is especially effective against soil insects and termites. It should not be used on leafy vegetables. It becomes non-poisonous due to alkaline dehydro-chlorination. That's why it is not kept in Zinc containers or galvanized containers. Its use in India is withdrawn.

3b. Heptachlor : $C_{10}H_5Cl_7$ – It was introduced in 1948. It is (contact + stomach) poison and has some fumigant property also. It is 4-5 times more effective than chlordane. It may be used for seed treatment and soil treatment. It has no residual effect. It has no harmful effect on leafy vegetables. Therefore it is used on agricultural and horticultural plants. It is generally compatible for all insecticides and fungicides. But now a days its use in India has been withdrawn.

3c. Aldrin : $C_{12}H_8Cl_6$: The insecticidal properties were firstly described by C.W. Kearns et. al. in 1949. It is named after the German chemist Kurt Alder who received the Nobel prize in chemistry in 1950 for his work on diene synthesis used in formulation of cyclodiene insecticides. It is a persistent stomach + contact poison which is used against soil insects. The epoxidised conversion of Aldrin into Dieldrin ($C_{12}H_8Cl_6O$) in soil is highly persistent but Aldrin itself is not persistent. Therefore it has limited use. In alkali soils Aldrin is used instead of r-BHC or lindane. It's use is also withdrawn in India. In India Dieldrin is

only used for locust control. Endrin is banned in India which is an isomer of Dieldrin.

3d. Endosufan (Thiodan) : $C_9H_6Cl_6O_3S$: It is an insecticide of Sulphite group. The insecticidal properties were firstly described by W. Finkenbrink in 1956. It is a contact + stomach insecticide and has slight fumigant action. It is practically soluble in water, persistent and non-volatile. It is used in the form of spray and its general formulation is 35% EC. Due to high toxicity, the sprayed crop may be harvested after at least six weeks gap. Due to its harmful effect, the state govt of Keral Banned it in July 2002.

[B] Organo-phosphorus compounds :

The insecticidal properties of Organo-phosphates were firstly discovered by Gerhard Schrader (chemist) in 1939. He found that some poisonous compounds were absorbed through the plant leaves or roots and were diffused into the whole parts and thus the plant escaped from the insect attack due to poisoned sap. The one such compound was Octamethyl Pyrophosphora mide (OMPA/Schradan). Schrader developed Tetraethyl pyrophosphate (TEPP) as a substitute for nicotine. The insecticide detoxified into the plant due to enzymes of plant.

Cholinesterase, an enzyme, is an essential constituent of the nervous system in both insects and higher animals. The Organo-phosphate phosphorylate the active site of this enzyme and such phosphorylated enzyme is an irreversible inhibitor which inhibits the normal process of quick removal and distruction of neurohormane acetylcholine (Ach) from nerve impulse resulting into the accumulation of acetylcholine and therefore the normal process of Nervous system is disrupted. Such Organophosphate as a nerve poison was firstly systhesized during the first world war.

Before the spraying of any systemic organophosphate one should verify the sufficient moisture into the soil. The deficiency of soil moisture causes the accumulation of active ingredient (a.i.) on the leaf margin which may result into margin burn or Necrosis. Most of the Chlorinated insecticides can be stored for a longer period but Organo-phosphate for the shorter period.

Organiophosphate has certain advantages such as rapid action against a wide spectrum of pests, low persistence, breakdown to form products non-toxic to man & animals, low dosages required per unit area, comparatively low mammalian toxicity and relatively thick metabolism in vertebrates and absence of accumulation in their bodies. Organo-phosphates are successful insecticides.

[B_1] Phosphomidon (Dimecron) :

It is a systemic insecticide since it is highly soluble in water, it is suitable for low volume and Ultra low volume spray (LVS/ULVS). In alkaline medium, its insecticidal property is reduced due to rapid hydrolysis. Therefore it is not sprayed along with such fungicides like Bordeaux Mixture, Lime Sulphur, Nicotine Sulphate and Copper Oxychloride. It was first synthesized in 1955 by E. Beriger of CIBA but its insecticidal properties were described in 1956 by F. Bachmann and J. Meierhans. It is used to control sucking pests, leaf miners, certain mites etc.

[B_2] Dichlorovos (DDVP/Nuvan) :

It is contact + Systemic poison and slow fumigant also. It brings about quick knock down effect. Its insecticidal properties were described. First in 1951 by CIBA. It does not leave any residue on plant and therefore it may be used on all crops until shortly before harvest. Soon after sprayed on leaves, it starts hydrolyzing into harmless dimethyl phosphoric acid and dichloroacetaldehyde which thereafter decomposes and evaporates. It is used to control household pests, lepidopterous larvae, sucking pests etc.

[B_3] Trichlorfon :

This product was prepared by W. Lorenz but was introduced by Bayer in 1952. It is a contact and stomach insecticide with some fumigant action. In an alkaline medium of above P^H–6, it is dehydrochlorinated and the principal product of this reaction is dichlorvos. In insects its toxic activity is attributed to metabolic conversion to dichlorvos. It is quick acting and effective against lepidopterous and dipterous pests and sucking insects. Registered formulation are 5% DP, 50% EC and 5% Gr.

[B_4] Phosdrin (Mevinphos) :

For a short period, it is a good insecticide to control sucking and chewing insects. But it is rapidly hydrolysed in alkaline medium.

[B_5] Monocrotophos (Nuvacron/Corophos) :

It is highly effective organophosphate insecticide which has systemic and contact action. It is *acaricide* also. It is effective against thrips, leafminers, chewing and sucking pests. It is harmless on the normal recommended dosage. It should not be mixed with the alkaline pesticides.

[B_6] Parathion (Thiophos) :

Its insecticidal properties were first described by Schrader in 1944. It is known for contact action whose effect is rapid. It may be used as nematicide. It is not suitable for alkaline medium.

[B_7] Methyl Parathion :

The toxicity of Methyl Parathion is comparatively very less to mammals but highly toxic to insects. Therefore its use is comparatively more. It is used to control a wide range of pest. Registered formulation is 2% DP and 50% EC.

[B_8] Malathion :

It was introduced in 1950. Its toxicity for mammals is very low e.g. acute oral LD_{50} for rat is 2800 mg/kg. It is corrosive to iron and on prolonged contact with it loses its insecticidal activity. It is incompatible with alkaline pesticides. It is a non-systemic and used to control a wide variety of pests especially in fruits, vegetables and stored grain pests and external parasites of livestock. It is harmless for almost all corps except ornamental plants. It's technical product is 95% pure.

Although its low mammalian toxicity, there should be a gap of at least 4 days between the spraying the crop and its harvesting.

[B_9] Diazinon :

It was introduced in 1952 but its insecticidal properties were described in 1953 by R. Gasser. It is a contact & stomach poison with fumigant action and penetrating effect. It has nematicidal effect also. It is used to control aphids, thrips, mites and houseflies. It controls soil insects successfully. It should not be mixed with Copper fungicides. It is harmless for crops but it may harm to tomato and cucumbers at low temp.

[B_{10}] Dimethoate (Rogor) :

It was described in 1956. It is a systemic and contact insecticide and acaricide. It is used to control a wide variety of sucking pests & lice infesting poultry. It loses its insecticidal properties in alkaline medium. The crop should be irrigated before spraying it. It is formulated as 30% EC.

[B_{11}] Thimet (Phorate) :

It is a systemic insecticide and mainly used for soil treatment to protect the crops at the sowing time. It has contact and fumigant action and to some extent nematicidal and acaricidal action also. It does not persist for a longer period. It is also effective against sorghum shootfly and rice gallfly. It is formulated as 10% a.i. granules. It protects the crop for 20-25 days.

[B_{12}] Metasystox (Methyl demeton) :

It is comparatively more effective than systox (Demeton). It is a systemic insecticide and effective against sucking pests. Its formulation is 25% EC.

[B_{13}] Chlorfenvinphos :

It's insecticidal properties were described in 1962 by W.F. Chamberlain et. al. It is contact insecticide effective against pests resistant to organochlorines. It is used to control root flies, cutworms etc. as a soil insecticide. @ 2 – 4 kg a.i./ha and on foliage stem borers, leaf hoppers, leaf beetles etc. It's registered formulation in India is 10% granules (Gr.)

[B_{14}] Chlorpyrifos :

Keraga et. al described its insecticidal properties in 1965. It is effective against sucking and chewing pests and household pests particularly in mosquito larval control @ 0.5 kg a.i./ha. It is rapidly detoxified in the animal body. Registered formulations are 20% EC, 10% Gr & 1.5% DP.

[B_{15}] Phosalone / Zolone :

It is a non-systematic contact insecticide and acaricide effective against a wide spectrum of pest spp., particularly of cotton. It is safe to bees and natural enemies of pest spp. Formulation is 4% dust & 35% EC.

[B_{16}] Quinalphos :

Its insecticidal properties were discovered in 1969 by Schmidt & Hammann. It is an insecticide and acaricide with contact and

stomach action. It is used to control sucking insects and lepidopterous larvae particularly of cotton and rice. Formulation is 25% EC, 5% granule & 1.5% dust.

[B_{17}] Triazophos :

It is a broad spectrum insecticide/acaricide with contact & stomach action and efective against lepidopterous larvae etc. on cotton, vegetables etc. Registered formalition are 20% EC & 40% EC.

[B_{18}] Propetamphos :

It is a contact & stomach insecticide with long residual activity. It is effective against household and public health pests especially cockroaches, flies, fleas, mosquitoes, clothes moth, ants and animals ectoparasites such as lice, ticks & mites. Registered formulations are 20% EC & 1% spray.

[C] 'S'– Containing Insecticides :

(a) Metasystox	(i) Diazinon
(b) Rogor (Dimethoate)	(j) Coumaphos
(c) Malathion	(k) Phorate
(d) Parathion (Thiophos)	(l) Endosulfan
(e) Methyl Parathion	(m) Chlorpyrifos
(f) Dimeton (systox)	(n) Phosalone
(g) Propetamphos	(o) Quinalphos
(h) Fenitrothion	(p) Triazophos

[D] Carbamate Insecticides :

Carbamate compounds are derivatives of Carbamic acid and dithiocarbamic acid. Organophosphates are highly effective against a wide spectrum of insect-pests due to their capacity for inhibiting cholinesterase in insect nerve tissue. In the same way some Carbamates (e.g. aryl esters of N-methyl carbamic acid) show insecticidal properties becoming competitive inhibitors of cholinesterase. The insecticidal properties of carbamates are attributed to their structural resemblance to acetylcholine and thus have a high affinity for the particular enzyme cholinesterase.

[D_1] Carbaryl (Sevin) :

H.L. Haynes et. al first time pointed out its insecticidal properties and was introduced in 1956. It is a contact insecticide with slight systemic action. It is comparatively safer for human and mammals than chlorinated and Organophosphates. It is effective against a wide spectrum of insects pests of crops particularly cotton but ineffective against mites. It should not be mixed with alkaline compounds. It is formulated as 5% or 10% dust, 4% granules & 50% WP or 85% SP or 40% LV

Sevidol (granules) = 4% Carbaryl + 4% r-HCH used to control rice pests

Sevimol 40LV = 40% Carbaryl + Molasses.

[D_2] Carbofuran (Furadan) :

It is an systemic insecticide and nematicide effective against sucking and soil inhabiting pests. It is used to control sorghum shootfly. It is unstable in alkaline medium, Its application stimulates growth in cotton, rice, tobacco, sorghum and corn. It is formulated as 50% SP and 3% granule.

[D_3] Carbosulfan :

It is effective against a broad spectrum of pest species on various crops. It is metabolized in plants to carbofuran and 3-hydroxycarbofuran.

[D_4] Aldicarb (Temik) :

It is a systemic insecticide, acaricide and nematicide and highly poisonous for mammal. Its insecticidal properties were described by M.H.J. Weiden et. al. and was introduced in 1965.

[D_5] Methomyl :

It is effective against sucking insects and mites and lepidopterous larvae especially cabbage looper and diamond back moth. It also controls nematodes.

[E] Synthetic Pyrethroids :

The First synthetic analogue of pyrethrum was Allethrin which was firstly developed by Green & La Forge in 1949. Since then so many synthetic pyrethroids have been developed.

[E_1] Allethrin :

It is known for quick knock down effect on flies and mosquitoes when applied with synergists like piperonyl bitoxide.

[E_2] Cypermethrin :

It was discovered by M. Eliott et. al in 1975. It is a stomach and contact insecticide effective against various lepidopterous larvae particularly boll worms & leaf eating caterpillars of cotton. Formulations are 10% EC & 25% EC.

[E_3] Etofenprox :

It is non-ester pyrethroid introduced in 1987. It is a contact stomach insecticide. It is effective against Rice leaf hoppers and brown plant hopper (BPH). It is also effective against cockroaches and houseflies. Its Formulation is 10% EC.

[F] Acaricides :

Such chemical controls or kills the acarina (mites) is called acaricide. Aramite is the ideal acaricide which controls mites. It is harmless for predators, human and animals. DINOCAP is an another acaricide and contact fungicide and was firstly introduced in 1946 by Rohm and Hass company. Trade name of DINOCAP is ***Karathane***. The registered formulation of DINOCAP is 48% EC. Other acaricides are : Azobenzene, Dicofol, chlorobenzilate, Chlorafenson, Fenson, Tetradifon, chlorben, side, abamectin, Flufeboxuron.

General dose :

Systemic Pesticides @ 0.02 – 0.05% a.i. for spray.

Contact pesticides @ 0.05 – 0.07% or even 1.0% a.i. for spray.

Granular systemic insecticides @1-2 kg a.i./ha for soil application.

Fungicides @ upto 2 g/l depending upon chemical used, pest species and season of application.

4. Fumigants :

Fumigants are such pesticides which have the capacity to kill the particular pest by converting into gaseous state at the required temp. and pressure. It is also called gaseous poison. Such gas enters into the larvae, pupae and adults of insects through spiracles and the eggs through the chorion during respiration and thus brings about death. Fumigant may kill all types of insects because it has no significance of mouth parts and feeding habit of insects. Such fumigant which vapourizes readily at the room temp. is the most useful. The essential feature of soil fumigant is that the released vapour must be slowly.

Fumigation is required to kill or control a great variety of pests of stored products, household articles, soil inhabiting insects & nematodes as well as for a quarantine measures at the time of export-import. The following prevalent fumigants are :

(i) HCN (Hydro-cyanic acid or Hydrogen Cyanide) : It is most extensively used fumigant and was firstly used to control cottony cushion scale *Icerya perchasi* in 1886 by D.W. Coquillett. HCN is obtained from treating the sodium with sulphuric acid.

(ii) Bromo-methane/Methyl bromide. It is 1.5 times heavier gas than air, therefore its penetration power is remarkable. In 1932, its insecticidal properties were described by Le Goupil. It is used to control soil insects, nematodes, soil weeds and fungi and rodents.

(iii) Chloropicrin (Trichloro-nitromethane): It is a tear gas. Its use is not registered in India.

(iv) Ethylene dibromide (EDB): Its insecticidal properties were described by Neifert et. al. in 1925. It is used for fumigating fresh fruits and vegetables to control fruitfly larvae because it does not affect plant materials. It is also used to control nematodes (except cyst nematodes *Heterodera* spp. and soil fungi).

(v) Phosphine (PH_3) / Hydrogen phosphide : It is widely used in fumigating grains, flour and cereals in godowns. PH_3 is liberated from Aluminium phosphide in presence of moisture :

$$AlP + 3H_2O \rightarrow \mathbf{PH_3}\uparrow + Al(OH)_3$$

But it is available in the market in the pellet forms. The combination of pellet is 55% Aluminum phosphide, 40% ammonium carbamate and 5% aluminium oxide. PH_3 is highly toxic to all stages of insects and rats. The pellet containing ammonium carbamate releases CO_2 and ammonia (NH_3) which prevent spontaneous ignition of phosphine gas. And the final product formed is aluminium hydroxide which is harmless. A pellet (Tablet) weighing about 3 kg liberates 1 kg PH_3 approximately. **Celphos** is the such tablet.

Other fumigants are Nicotine, carbon disulphide (CS_2) Dichloropropene, vapam, Napthalene etc.

[5] Rodenticides :

Generally two types of poison are used to kill rats/rodents:

(a) **Acute Poison** : It includes

(i) Antu
(ii) Barium Carbonate
(iii) Zinc Phosphide
(iv) Thallium Sulphate
(v) Arsenic Compound

Pre-baiting is required for all the poisons.

(b) **Chronic/Multidose Poison** : Such poisons are anticoagulant. which are derivatives of hydroxy-coumarin. Anticoagulant is the name of that compound which prevents the blood clotting. The prevalent examples are-warfarin (tomorin/Coumachlor), Diphacinone, Coumafuryl, Coumatetralyl, Bromadiolone.

To control the mole rats (which live in the burrow), Aluminium phosphide ($PH_3\uparrow$) is used.

(6) The maximum use of pesticides in India is on cotton (more than 50% of the total pesticides used) 2nd on cereals and 3rd on Fruits & vegetables. The Insecticide accounts for 80% of the total pesticides.

(7) The enzymes present in the plant is responsible for the detoxification of pesticides in the plant body.

[8] Generations of Insecticides :

(i) First generation of Insecticides : The majority of the Insecticide used before the second World War were Inorganics and a few were Plant's origin. But the discovery of DDT in 1939 revolutionized the concept of chemical method of Insect control. Just after this discovery r-isomer of BHC was discovered. Schrader described the Organophosphates and thus the initial stage of the use of Chlorinated and Organophosphates is known as Ist generation of Insecticides.

(ii) 2nd generation of insectivides : After the Ist generation of insecticides those insecticides have been used which have less toxicity and more selective effect on target organism. This generation is known for modern synthetic insecticides. India is now crossing the 2nd generation.

(iii) 3rd generation of Insecticides: The era of target specific and non-toxic insecticides e.g. the use of Juvenile hormone, repellents, sex attractants etc. is called 3rd generation. such insecticides are used in vogue in developed countries but also gaining momentum in our country.

(iv) Fourth generation of Insecticides : The use of anti-hormonal (precocene) insecticides is called fourth generation e.g. U.S.A.

[9] Insecticide Additives :

Only a small quantity of the poison or toxicant is required to control the pest. Such a small quantity is difficult to apply in an effective manner. Therefore the toxicant is required to be formulated. The volume of the toxicant is increased by adding inert materials to the pure and technical form of Poison. The inert material is called Additive and the process to get mixture by adding inert materials to the pure and technical form is known as Formulation. The common formulations are :

(i) Dust Additives :

Toxicant + Carriers/Extenders/Diluents/Vehicles. Particle's size is the determing factor to choose the carrier.

Dust Carrier :

(a) Organic Compounds e.g. Flour of Walnut, Soybean, Shell, & Woodbark.

(b) Inorganic compounds e.g. Pulverized mineral (sulphur, diatomite (Silicon oxide) tripolite, lime, gypsum, talc, pyrophyllito) or clay (attapulgite, benetonites, kaolins, volcanic ash).

(ii) Spray Addititives :

(a) Solvent : Kerosene Oil, diesel of petroleum, xylene etc. are used as solvents.

(b) Wetting agents : It is required to convert a water insoluble toxicant into a soluble or partly soluble one.

(c) Emulsifier : It is required to prevent a solvent dissolved toxicant from precipitating out. e.g. sodium oleate, amines, sodium lauryl sulphate etc.

Commercially many pesticides are sold in the market as an Emulsifiable concentrate (EC).

EC = toxicant + solvent + Emulsifier + Water

+ water means the recommended amount of water which is required to add at the time of use.

(d) Spreader/Deflocculator : Such additives are required to improve wetting through spreading property e.g. Calcium caseinate, Soybean flour, sulphated alcohols or sulphonated compounds etc.

(e) Sticker : It prevents the pesticide from washing off by rain or dew e.g. gelatin, resin, glue, starch, vegetable oil etc.

(f) Stabiliser : Such additives are required to retard rapid decomposition of unstable organic pesticides e.g. isopropyl cresols, hexamethylene tetramine & epichlorohydrin prevent the decomposition of pyrethrins, endrin and aldrin respectively.

(g) Softener : It reduces the phytotoxicity of pesticide e.g. sulphur, zinc sulphate, lime casein etc.

(h) Masker or Deodorant : It suppresses (masks) the unpleasant odours when used for household purposes e.g. cedar oil, pine oil, scents etc.

10. Types of Formulation :

[A] Solid Formulation :

(i) Dust : Such mixture which is obtained by mixing toxicant with the dust carrier, is called dust. Dust is the general term of the particle having the size less than 100 micron (u).

Finished Product	=	toxicant	+	carrier
		0.1 – 25%		99.9 – 75%

The amount of toxicant ranges from 0.1% to 25% and the rests in the dust formulation are carriers.

Lesser the particle size, higher the toxicity. Particle size of the Dust formulation 1 – 40μ

(ii) Granules :

Toxicant : 2 – 10%
Particle size : 0.25 – 2.5 mm diameter
but usually 250μ – 1250μ
i.e. 0.25 mm – 1.25 mm

Those having particle size 100μ - 300μ are called microgranules and those above 300μ are known as granules.

Micrograpnules : 100μ – 300μ
Granules : > 300μ

(iii) Insecticide – Fertilizer mixture is also prepared to control the soil insect.

[B] Liquid Formulation/Spray :

(i) Concentrate liquid or Undilated liquid: The Highly concentrated liquid of technical grade of the toxicant is dissolved in non-volatile and non-phytotoxic solvents. To enable solution and drop formation a volatile solvent is also added but emulsifier is not added.

The concentrate liquid formulations of Malathion & Fenitrothion are used in ultra-low-volume (ULV) quantities.

(ii) Solutions : Such pesticides are formulated in a single liquid phase either in water or in an oil.

In water : Monocrotophos, Organophosphates

In Oil : Flint type domestic spray.

(iii) Emulsifiable concentrate (EC) : Such formulation contains the toxicant, a solvent. For the toxicant and an emulsifying agent i.e. emulsifier

E.C. = toxicant + solvent + Emulsifier

It may be of two types

(a) Oil in water type (b) Water in oil types

Reasons to add emulsifier are :

(a) To dilute water insoluble chemical (with water).

(b) To spread and wet the treated surface by reducing the surface tension of the spray.

(c) To stablize the emulsion.

(d) A better contact is possible with insect cuticle.

(iv) Suspension : In such formulations, active materials are suspended as solid particles in water.

Such formulation is required when an active ingredient is insoluble in either water or organic solvents. Such formulation is called suspension or **Flowable.**

(v) Foam : Foam producing nozzle converts the pesticide spray into foam.

(vi) Mist : Very small droplets are called mist.

Droplet size : 50 – 150μ (micron)

[1μ = 10^{-6}μ]

Droplet size means the median diameter of the droplet.

(vii) Fog : Its droplet size is more lesser than mist.

Droplet size : 1 – 50μ

[Particle size of smoke : 0.001 – 0.1μ]

(viii) Aerosols : When minute droplets or particles are suspended in the air like mist or fog, are called aerosols i.e. aerial solution.

Droplet or particle size : 0.1 – 50μ

A more popular form of aerosol formulation is ***aerosol bomb*** which is used in household or camps to kill mosquitoes.

(ix) Water Dispersible Powder/Weltable Powder : (WDP/WP) : W.P. is the powder formulation which yields rather stable suspension when diluted with water. Water insoluble toxicant is mixed with carrier. Carrier is partly soluble in water and is capable of making a fine suspension in water and thus such mixture is called WDP. The active ingredient in W.P./WDP ranges 15-95% but commonly a.i. is 25-50%.

The concentration of toxicant is comparatively more than that of Dust.

(x) Water Soluble Powder (WSP/SP) : WSP is a powder formulation readily soluble in water. It usually contains a high conc. of active ingredient and therefore easy to store and transport. e.g. Carbaryl 85 SP and Acephate 75 SP.

[C] Gaseous Formulation :

It is also called fumigants.

Particle size of smoke, 0.001 – 0.1μ.

[II] Classification of Spray Volumes :

(a) High Volume Spray (HVS) : Here spray liquid is used more than 400 l/ha.

⇒ 400 l/ha of spray liquid used

(b) Low volume Spray (LVS) : 5 – 400l/ha of spray liquid.

For aerial dose : 15 – 75 l/ha

Ground dose : 100 – 200 l/ha

(C) Ultra-low volume spray (ULV) or Low volume concentration spray (LVC) :

ULV/LVC : < 5 l/ha of spray liquid used.

Here quantity of formulation is less than 5 l/ha and more concentrated formulation is used without diluting with water. To compensate the low (Small) volume, it is required to break down the concentrate into extremely fine particles. In India ULV is sprayed by the aircraft e.g. Malathion conc. (95% a.i.). In our country, due to lack of proper equipments, the ULV spray is generally used in aerial spray. Aerial spraying is done by both by *fixed-wing aircrafts* and *helicopters*. For ground spraying, Aspee's modified mist blower and Knapsack are used.

12. Calculations Regarding Formulation :

Question 1. The quantity of endosulfan 35% EC required for treating an area which needs 1000 litres of spray fluid at 0.05% (a.i.) strength is

(a) $35 \times 0.05/1000$ litres (b) $2.5 \times 1000/1000$ litres
(c) $1000 \times 0.05/35$ litres (d) $35 \times 1000/0.05$ litres

Solution :

By the formula :

$$\text{Amount of insecticide required (kg)} = \frac{\text{Total spray required (l)} \times \text{Percent Strenght required}}{\text{Given percent strenght}}$$

Therefore, $\frac{1000 \times 0.05}{35}$ litres Ans – c

Q.2. Spraying of one hectare of cotton crop is done using 500 litres of spray fluid prepared from 2 kg of Carbaryl 50% water dispersible powder. The concentration of active ingredient of Carbaryl in the spray fluid is

(a) 1% (b) 0.2 %
(c) 0.1% (d) 0.5%

Solvn.

Here,
Total spray liquid = 500 l
% strength required = ?
Amount of insecticide required = 2 kg
Given percent strength = 50%

By the Formula :

$$\text{Amount of insecticide required (kg)} = \frac{\text{Total spray required (l)} \times \text{Percent Strenght required}}{\text{Given percent strenght}}$$

$$\Rightarrow \quad 2 = \frac{500 \times \% \text{ Strenght required}}{50}$$

$$\% \text{ Strenght requried} = \frac{50 \times 2}{500} = 0.2\%$$

Ans. – b

Q.3. The quantity of liquid insecticide with 25% active ingredient required for preparing 500 litres of the spray fluid of 0.25% strength is

(a) 1.25 litre (b) 2.5 litre
(c) 5.0 litre (d) 10 litre

Solution :

Here,

Amount of insecticide = ?
Required % strength = 0.25%
Required total spray = 500 l
Given % strength = 25% a.i.

By the formula:

$$\text{Amount of insecticide required (kg)} = \frac{500 \times 0.25}{25} = 5 \text{ l}$$

Ans – c

Q.4. What is the amount of Bavistin 50W required to be added to 1000 litres of water to make a spray mixture of 0.05% a.i. concentration ?

(a) 0.5 Kg (b) 1.0 Kg
(c) 1.5 Kg (d) 2.0 kg

Soln. Amount = $\frac{1000 \times 0.05}{50}$ kg = 1.0 kg

Ans. – b

Q.5. What is the concentration of active ingredient in the spray liquid when one gram of pesticide formulation having 50% active ingredient is mixed with one litre of water ?

(a)0.5 ppm (b) 5.0 ppm
(c) 50 ppm (d) 500 ppm

Soln. Here,

Required total spray liquid = 1 *l* (one litre)
Required strength percent = ? (to find out)
Given strength percent = 50% a.i.

Total amount of Pesticide = 1g = $\frac{1}{1000}$ kg .

From the formula :

$$\text{Total amount of pesticide (kg)} = \frac{\text{Required total spray liquid (l)} \times \text{Required Strength percent}}{\text{Given strength percent}}$$

$$\Rightarrow \frac{1}{1000} = \frac{1 \times \text{required \% strength}}{50}$$

$$\Rightarrow \text{Required \% strength} = \frac{50}{1000} = 0.05\%$$

ppm means parts per Million (10^6)

Here required % Strength = 0.05%

$\Rightarrow$ 0.05% means in 100 there is 0.05

$$\because \quad \text{in } 10^6 — \frac{0.05}{100} \times 10^6$$

$$= 0.05 \times 10^4$$

$$= 500$$

It means 500 parts per million

$\Rightarrow$ 500 ppm

Ans.– d

❋❋❋

9. Plant Protection Equipments

Diluents are of three types viz. solid, liquid and gas. Accordingly respective application methods of pesticides are called dusting, spraying and fumigation and the equipments used in such application is named duster for dusting, sprayer for spraying and fumigator for fumigation.

Dusters

Introduction :

(i) It consists essentially of a ***Fan*** or ***Blower*** or ***Bellow Venturi*** and a type of container named ***Hopper***.

(ii) Bellow/Fan/Venturi is required to produce desired air current.

(iii) To produce air blasts is the basic principle of duster.

(iv) Duster is much lighter than sprayer.

(v) It is said that the efficiency of dusting is ten times more than that of spraying but the average job of spray is equivalent to very good dusting.

(vi) The function of *nozzle* which is attached at the end of delivery tube is :

(a) To atomise (to break) the formulation into proper sized particles (or droplets) i.e. atomization of the particles.

(b) To provide proper shape to the outgoing formulation

(vii) How does duster work? – Dust particles are kept agitated and in motion in the hopper and then are fed into the air current to discharge the particles into fine dusts. And thus the fine dusts are dispersed both horizontally and laterally over a large area in cloud-form.

[A] Hand-operated duster or Hand Duster :

Such hand dusters are package duster, plunger duster, Bellow duster, Rotary hand duster, Traction duster.

(1) Package/container duster : It is of very primitive type duster. It consists of a container and which, when is squeezed with fingers, dust is discharged with the small air stream. On squeezing the package or container, dusting is done. It is used at small scale in the kitchen garden and house. e.g. BHC dusting through muslin or fine cloth to kill bed bugs.

(2) **Plunger (Piston) duster/Hand Pumps :** It is operated by a plunger pump and dust is discharged through the outlet by the compression stroke of plunger pump. It is small and easy to operate. It is very cheap also. The double action plunger pump enables a continuous dusting operation. Upward movement of handle enables the dust to enter into the pump from the container and pushing of the handle i.e. downward movement enables the dust to discharge through nozzle. It is used at small scale in the kitchen gardens and houses. Since it is also used in fumigating the rodent burrows with calcium cyanide (Cyanogas) or sodium cyanide (Cyanomag), therefore it is known as ***Cyanogas pump*** or ***Foot pump duster***.

(3) **Bellow Duster :** It is operated through the expansion and contraction of a pair of bellows during which process the dust is sucked in and then thrown out into the delivery system. Dust is discharged by the air current produced by the movement of bellows. It is used in kitchen garden and domestic pest control.

(4) **Rotary hand (Crank) duster :**

(i) Air current is produced by ***Fan*** (blower).
(ii) Fan is driven by rotary motion of a handle through a reduction gear.
(iii) Here delivery of dust is direct from the fan.
(iv) Spoon type or fain tailed nozzles are effective.
(v) Feeding mechanism of dust is carried by a rotating brush inside i.e. ***Feeding brush.***
(vi) Discharge rate : 0.5 – 150g/minute at 35 rpm. (rpm = revolutions per minute)
(vii) Such duster is of two types viz. shoulder type and belly type. The use of Belly type is more comfortable.
(viii) It is quite popular for use in different crops and in different situations for treating small acreage and row crops like potatoes, tobacco, cotton etc.
(ix) It's hopper contains 5 kg material.

(5) **Traction duster :** Such duster is mounted on wheels and the blower fan is connected to the wheel. The traction (to push up) of duster runs the fan. It's use is for large scale dusting.

[B] Power (operated) dusters :

(i) Here power operated motors are used to run both the agitator inside the hopper and the blower (fan). Blower produces the air-blast.

(ii) Normally 1-3 hp (horse power) aircooled engines are used.
(iii) Hopper capacity is usually 10-20 kg.
(iv) Discharge rate : 1-9 kg/minute
And an outlet coverage area in one hour is 12ha.
(v) The dust flow can be regulated from 0-1.5 kg per minute by adjustment of multi-hole discs.
(vi) Such dusters are large sized duster with hopper capacity of 500 – 1000 kg and is operated by more powerful engines (upto 25 hp.)

Sprayer

Introduction :

(i) Sprayers are the most commonly used in the pesticide application.
(ii) Three types of formulations are used in
(a) aquous solution in case of soluble toxicant
(b) suspension of particles in case of insoluble material.
(c) Emulsion in case of insoluble material.
(iii) Both Wettable powder (WP) and water dispersible powder (WDP) are suitable for high volume spraying and are not suitable for low volume spraying.
(iv) In sprayer, container is called 'Tank' but in duster it is called 'Hopper'.

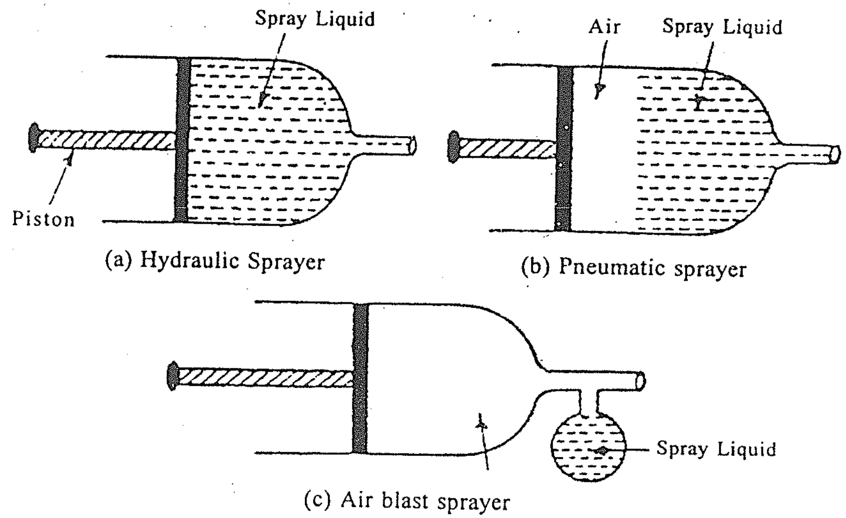

Fig. Showing the principles of Sprayer

(v) Sprayer : How to function? There are three main principles :

(a) To discharge the spray liquid it is directly pressed through a plunger or piston, such sprayers are called ***Hydraulic Sprayers.***

(b) To discharge the spray liquid, a layer of air is compressed through a plunger which in turn presses the spray liquid; such sprayers are called ***compression*** or ***Compressed Air*** or ***Pneumatic Sprayers.***

(c) To discharge the spray liquid, an air blast is produced through a plunger or a blower (fan) which atomises the spray liquid and carries it along to the target. Such sprayers are called ***air blast sprayers or blowers.***

(vi) Following essential parts are present in sprayers :

(a) Tank	(b) Pump
(c) Nozzle	(d) Agitator
(e) Pressure chamber	(f) Pressure guage
(g) Hose	(h) Spray lance.

(vii) Pump : It is used for atomization of the liquid through air. There are two basis for the pump selection:

(a) nature of the spray liquid.

(b) Pressure of discharge of the liquid through nozzle.

Types of Pump :

(a) **Air/Pneumatic pump :** It is mostly used in hand compression or pneumatic sprayers. It is used to force air into the airtight tank upto a certain pressure. It is really a force pump.

(b) **Plunger or Piston Pump:** It is used in power operated sprayer and generates high pressure upto 70 kg/cm^2. It is suitable for high volume spraying.

(c) **Rotary Pump :** It is of two types viz gear type and Roller vane type. Gear type rotary pump is used for low volume spraying and generates a pressure upto 4.2 kg/cm^2 whereas Roller vane type generates a pressure upto 8.4 kg/cm^2. Majority of the medium output sprayers are fitted with roller vane type rotary pump.

(d) **Diaphragm Pump :** It works on the same principle as the plunger pump works.

(e) **Centrifugal or Impeller Type Pump:** It generates pressure upto 7 kg/cm^2 and is not suitable for high pressure sprayers.

(f) Positive displacement pump.

(viii) Nozzles : Such device is used to break up the liquid coming out of the spray tank into fine droplets.

Function of nozzle :

(i) *atomization* of the spray liquid into proper sized droplets.

(ii) To impart desired *shape and angle* to the outgoing spray.

(iii) To regulate the *discharge* of the spray liquid per unit time at a known pressure.

Types of nozzle :

(a) **Gaseous energy nozzle :** Such nozzle consists of an orifice across which air is blown up at high speed to break up the liquid into fine (small) droplets. The drop size is dependent on the air velocity.

(b) Centrifugal energy nozzle : Fine mist forms of droplets are obtained from such nozzle which is used in ***ultra low volume spraying*** and ***aircraft spraying.***

(c) Kinetic energy nozzle : Such nozzle consists of an oscillating tube having holes. The spray liquid is come out by gravity. It is suitable for ***herbicide*** application.

(d) Thermal Energy nozzle : Such type of nozzle is used for getting ***fogs.***

(e) Hydraulic nozzle : It is of two types :

(f) (i) Fan/Flat cone type : It has V-shaped orifice.

(ii) Cone/Swirl type : It has central aperture and swirling motion is given to the spray liquid in the chamber before emitting of spray. Higher the pressure, smaller the droplet's size. For getting better atomization and more efficiency, Cane nozzle is used but it is costly. It is used to spray on bushes and crop plants.

(ix) Effective droplet size :

(i) For Sprays : 100 – 400μ VMD

where μ = micron = 10^{-6}m

VMD : Volume Median Diameter

(a) For spraying Lawns : 400 – 500 μ
(b) For space spraying : 30 – 80 μ
(c) Droplet size of Mist (Kuhasa) : 50 – 150 μ
(d) Droplet size of Fog (Kuhara) : 1 – 50 μ
(e) Size of smoke particles : 0.001 – 0.1 μ
(f) Size of Dust particles 1 – 40 μ
(g) Size of granules : 0.25 – 2.4 mm (Millimeter)

(x) Classification of Spray Volumes :

(1) High Volume Spray : More than 400 litre/ha of spray liquid used i.e. > 400 l/ha of spray liquid.

(2) Low volume Spray : 5 – 400 l/ha
Normal aerial doze : 15 - 75 l/ha
Normal ground doze : 100 – 200 l/ha

(3) Ultra-low volume (ULV) or Low Volume concentration (LVC) Spray : Less than 5 litre/ha
i.e. < 5 l/ha

(xi) In case of the spraying, the size of droplets less than 30 μ is more effective but the lightness of the droplets causes the drifting problem and the spray may not reach the target.

Hand Operated Sprayers :

[A] Hydraulic (Energy) Sprayers :

Here the size of droplets are mostly 300 – 400 μ. Such sprayes are high volume – High pressure sprayers and are suitable for complete coverage of both ground and field crops. Under this heading, followings are the sprayers :

(A_1) **Syringes** : It is the simplest hydraulic sprayer and very tiresome to operate. The rate of spraying is difficult to control. Therefore it is used only for small areas and Kitchen gardens and laboratories.

(A_2) **Bucket pump sprayer** : Suction hose is placed in the bucket. Spraying is done in both suction and delivery stroke, therefore spraying is continuous. Although the rate of application is difficult to control. Its application requires only one person (operator). It is suitable for spraying shrubs, low crops (Vegetables) and nurseries.

(A_3) **Stirrup pump Sprayer** : It's application requires two operators i.e. one for pumping and agitating the suspension (if necessary) and another for spraying (application). It gives satisfactory performance and generates a pressure upto 4 kg/cm^2
To cover bigger areas for spraying, a bigger sized double action pump is fitted permanently in a large container and is mounted on wheels: which is commonly called wheel barrow type of Sprayers.

(A_4) **Knapsack/Backpack Sprayer** : The name of sprayer itself shows that it is used by carriying on ***Back*** of the operator. Spraying is done by right hand of the operator. It has double action lever. Here only one operator is required. Normally coarse nozzle is used to spray any type of material. Presently low volume nozzle is used to achieve low volume spraying. It is simple and durable, therefore it is useful for diverse use i.e. spraying the bush of ***tea*** and ***Coffee***. It is suitable for ***hilly*** and ***muddy*** tarains where the use of large or power sprayers is not possible.

(A_5) **Rocking Sprayer** : The word 'Rocking' means forward and backward movement of handle. It gives the pressure of 14-18 kg/cm^2. It requires two operators one for pumping system and another for spraying. It is used for spraying ***tall plants*** like ***arecanut, coconut*** and sugarcane etc. It gives uniform spraying at sufficient pressure.

(A_6) **Foot/Pedal Pump Sprayer** : It is based on the same principle of Rocker but here foot (Pedal) is used for rocking instead of hand. It means it may be used by only one operator. It may be used to spray ***tall trees*** with the help of extension rod. The plant up to of 6m height is easily sprayed. Therefore it is suitable for spraying the trees in orchards and also for crops on medium sized farms. It generates a pressure of 14 kg/cm^2.

[B] Compression/Pneumatic/Air Sprayers :

(i) Air is compressed into the container by the compression air pump.

(ii) Tank is usually filled to 3/4th of its capacity and 1/4th (one-fourth) volume is left for the compressed air.

(iii) Such sprayers are not provided with agitators. Hence those spray materials which require continuous agitation for keeping them in suspension, normally cann't be effectively sprayed.

(iv) Such sprayers can't be used for diverse purposes like hydraulic types.

(v) Flame Thrower is certainly a Pneumatic Sprayer.

(vi) It is of two types depending on the size viz compression hand sprayers and Pneumatic Knapsack sprayer.

(B_1) **Pneumatic/Compression Hand Sprayer :** The capacity of the tank of this sprayer is 0.5 to 3.5 litre and tank itself acts as pressure chamber. There is a provision of fine nozzles in these sprayers and due to this provision, solutions and emulsions can be effectively applied. Such sprayer is suitable for household and Kitchen gardens.

(B_2) **Pneumatic/Compression Knapsack sprayer :** It works on the same principle as of Hand Sprayer. It's tank is cylindrical and capacity is 10 to 20 litres. It is used by fixing on back of the operator. Pressure is developed 4-5 kg/cm^2. It is good for large areas.

[C] Gaseous Energy/Air Blast Sprayer :

The example of such sprayer is ***Hand Atomiser*** or ***Flint Pump*** which is the simplest air blast sprayer. The chamber capacity is 0.5 to 1 litre. It is suitable for experimental work on individual plants. The long time spray by this sprayer is tedious.

The working principle of such sprayer :

When plunger is pushed forward (downstroke) a gust (or blast) of air is come out from the nozzle which creates a momentary vacuum in the tube. Due to vacuum, spray liquid of the container rises out into the tube. When the plunger is drawn backward (upstroke) fresh air enters into the barrel through its nozzle and the spray liquid (i.e. pesticide + air) is only to be expelled out by the next down stroke.

Power Sprayers

Such sprayers are used for large areas and on the basis of mechanism of action, these are of four types :

(A) Hydraulic energy sprayer

(B) Air Pump/Compressor or Pneumatic energy sprayer

(C) Gaseous Energy Sprayer or Blow applicator

(D) Centrifugal Energy Sprayer.

(A) Hydraulic Energy Sprayer : It is a High Volume – High pressure sprayer . Tank capacity is 160-200 litres and developed pressure is up to 40-50 kg/cm^2. High volume spraying is also called Full coverage spraying. It needs more water and obviously more labour is required. It is suitable for partially soluble or low dispersible chemicals (like Bordeaux Mixture) or highly soluble products (i.e. nicotine sulphate). Here phytotoxicity injury is minimized due to high degree of dilution. Clogging of nozzle is also avoided due to large aperture. Such sprayer requires 500-1000 litres of spray liquid for one hectare of field crop. Therefore it is ***not*** suitable for ***arid areas***.

Low Volume Spraying needs 8-25 times lesser amount of water and chemicals as compared to High Volume spraying. Therefore Low volume spraying is also called *concentrate spraying*. A water miscible liquid pesticide like malathion is more suitable for low volume spraying since it can be atomized without the danger of sedimentation. It needs 10-125 litres of spray liquid per hectare. I.e. 10-125 l/ha.

Semi-low volume/semi-concentrate spraying requires 0.5 – 6.25 litres of spray liquid/ha.

Recently ultra-low volume spraying i.e. ULVs is more prevalent where less than 6 litres of spray liquid is needed for one hectare i.e. $<$ 6 l/ha low volume, low pressure with the use of a.i. in more concentrated form is the main principle of ULVs. Efficiency of low volume spraying depends on the droplet size and its spreading power. Therefore here more emphasis is given on to control droplet size to cover large area per unit time even with reduced consumption of pesticide.

Hydraulic energy sprayers are of two types viz.

(A_1) Small portable sprayer

(A_2) Large Sprayer

(A_1) **Small Portable Hydraulic Sprayer :** Generally it has two delivery hoze and it is operated by 1-3 hp aircooled engine. It is suitable for spraying ground crops and orchards in plantation for smaller areas. It is available in the market in two forms-stretcher type and wheel-barrow type.

Stretcher type is light i.e. 20 kg in weight whereas wheel-barrow type is heavy that's why it requires one or more wheels.

(A_2) Large Hydraulic Sprayer : It's tank capacity is 200-2000 litres or more. The developed pressure is upto 28 kg./cm^2. Such sprayer is mounted on jeep or another vehicle. It is suitable for such field crops which has long rows and regular spacing with larger area. It is also used for orchards and plantations. It is unsuitable for tall field crops like jute, sugarcane at latter stage and wet rice field.

[B] Pneumatic/compression/Air Energy Sprayer :

There is no use of pump but a layer of compressed air is produced by Engine power over the spray liquid in the tank and the developed pressure is upto 14 kg/cm^2. Since there is no pumping action, such sprayer may be used for the spraying of corrosive materials provided the inner surface of the tank has an anti-corrosive lining. It is of two types :

(B_1) **Portable and small mounted sprayer :** The tank capacity is upto 50 litres. Single cylinder compressor is used to produce compressed air which is operated by V-belt air-cooled engine. There is no system of agitation hence is not suitable for spraying of materials which starts to sediment quickly.

(B2) **Large mounted sprayer :** Here the tank capacity is upto 2000 litres. Here there is a arrangement for agitation, therefore it is suitable for spraying of all types of formulations. It is expensive and difficult to use on small undulating lands. It's use is limited to level lands only.

[C] Gaseous Energy Sprayer :

It is a low volume – low pressure sprayer. When a strong current of air is thrown on the spray liquid coming out of the sprayer, the air current atomises the spray liquid in the fine droplets. To throw air current at high velocity, *a fan/Blower* of 1.2 – 3 hp aircooled engine is required. Such sprayer is suitable for spraying concentrates but difficult to regulate the uniformity of spray deposits at different distances. It is known as *Blow applicator*.

Some machines are so designed that both dusting and spraying may be done.

The droplet's size produced by such sprayer is 100-400 μ VMD (Volume Median Diameter)

Motorised knapsack sprayer is a blow applicator. Presently it is most common because of only one person is capable to treat more than 2 ha areas conveniently. The hopper attached with it is made up of polythin of high density whose tank capacity is 7-12 litres. One more tank is attached which is fuel tank and its capacity is 0.75 – 2.25 litres. It is operated by 1.2 – 3 hp aircooled engine. Its weight when empty is 7-15 kg. Therefore it is easily kept on back of the operator. The spray liquid is sprayed by strong air current having velocity of 175-320 km/h at which the discharge rate of air current is 2.7 – 9.1 cubic metre (m^3). The discharge of spray liquid is 0.5 – 5 l/minute and the fuel consumption is 0.6 – 1.86 l/hour.

The heavy Knapsack is not taken on the back of the operator. In such condition, it is of two types viz-stretcher type and wheel barrow type. Such sprayer is used for greater areas and for spraying on orchards and bushes. Motorised Knaksack sprayer is used for both dusting and ultra-low volume spraying.

[D] Centrifugal Energy Sprayer :

Such sprayers are designed to produce fine drops (50 – 150 m VMD) in the form of mist hence called ***Mist blowers/Mist Sprayers.*** The centrifugal or axial flow of air at high velocity carries small droplets to the target. It is used to spray large area with small quantity of the spray liquid. It is suitable for spraying ***shade* or *Orchard trees*** with droplet size *80-100*μ . For mosquitoes control the droplet size is 50-70 μ. Such sprayer is ***High Concentration*, *Low Volume*** and ***Low Pressure***. The centrifugal force of rotor determines the size of the droplets. Here pressure is kept constant at 0.7 kg/cm^2.

Mist sprayer is used for Blast spraying and Drift spraying. In case of blast spraying, a blast of air produced by machine carries fine droplets of the spray liquid to the target. But in case of Drift spraying, the fine droplets of spray liquid are carried to the target by using the blow and direction of the wind. Large sized mist blower is grouped into stretcher or wheel barrow or vehicle mounted.

In India, an ***aircraft*** was first used to ***control mosquitoes*** in Delhi in *1944-45* and to control ***desert locust*** in *1951*.

Other Equipments :

(I) Fog generator : When the droplet size of the spray liquid is *1-50μ VMD* means smaller than that of mist, such used sprayer is called Fog generator and such fine drops are known as *Fog*. It is used to Kill flying insects because droplets remain floating in the air. It is suitable for treating very dense foliage or enclosed spaces to present drifting. For treating larger areas in shorter times with smaller quantities of the material, Fog generator is one of the best use.

(ii) Smoke generator : Smoke producing equipment is called smoke generator. The size of smoke particles is *0.001–0.1μ* . Here slow burning pellets are used to treat greenhouse and warehouses.

(iv) Aerosol Bomb/Liquified gas aerosols : Aerosol means a fine spray ejected by pressurized can. Aerosol bomb is used by the Military group to kill mosquitoes.

(v) Soil Fumigator/Soil injecting gun : It is used to control soil insects and soil nematodes.

(vi) Dust applicators for burrows : It is used to apply dust in the burrows e.g. cyamag Foot Pump where calcium cyanide is used.

Cyanogas pump is used to kill rodents by fumigating Hydrocyanic acid gas in their burrows. Here calcium cyanide is used.

e e e

(10.) Integrated Pest Management

Introduction :

The Pesticide has an indirect role in the agricultural production because it protects the plant from insect, pest and diseases. In modern agriculture, farmers are intensively using pesticides to ascertain high yield, but in the due course the pests becoming resistant to pesticides. The crops valued more than seven crores are damaged only due to pests in India in which weeds cause 33%, diseases 26%, insects and rodents 26%, and birds, nematodes etc. cause 15% damage. The seventy percent (70%) of the used pesticides are insecticides, 12-15% fungicides and 4-5% weedicides.

In India ninety thausand tonnes pesticides are used every year, out of which 63% are used in agricultural purposes. Insecticides valued of nearly Rs. 6 hundred crores are used in Andhra Pradesh, Karnataka, Gujarat and Punjab, out of which 76% are used on cotton, paddy, jowar and wheat crops; 10% insecticides are used on the cultivation of vegetables and fruits. A comparative consumption of insecticides in developed countries in as follows -

S.No.	Country	Per ha consumption of insecticide (in grams)
1.	Japan	10,000
2.	Europe	2,000
3.	America	1500
4.	India	400

From the above table it is evident that the consumption of insecticides in India is very less as compared to of developed countries, though there are some states vize, Punjab, Haryana, U.P., A.P., Tamil Nadu Gujarat where consumption is very high. The residue of the pesticide contaminates the food-chain and pollutes the environment. Therefore to control insect-pests and diseases, it is advisable to go for Bio-intensive integrated pest Management by adopting Judicious use of chemicals.

Harmful Effects of Pesticides :

Repeatedly use of the pesticides contaminates soil, air and ground water in addition to crop plants and its produce. Carelessly use of such pesticides creates intensive toxicity. It's long term use affects the biological system of the animals. Such pesticides are generally known for its carcinogenic (Cancer producing) effect, tertogenic (deformity producing), tumouragenic (tumour and cyst producing) effects. The heavy and uncontrolled use of chemicals brings down the bio-diversity of natural enemies due to which epidemic of secondary pests may spread and above all these pests become resistant to pesticides. The persistent use of pesticides causes hazards to non-targeted and useful organism and thus several minor-pests may appear in epidemic form. For example in rice-ecosystem, there is 3.5 times decline and in cotton-ecosystem, there is 12 times decline in natural enemies. Previous several minor-pests have become harmful and major pests viz. Rice leaf folder *(Canphalocrocis medinalis)*, Green leaf hopper (Nephotettix spp.) and white backed planthopper *(Sogatella furcifera)* in rice-ecosystem and old world boll worm ***(Helicoverpa armigera)*** in cotton ecosystem. Several other pests have developed resistance to pesticides at the normal doze viz. Old world bollworm *(H. armigera)* Brown plant hopper *(Nilaparvatha lugens)* of rice; diamond back moth *(Plutella xylostella)* of crucifers, black aphid *(Aphis craccivora)* of groundnut, tobacco caterpillar *(Spodoptera litura)* of groundnut and other crops, Mustard aphid *(Lipaphis erysimi)* of castor, Serpentine leaf miner (Liriomyza trifolii) of tomato and other crops.

Some pesticides are easily degraded and decomposed in soil after doing their works but some don't. Some are cyclic-hydrocarbon viz. BHC, DDT, Aldrin etc. in which chlorine is the main constituent. Such elements are inbibitors of the biological degradation and stop the oxidation-ring. These elements are remained in the environment for the long time. The concentration of such materials are increased year by year. These materials are accumulated in the soil and water. From there they enter into the food-chain through producers. When vegetarians consume them as food, these harmful pesticides are deposited in their body tissues where their concentration becomes more than that of the producer. And if these vegetarians are consumed by the non-vegetarian consumers, these pesticides reach in their body where they become more and more concentrated. Moving through different levels of food-

chain, these injurious pesticides are deposited in human body where their concentrations reach to the highest because man is the top consumer. Such increment in the concentration of pesticides is known as ***Biological Magnification/Bio-Magnification***. Many surveys showed that majority of the people living in the Indian cities have more amount of DDT above the tolerance level in their bodies. The more concentration of pesticides like DDT in birds decreases the thickness of egg shell as a result these eggs hatch prematurily before the complete embryo-development. For this reason, a number of aquatic birds like pelican has been decreasing day by day.

The use of different agricultural chemicals causes the effect of phytotoxicity, Pollen-sterility, pollution and developmental obstruction. Due to these hazardous effects of pesticides an awakening has been seen in the agricultural scientists and now they have been emphasised on the need-based use of chemicals and Bio-intensive integrated pest management. Now the farmers are instructed to use chemicals in the special conditions only after the recommendation when other methods of pest-control become failure.

Integrated Pest Management :

Any single measure of pest-control has never been proved effective and permanent solution. Heavy use of pesticides caused environmental problems and the residue of pesticides started to accumulate in the human body. Some pests are aclimatised themselves and developed resistant to pesticide. Presently intensive agriculture has been practiced by the farmer instead of mixed cropping and crop rotation like traditional agriculture.

Modern Farming practices viz. Monoculture, Cropping scheme, multiple cropping, i.e. to say transformed agri-economic; induced the pest-hazards.

Therefore the need has been felt to develop such pervasive programmes of pest-management which are favourable to environment and able to control the pest-damage. Considering this concept, one policy. measure has been developed which is named as 'Integrated pest Control/ Management'. The term IPM was first coined by Barlett in 1956 and suggested to integrate chemical and biological control methods.

Geir and Clark (1961) modified his view and defined IPM as "Integrated pest management, briefly IPM wherein not only biological and chemical but all available methods were meant to be integrated".

FAO (1967) again modified and defined as - 'a systems that, in context of the associated environment and the population dynamics of the pest species, utilise all suitable techniques and methods in a compatible a manner as possible and maintains the pest population at level below those causing economic injury. A modern definition of IPM has been given by Smith (1978) - 'A multi disciplinary, ecological approach in the management of pest populations which utilizes a variety of control tactics compatibly in co-ordinated pest management'.

According to Pedigo (1991) : - 'IPM is a comprehensive approach of pest control that uses combined means to reduce the status of the pest to tolerable level which maintaining a quality environment.'

It is evident from the above definitions that all the different pest control measures are integrated and are planned to minimise the crop-damage without disturbing the ecological system. Later on scientists feel that neither the eradication of pests is possible nor such is beneficial and keeping this view in the mind, conservation of natural enemies to pests are compulsory and thus the new name of IPM is *Bio-intensive Integrated pest Management* (BIPM). Under the BIPM the population of the pests and the population of concerned natural enemics are so co-ordinated that the pest population can not cross the line of economic injury. The objective of this programme is to get maximum cropprotection against pests at the least cost.

The measures for minimization of pest population depend upon agro-climates, land conditions, selection of varieties, local agro-economical systems and socio-economical conditions of the farmers. The conservation of natural enemies of pests and all the possible meausres are adopted under BIPM. These are as follows :-

[A] Cultural Measures :

Cultural measures means such cultural practices which do not allow the favourable conditions for life-cycle, growth and breeding of the pests. In this measures the practices like ploughing, sowing, irrigation and harvesting etc. are so managed that pest population does not cross the economic injury level. Such measures do not require special cost and input. Here following measures and practices are adopted :-

(1) Selection of site/crop : For successful production of crops and trees, it is essential to select proper field and climatic region. The selected varieties should be tolerant to the pests of that particular climatic region. For example-*Mythimna separata*, *Spodoptera mauritia* and

S. litura are found generally in all the regions but are specially seen in flooded area of some states after the flood recedes. Citrus plants in sandy soils and waterlogged areas are more prone to pests. Ratooning of sugarcane in the gurdaspur borer *(Acigona steniella)* infested field is more prone of this pest. Irregular and unequal growth of the crop promotes the pest-infestation on smaller and younger crops.

(2) Ploughing : Deep ploughing of soil exposes the hidden eggs and pupa of insects, nematodes, rhizomes and bulbs of the persistent weeds and other organisms which become food for their natural enemies. Some birds follow the plough or tractor at the time of ploughing is the good example. Insects in the pupal stages are helpless and are easily removed and killed. Summer ploughing by soil turning plough is specially useful in this respect. The type of equipmnet used for ploughing has also a significance.

(3) Planting material : Many insect pest and diseases are transmitted from one crop to the next crop through infested/infected seeds or any other planting materials.

Therefore to grow new crop such certified seeds should be used which are free from all the insect-pests and diseases.

(4) Time of planting and crop duration : Adjustment in the time of sowing or transplanting helps in pest-control. Early sowing of mustard prevents from infestation of aphids. Gram sown before 15th of October shows less infestation of Heliothis. Late sowing of groundnut prevents from infestation of white grubs. Crops of the short duration give less chance to pest-infestation because these crops mature before the emergence of the pest.

(5) Destruction of off type and volunteer plants : Off type plants is impure of new variety grown during the crop-production. Such off type is more susceptible to pest which is grown along with the standard variety. Potato tubers which are remained in the soil during digging, germinate early and attract potato cutworm *(Agrotis segetum and other spp.)*. Ganganagar ageti (off type plant of cotton) is comparatively more prone to jassid *(Amrasca biguttula biguttula)* and pink bollworm *(Pectionofora gossypiella)*.

(6) Destruction of Alternate hosts : Many plants especialy weeds work as alternate hosts in off-season for insect pests and diseases. Paddy mealy bug, Army worm and fruit sucking moth spend their life on alternate hosts before attacking on main host crops. Tomato leaf curl virus multipfly on parthenium.

(7) **Thinning and Topping :** Such practices affect the pest-population. Topping of cotton removes the eggs of *Heliothis armigera*. Sowing of cotton, maize and hybrid millets at a higher seed rate saves the crops from pest-infestation. Unhealthy and infested/infected plants are removed through thinning.

(8) **Prunning and destruction of crop residues :** Unhealthy and infested protions of the fruit trees and horticultural plants are removed through Prunning and are collected and burnt. Prunning in citrus plants during April and May minimises the infestation of shoot borer. Burning of fallen leaves and stubbles in the mango-orchard kills the nymphs of mango mealy bug. Many insect-pests hibernate and hide in the crop-residues and stubbles in the cold season, later on who emerge after becoming adults. Therefore it is essential to destroy the crop residues completely.

(9) **Fertility Management :** The crop growth depends on the soil fertility which indirectly affects the pests. Use of phosphatic fertilizer protects from jassid *(Amrasca kerri)* in lobia and *H. armigera* in gram. Normal and excess supply of potassium protects from pest-attack where as low dose of K promotes pest-infestation. Excess of K increases the silica-content in the leaf due to which cell-wall of parenchyma and tissues containing epidermal sclerenchyma become hard and unfavourable for pest-attack. Excess application of nitrogen invites pest-attack. Use of Azospirillum sp. makes the plant hard against the attack of insect-pests and diseases.

(10) **Water management :** It is seen that in the flooded area the pests inhabiting in the soil are submerged, some are flown away and some are exposed to their natural enemies. Soil inhabiting pests like white grub and cutworm are reduced after the irrigation. The irrigation in sugarcane and wheat crop protects from white ants. The attack of aphid *(Lipaphis erysimi)* is more in rainfed mustard after 47 days of sowing in comparison to irrigated. The deficiency of normal water in the plant increases the concentration of nitrogen and soluble sucrose in the phloem-sap, due to which aphid-infestation is more.

Excess of malic acid in gram brings resistance against *Helicoverpa armigera*. Irrigation decreases the malic acid concentration resulting is more of pod-borer infestation.

(11) **Crop rotation/Roto cultivation :** Crop provides food for insect-pests and disease causing organisms and if the food is abundant all round the year, such pests flourish and multiply rapidly. Their abundance depends upon the fecundity, hibernation, brooding period, dissemination capacity etc. Therefore the pest problem of the specialised farming will be different from the mixed farming areas. The pest-problem of monoculture can be controlled by adopting crop-rotation/Roto cultivation.

(12) **Cropping Scheme and trap Crop :** Certain pests may be controlled by using trap crops in the cropping scheme. Certain pests are more attracted towards certain crops. Such crops are sown in narrow strips arround the major crop at a specified row distance are served as a trap for the pest that might be common to both. The preferred host plants can be grown around the valuable main crop and when the pest has appeared, they can be cut and destroyed. Lady's finger (Bhindi) is an good example of trap crop for cotton to attract jassids and cotton bollworms. To attract hairy caterpillar, sesame can be grown around the cotton.

To attract diamondback moth, leaf webber and aphids of cabbage, two rows of musterd are sown after each ten rows of cabbage. One row of musterded is sown after 15 days of transplanting and another one after 25 days. When the pest appears on mustard, spraying of 0.5% dichlorvos at a interval of 10-15 days can be done and the main crop (cabbage) is to be sprayed with neem based insecticide which protects natural enemies also.

Transplanting of yellow tall marigold *(Tagets sp.)* or bidi rustica tobacco (1:5) arround the tomato is useful to control *Helicoverpa armigera. H. armigera* lays her eggs on yellow tall marigold which is exposed to egg-parasitiod *Trichogramma chilonis*. Spraying of HaNPV or Bt (HaNPV→Nuclear Polyhedrosis Virus of H. armigera; Bt → Bacillus *thuringiensis* (bacterium)] is done on the main crop of tomato which is safe to Trichogramma. H. armigera on rustica tobacco may be controlled by Mirid predator named *Cyrtopeltis tenuis*. In the locust *(Schistocera gregaria)* affected areas, neem trees are grown to attract predatory birds.

(13) **Use of resistant varieties :** It is well known that some crops are less attacked by pests because they have more natural

resistance than others.They have some special characteristics like acidity or tasteless of cell sap, early maturity, hard bark etc. which help in building their resistance.

[B] Mechanical and Physical Measures :

Such measures involves the use of physical components of environment or the use of labour with or without the help of special equipment. Such measures give quick result therefore these are popular among the farmers but it is laborious and time-consuming and not possible on large scale. The important components are as follows :-

(1) **Destroying after Hand-picking :** Different stages of pests viz egg, larva, pupa and insect itself are picked up regularly and are destroyed. It is the oldest method and is suitable for adults and egg cluster of lemon-butterfly, grubs of mustard sawfly and all stages of Espilachna spp.

(2) **Use of net or Screens/barriers :** Outlets of the farmhouses viz windows, doors & ventilators are screened to prevent flies, mosquitoes, bugs etc. The net is used to cover the nursery of tomato and chilli to protect from transmission of virus through *Bemisia tabaci.* Wrapping of pomegranate fruits with butter paper or cloth protects from Anar butterfly. Wrapping of orange fruits with bamboo-baskets protects from fruit sucking moth. Coconuts are saved from monkey by planting thorny plants around the coconut plant.

(3) **Temperature :** Almost all the insects are inactive at the low temp. between 60^0F (15.5^0C) and 40^0F (4.4^0C) and even at the lower temp. i.e. below 40^0F (4.4^0C) practically there is no damage by the pests. But higher temp is more suitable to control the pests than the lower temp. Steam sterilisation of glasshouse kills the soil pests (insects, disease causing organisms and nematodes). Simon cotton seed heater is used to kill the larvae of *Pectinofora gossypiella* in which cotton seed is treated for 3-7 minutes at the temp. of 125 to 135^0F upto 140^0F (51.6^0C-57^0C upto 60^0C)

[Conversion formula : $\frac{^0C}{5} = \frac{(^0F-32)}{9}$]

Bullbs are given Hot water bath treatment to destroy nematodes and mites. Blow lamp is used to kill the colonies of wooly aphids. Seeds

and grains of godown pests and due to hot air treatment moisture content of seed is also reduced resulting in the increase in storage-life of seeds/ grains. The empty godown may be given superheating above 50^0C for 10-12 hours to kill hibernating pests.

(4) **Use of mechanical traps :** Light traps are used for those pests who attract towards light. Such pests are white grubs, Agrotis, rice stem borer, leaf hopper etc. Blue cloth is used to trap (polyphagous) tobacco caterpillar *(Spodoptera litura)*. Different types of traps are used to trap rats. Pheromone traps viz. Cis-9, trans-11-Tetradeca dienyl Acetate for *Spodoptera litura* and *S. littoralis*; and Cis-9-, trans-12-Tetradeca-dienyl Acetate for *Ephistia elutello* and *S. litura* are used. To control crawling insect-pests on trees, banding materials are used which are of two types- (1) Sticky band (e.g. *Ostico*) and (2) Slippery band (e.g. *Cellophane*). Greese bands are used to control mango mealy bug, wingless insects and ants.

(5) **Use of Radiant Energy :** High Frequency radio waves (2450 mega cycles, 12.25 cm wavelength and 940 watts) generates temp. of 170^0-187^0F (76.6^0C - 86.1^0C) which is used to kill hibernating or hiding pests in godown like grainery weevils and confused flour beetles within 15-20 seconds only.

Radiant energy is indirectly used to make male insects sterile. Male insects are made sterile by using r-radiation (gamma radiation) or chemo-sterilants and are released in the normal population of insects where such sterile insects compete with the fertile males for copulation with the female. And thus population of insect-pests can be controlled. *E. F. Knipling* and Co. of USA in 1937 made the pupae of *Screw Worm fly* (*Cochliomyia homini vorax*) sterile on *Curakao island.* He used the r-radiation by cobalt-60 (^{60}Co). Such male sterile insects were released @ 400 males per square miles to get 100% sterile egg masses and the pests were completely controlled. This technique was known as *Sterile Male* Technique and thus ***E.P. Knipling*** was the propounder of the concept of *genetic control* of insect pest.

(6) **Use of drie-die :** The Drie-die (prevalent in USA) is a very porous & fine silicagel. It desiccates water from the cuticle of insects resulting into death. It is used mainly for godown insect-pests.

(7) **Spike Thrust method :** Iron hooks are used to kill white grubs and adults of *Rhinoceros beetle* present in *Coconut-crown*. This method

is spike thrust method and is also used for sugarcane stem borer and Mango stem borer.

(8) Removal of insect-pests by sieving and winnowing.

(9) Use of scintillating tapes to protect from birds.

(10) By making intense sound and shaking the pests.

[C] Biological control Measure :

In a natural or unpertubed perturbed ecological systems the insect-pests and weeds are automatically controlled by their natural enemies. But in the perturbed ecological system predators, parasites, mites, fungi or any other organisms are used in excess to control different types of pests; which is called biological control measures. Parasitoid, Predators and Pathogens are used as the natural enemies to control insect pests but parasitoids and Predators are used more.

Parasitoid : When an insect is itself a parasite, then it is called parasitoid e.g. egg. parasitoids of *Trichogramma chilonis* and *T. japonicum* are used to control Tissue borers of sugarcane and Rice.

Primary parasite : such parasite attacks on phytophagous insects.

Hyperparasite : Such parasite attacks on primary parasite. Hyperparasite is also known as secondary parasite.

Autoparasite : In some species of insects it is found that male insect attacks on female insect of its own species which is called Autoparasite.

Homeostasis : Over a long time the population of pests become stable i.e. Homeostasis is the stability of pest populations over a long time. Pest populations may fluctuate temporarily but over a long range of time, they tends to be stable.

Predators : Who hunts or kills other organisms for food, is called predator. The first insect scientifically employed for any biological control programme was ***the Vadalia beetle (Rodolia cardinalis)*** brought from ***Australia*** into ***California*** (USA) in ***1888*** to control the *cottony cushion scale (Icerya purchasi)* a serious pest of ***citrus***. However the first natural enemy to be introduced by man from one country to another was a *Mynah* from India to Mauritius in 1762 to control the red locusts. Chandra Shekhar Lohmi of India discovered a bug in 1975 which successfully controlled the *Lantana camara* a flowering weed of Nainital. This bug is known as Lantana bug. Followings are the important

in biological control :

(1) Consevation of Natural enemies.

(2) To release parasite/parasitiods.

(3) Use os Microbials/Pathogens.

(4) Use of Predators.

(I) Conservation of Natural enemies :

Conservation and enhancement of natural enemies should be of first priority. If the natural enemies are properly conserved, the need of other control measures is greatly reduced. Conservation means to avoid such measures which are harmful to natural enemies and to enhance those measures which are helpful in increasing their longevity, reporduction or to build up attractive habitat. Conservation becomes most critical when there is a small reservoir of natural ememies outside the cropped area. Pupae of epipyrops are found in large numbers on the leaves and trashes of sugarcane at the time of harvesting. If these trashes/leaves are not burnt but are left around the harvested fields, the adults emerge to augment the supply of natural enemies in the premonsoon season against *Pyrilla purpusilla* on the young sugarcane crop. Cultural practices likes ploughing, mowing or burning of crop residues may be harmful to natural enemies. The concept, 'More is the diversity, 'more is the stability' holds true, since diversity may provide alternate hosts as source of food, sites in winter and so on. Almost all the pesticides have adverse effect on the natural enemies. Therefore good pesticide should be used and promote such predators who are relatively resistant to such pesticides different measures are so managed that the population of predators is increased. For predatory birds and wasps, artificial nests should be available and Flowering trees having pollen and nector like Euphorbia, wild clover etc. should be planted at bunds.

(2) To release parasite/Parasitoids :

For the effective control of the particular pest, the specific parasites or parasitoids are released. This method is the most effective and economical against pests those have only one or few discrete generations in a year. Massive release have been attempted in several programmes involving natural enemies like Trochoderma spp. and general predators like green lace wings and *Coccinella septempunctata*.

(3) Use of Microbials / Pathogens :

The micro-organisms like bacteria, virus, reckettsiae, protozoa, nematodes and fungi have the capacity to affect the pests. *d' Herelle* utilized one bacterium named *Coccobacillus acridiorum* (Modern name- *Cloaca cloaca* VAT. *acridiorum*) isolated from desert locust *Schistocerca pallens* for the control of locust. However his work was not confirmed by the later scientists, though d' Herelle may be named as the ***father of microbial control***. The term 'microbial control' was coined only in 1949 by Steinhaus. *Bacillus thuringiensis* (bacteria) is very effective in controling many *Lepidopterous* larvae like cabbage worm, *Pectinofora gossypiella*, sugarcane stem borer etc. *Bacillus popilliae* causes milky disease in Japanese beetle. NPV (Nuclear Polyhedrosis Viruses) have the effective control over *Spodoptera litura* and *Helicoverpa armigera*.

(4) Use of Predators :

The coccinellid predator *Cryptolaemus montrouzieri* (Muls.) feeds on citrus mealy bug and grapevine mealy bug. The exotic coccinellid *Curinus coeruleus* Mulsant a shiny bluish- black ladybird beetle was introduced into India from Thailand in October 1988 to control subabul psyllid, *Heteropsyla cubana* crawford. Ducks are employed to control striped bug, *Tetroda histeroides* in rice crop. The *Euglandina rose* and *Gonaxis quadrilaterlis* is employed to control Gaint African snail *Achatina fulica*. The predator *Cyrtorhinus lipidepennis* (Miridae) feeds on all developmental stages of brown plant hopper (BPH) but primarily on eggs. The wolf spider *Lycosa pseudoannulata* is also a potential predator in nature in rice ecosystem.

Due to increasing importance of biological control, many countries have now bilogical control stations that collaborate with each other to solve their pest control problem through natural enemies (biological control agents). The CIBC of India (Commenweath Institute of Biological control) is the unit of CAB (Commonwealth Agricultural Bureau) with its headquarter at Trinidad (West Indies). The CIBC, Bangalore came into existence in 1956 and since then it has imported over 100 species of insects. The function of the Institute (CIBC) is to furnish information on natural enemies of insect pests and supervise and supply biological control projects anywhere in the world.

Table : Successful examples of Bilogical agents used in Pest Management

Natural Enemies (Biological agents)	Host (to be controlled)
For Insect Pests	
[A] Parasitoids/ Parasite	
(1) Vadalia beetle *(Rodolia cordinalis)*	To control a serious pest of citrus . Cottony cushion scale *(Icerya purchasi)*; introduced in 1888 in California (USA) from Australia.
(2) Mirid Bug *Cyrtorhinus mundulus*	To control leaf hopper of sugarcane *(Perkinsiellla sacchaicida)*; introduced in Hawaii in 1905 from Australia.
(3) Hispid beetle *Pediobius parvuls*	Hispid beetle *Promecotheca reichei*, a serious pest of coconut palm in Fiji.
(4) *Metaphycus lounsburyi*	Black scale of citrus *(Saissetia oleae)* in South Africa.
(5) Lady bird beetle *Cryptolaemus montroyzieri*	citrus mealy bug *Pseudococcus* spp. in california (USA)
(6) Egg Parasite *Opencyrtus erionotate*	Banana Skipper *(Erionota thrax)* in Hawai.
(7) *Aphidius smithi*	Pea aphids in USA
(8) *Orgilus lepidus*	Tuber moth in Australia.
In India	
(9) *Leptomastix dectylopii*	Common mealy bug *(Planococcus citri)*
(10) *Apanteles flavipes*	Sugarcane stem borer *(Diatraea saccharalis)*
(11) *Apanteles subadinus*	Potato tuber moth.
(12) *Aphelinus mali*	Wolly aphid *(Eriosoma lanigerum)*
(13) Pupal parasite	
a. *Isotima Javensis*	Sugarcane top borer *(Tryporyza nivella)*
b. *Encarsia perniciosi*	San Jose scale
(14) Larval parasite *Campoletis chloridae*	*Heliothis armigera*

(15) Egg Parasitoid *Trichogramma chilonis* and *T. japonicum*	Tissue borers in sugarcane and rice ecosystem; 8-10 release @ 50,000/ ha.
(16) *Trichogramma brasiliense*	To control Tomato fruit borer; 6 times or release @ 50,000/ha; first release *T. prêtiasum* or *T. chilonis* at 30 days after transplanting
(17) *Trichogramma chilonis*	To control bollworm in cotton ecosystem; release @ 1,50,000/ha at 7-10 day interval during the egg laying period.
(18) *Epiricania melanoleuca*	For the suppression of sugarcane pyrilla; periodic release of 4000-5000 cocoons or 4,00,000-5, 00,000 eggs/ha
(19) *Goniozus nephantidis* or anthocorid bug *(Cardiastehus exiguum)*	To control coconut leaf caterpillar *(Opisina arerosella)* in coconut groves 1:5 parasitidi; Host ratio is released at 14-15 days intervals during peak availability of pest.
[B] Predators	
(1) *Deraeocoris indicus*	Aphids *Mysus persicae* and *Aphis gossypii*
(2) Aphidilion *(Chrysoperla carnea)*	released @ 2 larvae per plant during the peak activity of cotton bollworms and sunflower capitulum borer.
(3) Predacious mite *Phytoselulus persimillis*	Glass house red spider mite *Tetranychus urticae*
[C] Microbial/Pathogens	
(a) Bacteria	
(1) *Bacillus thuringiensis* (B.t. bacteria)	effective against the caterpillars of many Lepidoptera; extensively used; products of B.t. marketed as wettable powder, dusts granular preparations and Flowable concen trates.
(2) *Pasteuria penetrans*	antagonistic of plant parasitic nematodes

(b) Fungi	
(3) *Metarhizium anisopliae*	Applied at the breeding sites of the *rhinoceros* beetles after pre-monsoon rains, infects pyrilla,white grubs and aphids.
(4) *Paecilomyces lilacinus*	Antagonistic of plant parasitic nematodes.
(c) Virus	
(5) Baculovirus particularly Nuclear Polyhedrosis Viruses (NPV) of *Heliothis* and *Spodoptera litura*	In pulses, NPVs of *Heliothis* and *Spodoptera litura* has promising result.
(6) NPV of *Helicoverpa armigera* (HaNPV)	*Helicoverpa armigera* on tomato and on pulses.
(7) Baculovirus infected rhinoceros	For the suppression of coconut rhinoceros beetles, release 10 baculovirus infected rhinoceros beetles per plant.
For Diseases	
(1) Fungal Pathogens : *Trichoderma harzianum* *T. viride* *T. hamatum, T. virens.* *T. polysporum, T. Konigli,* *T.pseudo koningii,* *T.piluliferum* *Gliocladium deliquescens* *G.roseum, G. catenulatum*	Fungal pathogens *(Trichoderma sp. Gliocladium sp.)* screened against *Rhizoctonia solani* (Chickpea), *Sclerotium rolfsii* (gram, sunflower groundnut) *Fusarium solani* (gram), *Fusarium oxysporum* f.sp. *ciceria* (gram), *Botrytis cinerea* (rose and gram)
(2) Bacterial Pathogens : *Pseudomonas cepacia* (strain N-24)	Effective for the suppression of *Sclerotium rolfsi* in sunflower rhizosphere.
For weeds	
Parasitoids :	
(1) *Dactylopius opuntiae*	against prickly pear *(Opuntia dilleni, O.elatior)*
(2) *Dactylopius celonicus*	against drooping prickly pear.
(3) *Zygogramma biocolorata*	*Parthenium hysterophorus*
(4) *Cyrtobagous salviniae*	Water Fern *(Salvinia molesta)*

(5) *Neochetina eichhorniae* *N. bruchi* *Orthgalumna terebrantis*	Water Hycinth *(Eichornia crassipes)*
(6) *Lantana bugs*	*Lantana camara*

[D] Chemical Control :

Chemical control measure is the most prevalent amongst the different measures of pest management. For the effective and balance use of minimum quantity of the pesticide, There are two main principles:-

(1) Use of selected pesticides

(2) Need based use of Pesticide.

(1) Use of Selected Pesticide :

Physically and biologicaly selected pesticides are desirable from environment point of view. Monotoxic chemical kills only one species of pest and does not harm to other organisms, but such chemical is discoverd very few. The main object in selecting pesticide is that the selected one must be harmless and non-injurious to beneficial and non-targeted fauna and flora. Since very few such chemicals are available, therefore such measures should be adopted which minimise the hazardous and adverse effects of the pesticides. These measures are:-

(a) The minimum amount of pesticide should be prescribed.

(b) The chemical should be selected on permanent basis but at every time the pesticide of less strength should be used.

(c) The chemicals should be used in a planned way to kill targeted pests only and not harm natural enemies.

(d) Keep the surface rough at the time of transplating so that beneficial organisms can escape in hollow places.

(e) Use the pesticide only when the pest population crosses the Threshold injury level.

(f) Only selective and non-persistent pesticides should be sprayed at soil that the natural enemies can be escaped from to come in direct contact.

Study on selective protection of recommended concentration of chemical pesticides revealed that endosulfan-22 in chlorinated hudrocarban group is comparatively safer to natural enemies. Other safer pesticides are phosalone-29, monocrotophos- 12, oxydemeton methyl-11, dichlorvos-10 under organo-phosphate group. Botanicals or

biopesticides, fungicides, acaricides, and herbicides are generally safe to natural enemies.

There are about 1005 species of plants which have insecticidal properties; 384 species have antifeedant properties, 297 have repellant; 27 have attractants and 31 species have growth inhibiting properties. Neem (*Azadirachta indica*). *Pongamia globra* and Mahua (*Madhuca indica*) are well known botanical pesticides.

Extract from neem seed-kernel (2-5%) is effective against rice cutworm, diamond black moth, rice brown plant hopper, rice green leaf hoppers, tobacco-caterpillar and different species of aphids. Mahua seed kernel extract (5%) is effective against sawfly and other insects.

(2) Need based use of Pesticide :

The Strategy of a good IPM Programme advocates need based use of pesticides rather than calender based prophylactic treatments. The pesticide should be chosen on the basis of its effectiveness and least injury to useful non-targeted organisms. The pesticide formulations, application measures and time of application are also important for effective IPM Programme.

The following points are to be adopted under chemical control measures:-

a) Essential nursery treatment so that the population of pests borne in nersery can be minimised.

b)Minimum use of pesticide.

c) Proper care of nersery so that need based pesticides can be used.

d) The pesticide should not be used on calender basis with some exception.

e) Use of proper amount of pesticide at proper time.

[E] Pest Survellance :

Pest surveillance is the fundamental tool in IPM for taking management decisions. It requires estimation of changes in the pest distribution and their abudance information about the life history of pests and influence of natural enemies; and the effect of climatic factors on pest populations. Vulnerable stages of the pest are acertained. Their programme can be taken on the basis of area or at the farm level. The use and misuse of pesticides has led to the problems of pest resistance and resurgence, distruction of beneficial organisms and wild life, pesticide residues in food, fodder and feed etc. Pesticide resistance management (PRM) is possible only when survey and surveillance of pest is carried out.

[F] Forecasting of Pest Attack :

Ecology of pests is the basis for pest management. Regular pest monitoring, survey and surveillance is necessary to enhance the preparedness of the farmers to meet the challenges. The analysis of the agro-ecosystem under which the pests and their natural enemies thrive is vital. Forecasting of pest attack is essential for planning of successful management practices. The correct forecasting depends upon the vast knowledge of biology and ecology of the pest. For the correct forecasting, following primary informations are essential:-

(a) Seasonal quantitative study

(b) Study of life-history of pest and

(c) Effect of weather and season on pests.

The seasonal quantitative study of pests reveals the ups and downs in their number (population), geographical distribution, limit of the emergence in one season. The study of life history helps in finding out the important facts about the number of eggs laid down, place of egg-laying, time interval and food quantity taken by each instar, maturity period of female adults etc. The weather/ season directly or indirectly influences not only the crops but the population of pests their parasites, parasitoids and natural enemies also. The pest intensity from one crop to others is also affected by weather or season.

For sucessful IPM programme, the agro-ecosystem analysis on selected crops and the conduct of *Farmers' field Schools* (FFS) have been gaining importance. Farmers are trained on IPM approach on their field, rice/ vegetable fields or orchards to gain knowledge and skill as to how to grow healthy crops and to manage pests. Such schools are called Farmers' field schools.

[G] Quarantine Measures :

The method of exclusion of the pests, enforced through certain legal measures is commonly known as quarantine. Introduction of foreign pests is possible when agriculture produce, seeds, fruits and goods are imported. Partherium weed came into India with the import of mexican wheat. Due to lack of quarantine, the spread of following pests could be possible:-

Table : Introduction of pests from one country to other

S.No.	Name of pest	Introduced From	Introduced to	Year	Remarks
Insct-Pests					
(1)	Grape Phylioxera *Phylloxora vitifollae*	USA	France	--	destroyed French vineyard
(2)	Mexican boll weevil *Anthonomus grandis*	Mexico/Central America	USA	1892	extensive damage to cotton
(3)	European corn borer *Ostrinta nubilalis*	Italy/ Hungry	North America	----	reached probably through broom corn; became major pest
(4)	Pink boll worm *Pectinophora gossypiella*	native of India	Worldwide	----	highly destructive post in nearly about all cotton growing areas of the world
(5)	San Jose Scale *Aspidiotus perniciosus*		India	1920s	Pest of apple
(6)	Potato tuber moth *Gnorimoschema opercullela*	Italy	India	1900	Field and Store-house pest of potato all over the country
(7)	Wolly aphis *Eriosoma lanlgerum*		India	-----	Serious Pest of apple.
(8)	Fluted Scale *Icerya purchasi*	native of Australia (through Ceylon)	India	1928	introduced through Ceylon (Sri Lanka) serious pest of Citrus Spp.
(9)	Golden nematode of Potato/Potato eelworm/ Potal cyst nematode *Heterodera rostochiensis* or *Globodera rostochiensis*	-----	India	After Indepen-dence	Before 1973, Globodera was know as Heterodera
	Diseases				
(10)	Leaf rust of Coffee *Hamalleia vastartix*	SriLanka (Ceylon)	India	1876	Causal Organism-Hemileia vastatrix.
(11)	Fire biight of apple and Pear *Erwinia amylovora*	England	India	1940	Serious disease in Uttaranchal
(12)	Flag smut of wheat *Urocystis agropyri*	Australia	India	----	Spread in Punjab, Rajasthan, U.P.
(13)	Bunchy top of Banana (Viral disease)	Sri Lanka	India	1940	Serious damage to dwarf cavendish variety.

(14)	Wart of Potato *Synchytrium endobioticum*	Holland	India	1952	----
(15)	Onion Smut *Urocystis cepulae*	----	India	--	------

The pests problem also arises due to the transport of agricultural produce from one region to another. To stop the spread of such pests, the establishment of domestic quarntine is essential. For example the apples grown in the Kargil and Ladhakh areas of Jammu & Kashmir are not sent to outside because these areas are habitat of codding moth (*Cydia pomonella*). And due to such domestic quarantine the apple-industries of H.P. and Kashmir valley are protected from the damage caused by such pests. Domestic quarantine is implemented for the following pests-

Table : Domestic Quarantine for Pests

S.N.	Name of Pest	Infested area from where transport and movement of host plants prohibited
1.	**fluted Scale *Icerya purchasi***	Tamil Nadu, Karnataka, Kerala
2.	San Jose Scale *Aspidiotus perniciosus*	Punjab, H.P. Jammu & Kashmir, U.P. West Bengal, Assam, Orissa
3.	**Codling moth *Cydia pomonella***	Ledakh and Kargil areas of Jammu & Kashmir
4.	Golden nematode of potato/patato eelworm/potato cyst nematode *Heterodera rostochiensis* (before 1973) or *Globodera rostochiensis*	NIlgiri hills, Tamil Nadu
5.	Bunchy top of banana (Viral disease)	Assam, Kerala, Orissa, West Bengal
6.	Banana mosaic (viral disease)	Gujrat, Maharastra
7.	**Potato wart *Synchytrium endo-bioticum***	Darjeeling district of West Bengal
8.	**Cotton leaf curl** (Viral disease)	Areas of Punajb & Rajasthan bordering Pakistan

[H] Varietal Control :

Selection of the reistant varieties is an important component of I.P.M. It is essentailly a preventive measure.The use of resistant varieties is the cheap and the best measure of pest control. Gall midge and Brown plant hopper of Rice, Borer and scales of sugarcane, wheat rust, downey mildew of coarse grains, pulse viruses etc. have been controlled by the use of their concerned resistant varieties. Development of High yielding and pest resistant varieties are gaining importance throughout the world.

Varietal resistance against the insect pests is grouped into four categories:-

(1) Tolerance (2) avoidance
(3) non-preference (4) antibiosis

(1) Tolerance : In case of tolerance, the host plant is attacked by pests but there is little or no loss in biomass production or yield. Tolerance is mainly dependent upon growth capacity of the plant and the growth capacity is affected mainly by favourable conditions. In some cases, tolerant varieties show greater recovery than susceptible varieties from pest damage. It is generally found that the attack of shootfly, stem borer or cutworm in germination stage aggravates their growth. The tolerance may be due to ability of the host to suffer less damage by the pest e.g. aphids in sugarbeet and brassica, greenbugs in cereals. Thus the use of tolerent varities of agriculture is useful.

(2) Avoidance : Pest avoidance (or disease escape) refers to the freedom of susceptible host varieties from the pests purely due to environmental factors. Avoidance may be a result of environmental factors, early varieties, changed date of planting, change in the site of planting, use of resistant root stocks, balanced application of NPK, control of pest carriers and control of pest itself. Early maturing cotton varieties may escape from pink bollworm infestation. Early sowing of mustard varieties escapes from aphid infestation.

(3) Non-preference : Some varities are unattractive or unsuitable for colonization, oviposition or both by the insect pest. This type of resistance is also known as ***non-acceptance*** and ***antixenosis***. Non preferance involves various morphological and biochemical features of host plants. Female insect does not lay eggs on non-preferrred plant.

(4) **Antibiosis :** Antibiosis refers to an adverse effect of feeding on a resistant host plant on the development and /or reproduction of insect-pest. In other words the lethal or harmful effect of plant on the biosis life of the insect-pest is known as antibiosis. Such plants have characteristic features like hard and thick epidermis, hairy stems and leaves and above all the plant may be toxic. The morphological physological or biochemical features of the host plant either individually or in combination may attribute to antibiosis.

The capability of the disease resistance in plants is expressed in three ways i.e. the type of disease reisistance:...

(i) Disease escape/pseudo-resistance : Some crop varieties complete their life cycle before peak period of infection due to their characteristics of fast growth and earlier maturity. And thus such varieties escape from the development of lebilitating attack by disease causing organisms; Therefore it is called pseudo -resistance and escaping from the disese is Disese escape. For example Early variety of wheat escapes from heavy damage by rust. Early variety of potato escapes from the disesae caused by *Phytophthora infestans* because attack of this disease occurs after the harvest of early potato. The crop in young or seedling stage is very susceptible whereas the fully developed and matured crop is unaffected which is known as ***Mature Plant Resistance.***

(ii) Resistance : Resistance is the ability to withstand (insect-pests and) diseases which may be conditioned by a number of internal and external factors operating to reduce the chance and degree of infection. In resistant variety, disease symptoms do develop and the reproduction rate is never zero (i.e. r#0) but it is sufficiently lower than one (i.e r <1). It means the development of disease in the resistane variety is very less which is expressed in the term of reproduction rate of pathogen i. e r:-

$$0 < r < 1 \quad \text{or} \quad 1 > r > 0$$

(iii) Immunity: The inability of parasite to infect the host even under most favourable conditions is known as immunity. The state of immunity is the absolute where the crop (host) is fully protected from infection. In other words such immune varieties neither allow the pathogen to develop nor show any disease symptom. Here the reproduction rate of pathogen is zero (i.e. r = 0) which is called ***Absolute Resistance.***

According to van der Plank (1963) Resistance is of two types on the basis of physiological differences:-

(a) Vertical resistance/perpendicular resistance/Racial resistance: It is also known as race-specific, pathotype (biotype) specific or simply specific resistace. In this type, the resistance is effective against only one or some specific pathotypes or biotypes. It is generally determined by major genes (oligo-genes) and is known as pathotype specificity. Due to oligogenes, resistance is only for avirulent pathotype. In case of occurence of frequent virulent pathotype, epidemics are common.

(b) Horizontal resistance/Field resistance : It is also known as race-nonspecific, pathotype non- specific, partial resistance, General resistance. This type of resistance is effective against all the known biotypes or pathotypes. It is determined by polygenes i.e. many genes with small effects. Here reproduction rate is not zero but it is less than one i.e. $r > 0$ but $r < 1$. It means the symptoms of the disease appear but the rate of spread is slow.

(1) Male sterlie Technique :

Male Sterlie technique of pest control is known as genetic control under autocidal technique. The concept of ~~genetic control~~ was conceived by E.F. Knipling. For detail see 'the use of radiant energy'. For making male insects sterile, r-radiation obtained from cobalt -60 and chemo-sterilants are used. Chemo -sterilants are mainly derivatives of strong alkylating agent Aziairidine. TEPA [tris (1-aziridinyl) phosphine oxide] METEPA [tris (2-methyl 1-aziridinyl) Phosphine oxide] and Apholate [2,2,4,4,6,6, hexahydro-2,2,4,4,6,6.-hexakis (1-aziridinyl)-1,3,5,2,4,6-triazatri-phosphorine] are common alkylating agents. Male sterile insects made by radiation have shown less sexual competiveness whereas striles made by chemosterilants have shown increased sexual competitiveness. Successful examples of male sterile technique by radiation are in fruitflies Oriental fruit fly-*Dacus dorsalis* and Mediterranean fruit fly-*Ceratitis capitato*. Upto some extent this technique has been used is melon fruit fly (Dacus cucurbitae), Onion fly (*Hylemya antigua*) cotton boll weevil (*Anthonomus grandis*) cockchafer (*Melolontha vulgaris*) cabbage looper (*Trichoplusia sp.*) Corn earworm (*Heliothis zea*), gypsy moth, codling moth (*Laspeyresia pomonella*) Chemosterilants have been successfully used in cotton boll weevil, red bollworm (*Diparopsis castane*) Pink boll worm (*Pectinophora gossypiella*) to produce male sterile. Male sterlie made by TEPA has been successfully employed to control mexican fruit fly *(Anastrepha ludens)*.

[J] Use of IGR, Pheromones, Attractants & Repellants.

Juvenile harmone and chitin inhibitors are examples of IGR (Insect Growth Regulator) which affect insects only. Juvenile hormone (J H) inhibits developing adult insect under the pupal stage. JH is effective even if it is applied on the cuticle of pupa. It is secreted by corpora allata. Williams (1967) suddenly observed JH in the stomach of male Cecropia moth which has been chemically known as Neotenin. This hormone when sprayed on the target insects at the suitable stage, affects the metabolic activities and produces disorder in their reproduction and development resulting into death of the insects. Since it does not kill instantly, therefore it is not suitable to use at the time of outbreak of pests. Altoid, Kinoprene, Altozar etc. are commercially major IGR. Chitin synthesis inhibitor and Azadiractin like phytochemical are proved good IGR.

'Pheromones' are such chemical substances produced by an organism exogenously which influence the behaviour or physiology of other member of its own species. Pheromones are grouped as :–

(i) Sex pheromones: such pheromones attract opposite sex.
(ii) Trail pheromones: such activate others to follow.
(iii) Aggregation pheromone: to get aggregation response
(iv) Alarm pheromone: to alarm

The word 'pheromone' was coined by Karlson and Butenandt in 1959 for a chemical that is secreted into the external environment by an animal and that elicits a specific response in a receiving individual of the same species. It is also called 'ectohormone'.

Semiochemicals are those signalling chemicals that an organism can detect in its environment which may affect the organism's behaviour or physiology. Phermones are those that act between members of the same species wheras allelochemics are those that act between species. The allelochemics may be allomones, which favour the emitter, or kairomones,which favour the receiver. Many allelochemics act both as an allomone and a kairomones. Such chemicals are called synomones. Allomone is a substance produced by an orgnaism that, on contact with an organism of another species, induces a response favourable to the individual that produced the substance e.g. the neotropical social wasp *Mischocyttarus drewseni* applies a secretion to the stem of its nest that repels foraging ants. Kairomones are such volatile compounds which evoke behavioural response adaptively favourable to the receiver. Kairomones are secreted by host plant and host insects. The Kairomones secreted by host plant are used by the pets for their own benefit and the Kairomones secrted by the host insects are used by the natural enemies for their own benefit. The Kairomones secrted by host plant may be used as pest trap in the survey of the pest.

In the normal cases, the sex pheromone produced by the female acts as attractant and produced by male acts as aphrodiasiacs (i.e. to prepare female for copulation) The chemical nature of some sex pheromones have been discovered e.g. sex pheromone of Gypsy moth has been identified and synthesized as Cis-7, 8-epoxy-2 methyloctadecane. Pheromones are used in two ways:-

(a) used as a luring agent.

(b) by breaking normal mating behaviour i.e. intersexual communication system of the pests.

Attractants and Repellants are also used in pest control. Geraniol and engenol to trap japanese beetle *(Popillia japonica)* and Siglur to trap Mediterranean fruitfly are used as attractants. To repel cockroach N, N-diethyl-m-toluamide 2-hydroxy-n-octyl sulphide as repellant is used. Some chemicals like DTA [(4' -dimethyltriazeno) acetianilide], Fentin acetate (fungicide) are used as antifeedants. Natural Pyrethrin has the property of antifeedant. Antifeedants are such substances which inhibits from pest attack without killing or repelling the pests. These are also called feeding deterrents and rejectants. The pest dies slowly due to starvation. The crop or any material treated with such chemicals becomes antifeedant.

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11. Stored Grain Pests

The important pests causing damage to stored grains are Insect pests, Micro-organisms and rats:

The important insect pests which infest stored food grains are following :

S. No.	Common Name of insect pest	Genus	Species	Family	Order
1.	Rice Weevil	*Sitophillus*	*oryzae Linn.*	Curculionidae	Coleoptera
2.	Khapra beetle or Wheat Weevil	*Trogoderma*	*granarium Evert.*	Dermestidae	Coleoptera
3.	Rust red flour beetle	*Tribolium*	*castaneum* Herbat.	Tenebrionidae	Celeoptera
4.	Lesser grain Borer	*Rhizopertha*	*dominica Fab.*	Bostrychidae	Coleoptera
5.	Pulse beetle	*Callosobruchus*	*chinensis Linn.*	Druchidae (Lariidae)	Coleoptera
6.	Mung dhora	*Callosobruchus*	*analis*	Bruchidae	Coleoptera
7.	Saw-toothed grain beetle	*Oryzaephilus*	*surinamensis* Linn.	Cucujidae	Coleoptera
8.	Rice moth	*Corcyra*	*cephalonica*	Galleriidae staint.	Lepidoptera
9.	Angoumois grain moth	*Sitotroga*	*cerealella Cliv.*	Gelechiidae	Lepidoptera
10.	Almond moth	*Ephestia* (Cadra)	*cautella Walk.*	Pyralidae	Lepidoptera
11.	Indian meal moth	*Plodia*	*interpunctella* Hubener	Phycitidue	Lepidoptera

(1) Rice Weevil

Food : All types of Cereals

Damage : Adult and Larvae both attack grains suddenly and irregulary and eat them. Maximum damage is done in the month of August to October.

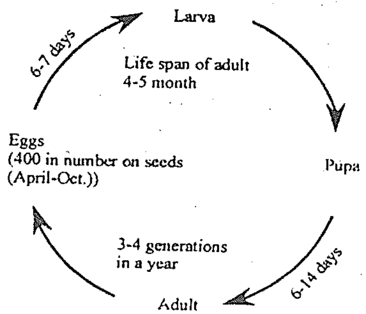

Fig.-1. Life Cycle of Rice Weevil

(2) Khapra beetle :

Damaging stage is larva only.

Though it is a major pest of stored wheat grains but it infests Jowar, Bajara, Maize, Rice etc. also sometimes infestation is seen on gram, Pea and urd also. Generally the superficial layer (50cm) of stored wheat is only attacked and embryo part of the seed is damaged, hence the seeds become unfit for sowing and consumption. Maximum damage is done during July to October.

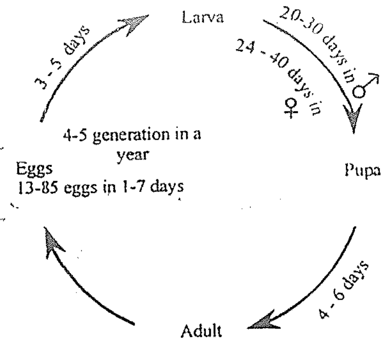

Fig.-2. Life Cycle of Khapra beetle

(3) Pulse beetle :

Only grub is responsible for damage, though it is a major pest of gram and cowpea but it feeds on other pulses also. Except the external shell all parts of grains are eaten up by the grubs. The peak period of damage is during April to October.

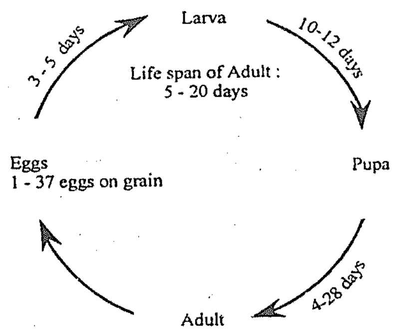

Fig.-3. Life Cycle of Pulse beetle

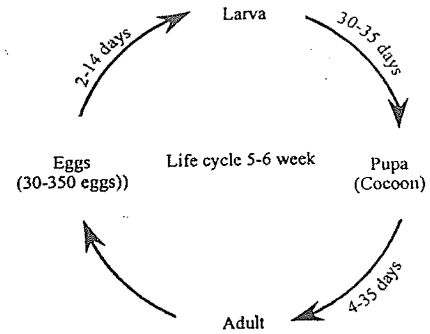

Fig.-4. Life Cycle of Rice moth

(4) Rice Moth :

It is a major pest of rice but it infests Gram, Jowar, Maize, groundnut and cotton seeds also. The larvae are responsible for damage. In serious infestations the godown turns in Webbed silken mass and gives unpleasant smell.

(5) Lesser grain borer :

Adult + grubs.The strachy materials of grains are eaten up. The young grubs are unable to pierce the grains hence they eat waste flour.

(6) Rust Red Flour bettle :

It feeds on damaged and broken grains only hence called secondary feeder. It produces pungent smell.

(7) Angoumois grain moth :

The grubs are responsible for damage. The females lay eggs on earhead in fields and after hatching minute larvae enter into the grains thus they reach in godowns and increases in number there. Their presence in godowns is always seen but maximum damage is done during the months of July to October.

Protection of Stored grain :

For it there are two basic principles :

(i) At the time of storage the grains must be completely free from pest infestation/infection.

(ii) And the grains should be stored on such a place where the chances of infestation/infection are minimum.

The damage to stored grains depends mainly on three factors –

(i) Moisture content of the grains to be stored.
(ii) Availability of Oxygen (O_2) in storage
(iii) The development of temperature gradient.

The storage structure, construction, design and method of storage affect the above factors :

For the control of stored grain pests two measures are adopted.
Preventive measures (Before Pest infestation)
Curative measures (After pest infestation)

Preventive Measures :

From the protection of insect pests infestation, seed treatment should be done before sowing. Balanced and clean cultivation is also necessary so that not a single seed may become the carrier of infestation upto godown. The moisture content of seed/grain at the time of harvesting must not be more than **14%**.

(a) Hygenic Measures :

(i) Threshing yards should be away from granaries and should be clean.
(ii) Gunny bags should be insect free.

(iii) All the cracks, crevices, holes existing anywhere in godown should be closed with cement or mud.
(iv) White washing is necessary before storage.
(v) Before storage the store should be disinfected by spraying Malathion 50% E.C. with dilution of 1:100.
(vi) Do not store infested/infected seed without proper treatment.

(b) Physical Measures :

(i) Drying of grain : Where the grain has moisture content below 9% most of the insect species do not survive/ multiply except *Trogoderma granarium*. In our country the grains are dried by spreading a thin layers of grains in the sun before storage. Dryers are also used nowadays. The model moisute content for storage is **8%.**

(ii) Heat treatment : Most of the insects die at 55^0C to 60^0C in 10 minutes.

(iii) Mixing of inert dust : Mixing of dust with grains like sand, clay, ash etc. makes the entry of insects in grains a difficult task and cause physical injuries to the insects.

(iv) Use of centrifugal force, x-rays, ultrasonic waves, atomic energy, aeration, cold treatment etc. are also there but they are very costly and out of reach to the farmers.

(v) Use of completely dried and infestation free grains for storage. Keep the storage damp proof, airtight, heat resistant and termits and rat proof. For keeping the grains use aluminium bins, steel bin, plastic bins or Pusa bins etc.

(vi) Refrigeration : Most of the pests does not multiply at less than 10^0C. The growth of mites is stopped at 0^0-10^0C and below 60% Relative humidity (RH). Most of the fungal growth and spore germination do not occur at 0^0-10^0C temp and below 65% RH.

(vii) Sometimes moisture content of stored grains is more than required which creates heating effect of moisture and there is possibility of decaying of grains. Therefore dry air is blown through the grains.

Chemical Measures :

(i) Malathion 50% E.C. is used as a Spray in ratio of 1:100 with water on grain bags, walls, floors, etc. @ 3 litres/100sq. metres.

(ii) DDVP or Dichlorvos 100% EC has properties of quick knock-down and high vapour density. It is applied @3 litres/100sq. metres surface in ratio of 1:300.

(iii) Food grains for seed purposes can be mixed with some insecticidal dusts like camphor, napthalene, etc. Dried neem leaves, tobacco pyrethrum dust and derries root dust have also been used.

Curative Measures :

(i) Drying of infested grains in the sun.

(ii) Few infested grains should be screened.

(iii) Wheat weevils stick to the gunny bugs kept on upper layer of wheat seed, remove them with bugs and destroy.

(iv) Spreading of sand on grains (5 cm deep) prevents egg laying.

(v) By sieving and winnowing the grubs of *Tribolium castaneam* and *Trogoderma granarium* may be separated and destroyed.

(vi) The superficial layer of rice infested with rice Weevil can be controlled by Pyrethrum aerosol.

(vii) The hidden insects are killed by generating 50^0- 70^0C for 10-12 hours in storages. Simon cotton seed Heater is used to kill hidden larvae of *Pectinofora gossypiella* for generating 125 – 135^0 F for 3-7 minutes.

(viii) Radiations are also used to kill insects and micro organisms. The first r-garden in India was established at Kolkata and 2nd at Mumbai where r-radiation is used for multipurpose.

(ix) Most practicable and useful method is fumigation. Some of the effective furmigants are given below :

Aluminimum Phosphide (Celephos) :

It is available in form of tablets of 3 gm each packed in sealed tubes. The active ingredient is phosphine gas (PH_3). It can be used for all food grains, milled products etc. 2 tablets are used for 10 quintal grains.

Methyl bromide-

It can be used @ 3.5 kg/100 m^3 for 10 to 12 hours.

Ethylene Dibromide (EDB) –

It is used @3 ml ampule for 1 quintal grain and 18 ml. for 5q. and 30 ml for 10q.

The above fumigants can be used as preventive measures also. Rat traps for rats can be used in godowns.

❈❈❈

12. *Insect Pests of Some Crops*

Most of the insect pests which cause damage to crops belong to the order Lepidoptera.

Insect pest of Paddy Crop

S.N.	Common Name of insect pest	Zoological Name	Family
1.	Rice gundhibug	*Leptocorisa varicornis*	Corcidae
2.	Rice gall midge	*Pachydiplosis oryzae*	Cecidomyiidae
3.	Stemborer (Yellow)	*Tryporyza incertulus*	Pyralidae
4.	Army Worm	*Mythimna separata*	Noctuidae
5.	Rice green leaf hopper (Jassids)	*Nephotettix viruscence*	Jassidae
6.	Rice hispa	*Dicladispa armigera*	Hispidae
7.	Kharif grasshopper	*Hieroglyphus banian*	Acrididae
8.	Swarming caterpillar	*Spodoptera mauritia*	Noctuidae
9.	White leaf hopper	*Tettigella spectra (Cicadella)*	Cicadellidae
10.	Paddy leaf roller	*Cnaphalocrosis medindis*	Pyralidae

Rice gundhi bug (Rice earhead bug) : The pest emits pungent smell.

Both nymphs and adults suck up the sap from the grains at the milky stage. Infested earheads become *chaffy*

Management :

Use of light traps.

Collection of and destruction of pest.

Destruction of weeds to remove alternate hosts.

Dusting of Carbaryl 5 per cent or Malathion 5% @ 25 kg./ha.

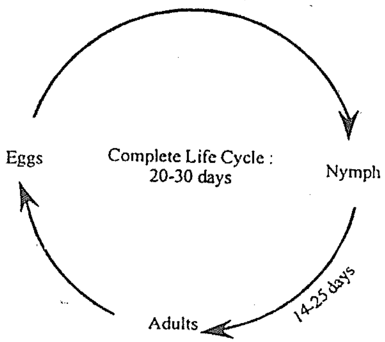

Fig.-6. Life Cycle of Gundhy Bug.

Rice gall Midge/Fly :

The maggots of pest pierce at the growing point of the plant and form a gall. The affected tillers become hollow pink or purple, dirty white or pale green cylindrical tube bearing at their tips a green reduced leaf blade complete with ligules and auricles. The gall is modified leaf sheath. The damage of this pest is characteristically known as ***'Silver Shoot'*** or onion shoot or **Silvery galls** since it produces long tubular gall of silvery appearance. For its management spraying of 0.05% phosphomidon, 0.02% Dimethoate, 0.2% Carbaryl 0.05% Diazionon can be done at the vegetative stage of the plants at the interval of 20 to 25 days. Granular insecticides like phorate can be applied in standing water at the rate of 1 kg/ha.

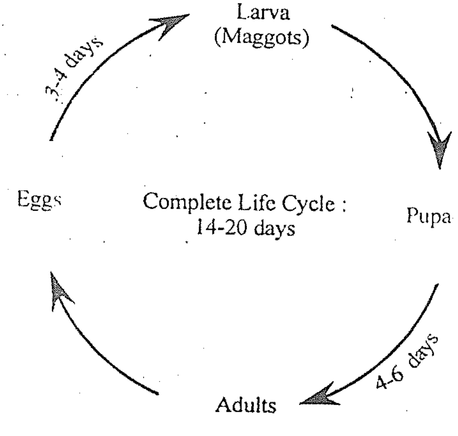

Fig.-6. Life Cycle of Rice gall fly

Yellow steam borer :

The damage is caused by caterpillars as a result ***'Dead Heart'*** formation takes place before flowering and after flowering ***'White Ear Head'*** (WEH) develops. The earheads dry up and no grain formation takes place. Basmati varieties suffer heavy damage than coarse varieties.

Management :

Clipping of tips of Seedling before transplanting, Removal & destruction of stubles at first ploughing. Fields showing more than 5% 'dead hearts' should be sprayed with 625 ml of phosphamidon or 1.4 litres of monocrotophos or 2.5 litres of chlorpyriphos.

Plant Hopper :

White Backed Plant hopper (WBPH) attacks in early crop season.

Brown Plant hopper : Attacks in later crop season.

Both the hoppers suck up the sap from plant and cause a serious damage. They also emit a toxin into the plant which produces a particular sympton known as *'Hopper Burn'*.

Brown Plant hopper transmits ***'grassy stunt virus'*** (GSV) to the plants.

Green leaf hopper (Jassidae) suck up the sap from leaves and transmits **'Tungro virus'.**

Insectpest Management of Rice :

In India paddy is grown in different climatic regions. So insect pest management adopted by farmers changes according to cropping system and climatic regions. For various environmental regions and cropping systems different management packages have been developed which includes clean cultivation and field sanitation, wide spacing of crop plants, in timely growing of nursery and transplanting, proper crop rotation, water and fertilizer management, preventive seedling root dip, use of resistant varieties, conservation of natural enemies and judicious use of pesticides.

Weeding, destruction of weeds and alternate host plants are important components of clean cultivation.

Ploughing of fields and bunds after harvesting destroys the egg of greenhoppers. The eggs are exposed to sun light and natural enemies for destruction.

Removal and destruction of stubles helps in destruction of hiding insect pests.

Resistant varieties have been developed by scientists for different insect pests. e.g.

For Brown Plant Hopper –

Chaitanya, Vajram, Sonasati, Jyothi and Bharatidason –

For gall midge –

Phalguna, Suraksha, Abhaya

For Yellow stem borer –

Vikas and Sasyasree (moderate resistant)

For Rice Tungro virus –

Moderate Resistant : Vkramarya, Suraksha

Resistant variety LET- 9994

Natural Enemies :

For stem borer	–	Testrastichus, Telenomus and Trichogramma.
For Brown Plant hopper	–	Dryinds, entomofagous fungi, Mirid bug.
For Leaf folder	–	Trichogramma, Apanteles, Brachymeria, Goniozus, Elasmus and Trichana etc.
For Gall midge	–	Platygaster

For control of yellow stem borer, clip the top portion of seedling before transplanting and destruction of eggs, destruction of stuble, ploughing and flooding of fields, crop rotation with non-graminaceous crops, use of tolerent and resistant varieties etc. are also helpful in management of the pest. When 50% dead heart at flowering stage and one moth or one egg mass/m^2 are seen, use of *Trichogramma japoncium* @50,000/ha/week at the interval of one week six time is useful. If necessary safe insecticide can be used. For monitoring yellow stemborer sex pheromone is useful.

Timely transplanting, proper use of fertilizers and spacing (20 cm x 15cm) is helpful in reducing hopper population. When number of hoppers reaches at ETL (Economic Threshold Level) Mirid bugs are released and according to need pesticides can be used.

To control Rice Tungro Virus (RTV) its carrier green leaf hopper should be controlled and resistant varieties should be used.

Following insecticides are effective in paddy fields –

As Granular : Carbofuran, phorate, Diazinon, Mephosfolon, Quinolphos. MICP and Cartap etc.

As Spray : Chlorpyriphos, Dicrotophos, Monocrotophos and phosalone etc.

From the point of view of bio-diversity and environmental protection minimum use of insecticide is good. For this a cheap technique has been developed which as under –

Soaking of germinated seeds for 3 hours in 0.2% chlorpyriphos or Isofenphos prevents infestation of gall midge.

Dipping of seedling roots before transplanting for 12 hours in 0.02% chlorpyriphos + 1% urea for 3 hours prevents infestation of stemborer, gall midge, whorl maggots etc. for at least 25 to 30 days.

Use of carbofuran in rootzone of plants prevents infestation for long period. For prevention of gall midge and stem borer urea coated with carbofuran is used in root zone of the plant.

In rainfed upland paddy carbofuran @2 kg a.i./ha can be used in furrows to prevent pests.

In rainfed low lands mix carbofuran in soil before trasplanting and spray monocrotophos or quinalphos if necessary to prevent stemborer and leaf folder.

Insect pests of Cotton

S. N.	Common Name	Zoological Name of insect pest	Family
1.	American ballworm	*Helicoverpa armigera*	Noctuidae
2.	Spotted bollworm	*Earis fabia* *Earis vittella*	Cymbidae (Noctuidae)
3.	Pink ballworm	*Pectinophora gossypiella*	Gelechidae
4.	Red cotton bug	*Dysdercus hoenigii*	Pyrrhocoridae
5.	Cotton Jassids	*Amarasca biguttula biguttula*	Cicadellidae
6.	Cotton white fly	*Bemisia tabaci*	Aleyrodidae
7.	Cotton leaf roller	*Sylepta derogata*	Pyrolidae
8.	Cotton aphid	*Aphis gossypii*	Aphididae

American bollworm :

In America it is a serious pest of cotton but in India it damages gram, red gram, tomato and many other crops. In our country suddenly in 1977-78 it started damaging to cotton and in 1987-88 it seriously damaged cotton in Andhra Pradesh.

Spotted bollworm :

The caterpillars damage young seedlings bud and boll. The affected bolls open prematurely and thus the quality lint is lowered.

IPM in Cotton :

Of the total insecticide used in agriculture more than 50% is used on cotton only. About 35 to 60% of the total cost of production in cotton is spent on pest control. In many parts of India pest control of cotton today also is completely dependent on insecticides that causes upset in environment, kills natural enemies, originates secondary pests and pesticides are becoming uneffective. For example during 1983-87 cotton

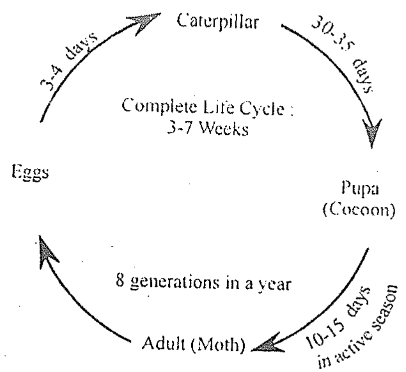

Fig.-7. Life Cycle of American Bollwarm

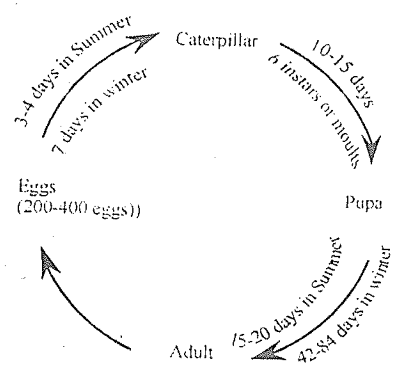

Fig.-8. Life Cycle of Spotted Bollworm

white fly and during 1977-78 American bollworm became major pests of cotton. Hence keeping the above points in view a package of management practices has been evolved which includes clean cultivation/ field sanitation, use of resistant varieties, destruction of crop residues, mechanical control, crop rotation, trap cropping, pest monitoring by using pheromones, protection and timely release to natural enemies and use of soft chemicals depending on ETL.

IC-1030, RKR 4145, KG9-18, S8/3 genotype are tolerent to bollworms and IC-625, SRT-1, B-1007 are resistant to jassids. Young bolls of *Gossypium arborium* have more amount of condensed tannin hence this genotype is resistant to bollworms. Condensed tannin is also more in pigmented lines which is attractive for bollworm. Prevention from sucking pests-

(i) Wider spacing

(ii) Less use of nitrogenous fertilizers

(iii) Don't have mixed cropping of cotton + Lady's finger. Cotton + Moong bean has less infestation of jassids.

Measures for Bollworms protection :

(i) Crop rotation of cotton with non-prefered crops like Ragi, Maize and Jowar etc.

(ii) Destruction of alternate hosts.

(iii) Adjustment in time of sowing according to need.

(vi) Hand picking of flared up squares and damaged fruiting bodies and their destruction.

(v) Sowing of cotton + cowpea encourages coccinellid predators and other natural enemies.

Castor is a good trap crop for *Spodoptera litura*.

In IPM production of Trichogramma and Chysoperla in large scale, their release in fields and use of biopesticides like NPV (Nuclear Polyhedrosis Virus) is necessary.

(i) Field release of predator *Chrysoperla carnea* 45 and 60 days after sowing : 50,000/ha and again after 130 days : 100,000/ha is very useful for the control of sucking pests like, Aphids, whiteflies, Jassids and thrips.

(ii) For the control of bollworms release of *Trichogramma chilonis* @1,50,000/ha/week starting from the bud formation stage of the crop is equally effective as chemical control.

(iii) If number of Helicoverpa reaches at ETL (means if it is seen 7 second stage larva/20 plants), spray biopesticide Ha-NPV @250LE/ha with 0.5% jaggery + 0.1% detergent.

(vi) Spray solution of Gossyplure gives effective control for pinkbollworm.

(v) For the effective control of cotton bollworms and sucking insects 0.5% Neem oil + 0.1% teepal and Neem seed Kernal extract (NSKE) is used.

(vi) 0.5% Neemoil + 2% mineral oil + 2% fish oil and resin soap reduces the number of white flies.

Insect pests of Sugarcane

S.N.	Common Name	Entomological Name	Family
1.	Sugarcane leaf hopper	Pyrilla purpusilla	Fulgoridae
2.	Sugarcane root borer	Emmalocera depressella	Pyralididae
3.	Sugarcane shoot borer	Chilo infuscatellus	Cramidae
4.	Sugarcane top borer	Tryporysa nivella	Pyralididae
5.	Sugarcane white fly	Alcurolobus barodensis	Aleurodidae
6.	Gurdaspur borer	Bissetia steniella	Pyralididae
7.	Stalk borer	Chils auricilius	Pyralidae
8.	Sugarcane mealy bug	Saccharicoccus sacchari	Pseudococcidae

(1) Sugarcane Leafhopper :

Adult and nymph both suck up the sap from the lower surface of leaves and secrete honey which promotes a black fungal growth on leaves called sooty mould. The presence of this fungus on leaves lower down the photosynthesis activity of the plant. In infested sugarcanes amount and quality of sugar both are decreased. 35% reduction in sugar

is not uncommon. Cane juice from infested cane does not solidify properly. The peak period for infestation is September to November. Conducive factors are –

(i) High Humidity
(ii) Low temperature
(iii) Low rainfall or longer period of monsoon break

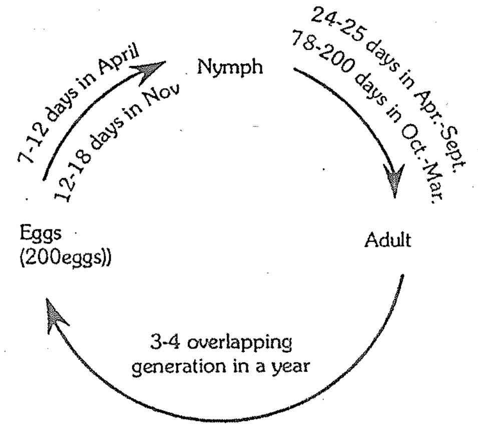

Fig.-9. Life Cycle of Sugercane Leafhopper

(2) Sugarcane root borer :

The caterpillars enter from the base of the stem and move downwards towards root as a result the 'dead heart' formation takes place which does not give foul smell and can not be pulled out.

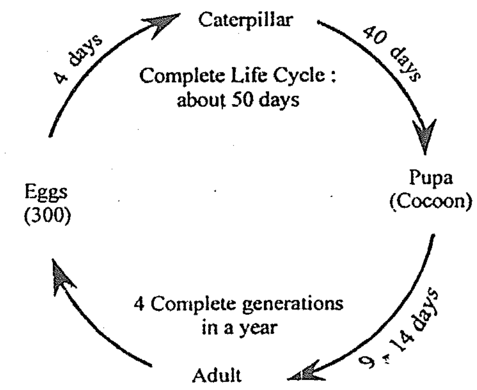

Fig.-10. Life Cycle of Sugercane root boror

(3) **Sugarcane shoot borer :**

The larvae reach to the plant base and bore into the shoot and move upward forming dead heart which gives offensive odour.

(4) **Sugarcane top borer :**

The young larvae bore into the mid-rib of the leaves mining their ways to base from there they enter the spindle, feeding on growing point and soft portion of cane causing **bunchy top** and dead heart. The first two broods of this pest attack young plant before cane formation. In subsequent broods, the pest attacks the terminal portion of the Cane. Damage by third and fourth brood may result in more than 25% reduction in weight and decrease in quality of juice. The loss in sugar recovery is from 0.2 to 4.1 units.

(5) **Gurdaspur borer :**

The young larvae enter the top portion of the cane through a single hole just above a node. There, they feed gregariously by making spiral galleries which run upwards thus killing the plants. After about 7-10 days, when the cane top has dried up, the larvae come out and enter the adjoining canes single or in twos.

IPM in sugarcane :

For IPM in sugarcane pest monitoring, biological control and preventive control measures are necessary. Use of healthy seeds, clean cultivation/field sanitation and destruction of pests of early infestation are must for pest control. For the control of shootborer, stalk borer, mealybugs, scale insects and white flies, cultural practices, like selection of healthy setts for seed adjustment in planting time, detrashing, removal of late shoots and proper use of water and fertilizers minimize the number of insect pest. For primary infestation of gurdaspur borer and top borer mechanical control is helpful. Avoid use of cane setts from field infested more than 40% due to stalkborers or scales. Egg mass of white grubs and beetles and others can be picked up with hand.

For the control of top borer indigenous parasitic wasp (*Isotima javensis*) is released in the fields. This parasite is not effective in north India because pest and parasite both hibernate in winter but in South India the parasitic activity is seen through out the year because winter does not exist there. The parasite minimizes the number of pest upto 5 to 10%.

For the control of pyrilla, release cocoons of *Epiricania melanoluca* 4000 to 5000/ha. For the control of shoot borer, internode borer, gurdaspur borer release Trichogramma 50,000/ha/week. *Trichogramma chilonis* @100,000/ha in 2-3 batches. For scale insects coccinellied (predator) is

effective. *Pharoscymnus horni* and *Chilocorus nigritus* may be released in the fields.

Insect-Pest of Pulses

S.N.	Common Name	Zoological Name	Family
1.	Pod borer	*Helicoverpa armigera*	Noctuidae
2.	Gram cutworm	*Agrotis ypsilon*	Noctuidae
3.	Tur Pod fly (Red gram Pod fly)	*Melanagromyza obtusa*	Agromyzidae
4.	Blue Butterfly (on Redgram)	*Lampides boeticus*	Lycaenidae
5.	The plume moth caterpillar	*Exelastis atomosa*	Pterophoridae
	*Tur means Arhar		

(1) **Pod borer :**

It is a serious pest of chickpea, pigeonpea, pea, mungbean, urdbean, lentil, Soybean and cowpea. In America it is known as 'Cornworm' or cottonboll worm due to its serious damage to maize and cotton there. The young larvae feed on foliage for some time and later bore into the pods and feed on developing grains.

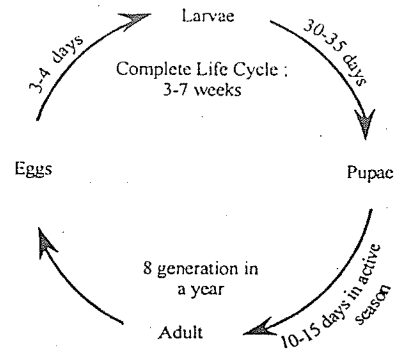

Fig.-11. Life Cycle of Pod borer

(2) **Gram cutworm :**

The caterpillars are responsible for damage. They cut the plants from the surface of soil at night (noctural in habits). In day time they hide in crack and crevices of fields.

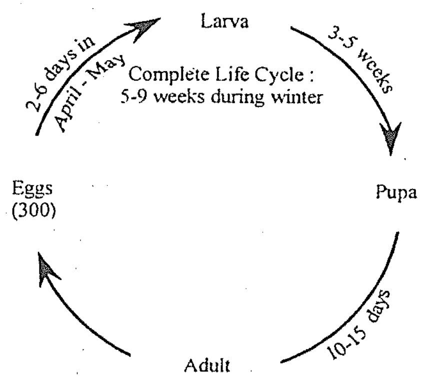

Fig.-12. Life Cycle of Gram Cutworm

IPM in Pulses :

Gram and redgram are main pulse crop grown in North India. The major pest of gram is gram caterpillar and pod borer and pod fly are the major pest of redgram. For the control of these pests following IPM Schedule is suggested :

(i) Early maturing and early sown (before mid October) varieties are not affected because these mature before peak activity of the pest.

(ii) Crop rotation with non-host plants.

(iii) Use of resistant or tolerent varieties – Gram JG 315 and JG74 (middle India) ICCV-7 (South India) Arhar-Bahar and ICPL 332 (South India) and JA3 and JA4 (Middle India)

(iv) In North India intercropping of Gram + Linseed/ Mustard and in South India Gram + Coriander encourage natural enemies. Don't grow Arhar in the cotton growing areas. Intercropping of Gram + Barley/ Wheat/Mustard/Linseed and Arhar + Jowar/Maize/Bajra should be adopted.

(v) For Control of pod borer use bioinsecticide HaNPV @250-500 Larvalequivalent (LE)/ha. The sraying should be done in evening time. Economic Threshhold level (ETL) for gram pod borer is one larva/ 5plants.

For control of this pest Neem Seed Kernel Extract 5%, Quinalphos, Endosulphan, Fenvelerate can also be used. For control of podfly spraying of monocrotphos is useful. After initiation of bud need based spraying at the interval of 15 to 20 days can be done.

(vi) Use of sex pheromone trap is also helpful in controlling podborers.

Insectpests of oil seeds

S.N.	Common Name	Zoological Name	Family	Remark
1.	White grub	*Holotrichia spp.*	Scarabacidae	Serious pest of ground nut.
2.	Mustard Aphid	*Lipaphis erysimi*	Aphididae	Serious pest of rape seeds
3.	Groundnut leaf miner	*Stromopteryx nertaria*	Gelechiidae	Pest of ground nut.
4.	Painted bug	*Bagrada cruciferarum*	Pentatomidae	Pest of Crucifers
5.	Mustard Sawfly	*Athalia proxima*	Tenthridimidae	Pest of Mustard

(1) White grub :

It is a root feeding pest. It feeds on functional roots of the plant leaving the original tap root. Some times it causes 100% damage. It is a soil inhabiting insect and prefers dry sandy/Sandy loam soils.

(2) Mustard Aphid :

All the stages of pest in gregarious form suck the sap from plant leaves, stems and branches, flowers and pods. It secretes honey duw on plants which promotes fungal growth, a black fungus called shooty mould. From Dec. to Jan. pest is very active. The females in plains multiply panthenogenetically. Females are viviparous. Winged and wingless both forms are present Groundnut aphid (Aphid Craccivora) cause ***Rosette viral*** disease in groundnut.

(3) Mustard sawfly :

The Females have saw like ovipositors hence called sawfly. Larvae have 8 pairs of prolegs. The larvae feed in group of 3 to 6 on leaves during morning & evening and remain hidden during day time.

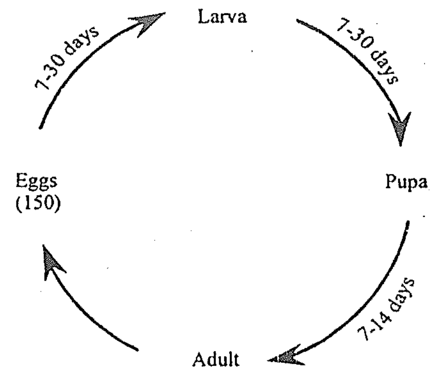

Fig.-13. Life Cycle of Mustaed Sawfly

(4) Painted bug :

Adult + nymph both suck the sap from plants of family cruciferae.

IPM in Oils seed :

For the control of white grub both the stages adult beetle & grub should be controlled. In the early mansoon season the adult beetle can be controlled by spraying inseticides. At that time they live on Neem, Ber and Gular trees. The control of beetles in comparison to grubs is cheaper and effective also. It should be done on co-operative basis. The seed can be treated with chlorpyriphos or Quinalphos @25ml/kg to prevent the damage of grubs. Fodder crops in summer may be sown in infested areas to attract grubs and plough in July/August to kill grubs. Beetles can be attracted by light traps. For the microbial control of grubs pathogenic bacteria, *Bacillus popillae* and pathogenic fungi *Matarrhizium anisoplinae, Beauveria brongniartii* and B. brassiana can be used for effective result.

Early sowing of mustard prevents aphid's attack.

For control of mustard aphid its natural enemies like predator, lady bird beetle and Aphidius (Parasite) may be encouraged. 50 to 60 aphids per 10 cm shoot length shows its ETL. At the time of minimum number of pollinators at morning and evening; the insecticide like monocrotophos can be used if necessary

Insect Pests of Vegetables

(1) Fruit fly :

Dacus cucurbitae, Family Tephritidae order-Diptera

Food – Cucurbitaceous plants.

The females lay eggs in shoft fruits, a cavaity is made by the sharp ovipositor and about a dozen white cylindrical eggs are laid, mostly in the evening time. The eggs hatch in 1-9 days and maggots bore into the pulp forming galleries. The attacked fruits decay because of secondary bacterial infection. After maturity the maggots drop down from fruits and pupate into the soil.

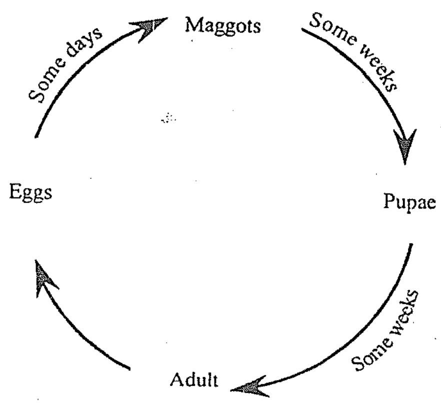

Fig.-14. Life Cycle of Furit Fly

(2) Red pumpkin beetle :

(Raphidopalpa sp) Fam. chrysomelidae Coleoptera Adult and grub both cause damage. The Grubs lead a subterranean life. Beetles are destructive to young plants, they injure the cotyledons, flowers and foliage by biting holes in them. Grubs bore the roots, underground stems and some time fruits touching the soil.

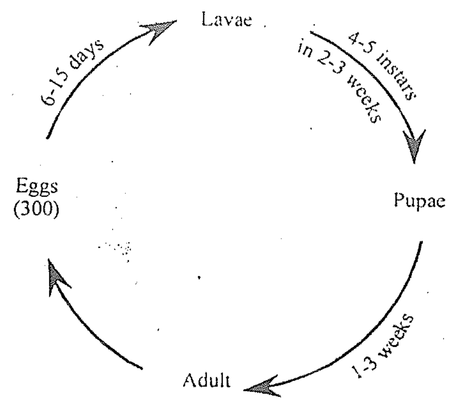

Fig.-15. Life Cycle of Red Pumpkin Beetle

(3) Brinjal borer :

Leucinodes orbonalis Family Pyralidae. The terminal shoot is attacked and the growing points are killed. They may bore flower buds and fruits also. The caterpillar may destroy 4-6 fruits.

(4) Hadda beetle :

Epilachna dodecastigme Fam. Coccinelidae. Adult and grub both are responsible for damage, they cause damage to plants of cucurbitaceae and solanaceae especially to Brinjal and tomato by feeding the upper surface of leaves. The pupae are found fixed with plant leaves, stem and base of the plant.

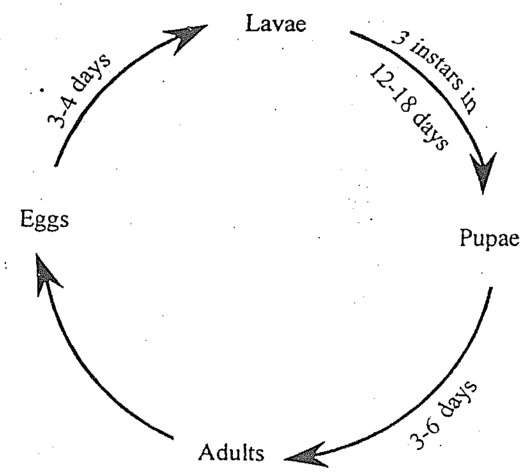

Fig.-16. Life Cycle of Epilachna Beetle

(5) Jassids (Leaf hoppers) :

Amrasca devastans Fam. Cicadellidae. It is popularly known as leaf hopper. It is a important pests of Potato and Lady's finger. They suck up the sap from plant leaves and tender parts. Both adult and nymph cause damage. They secrete a toxin which causes hopper burn in plants. Their legs are modified for hopping just like locusts or grasshoppers.

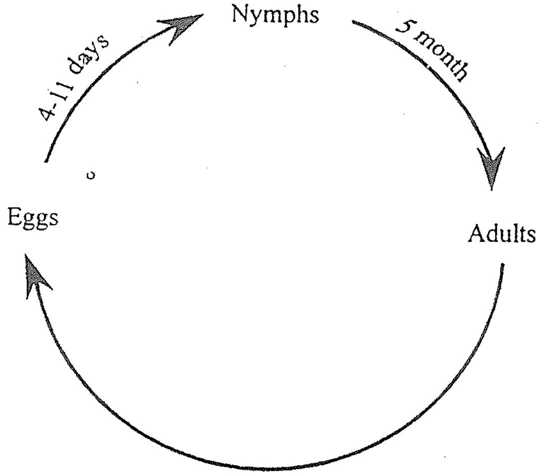

Fig.-17. Life Cycle of Jassids

(6) Tomato fruits borer. *Helicoverpa armigera :*

It is a major pest of tomato. For its control Marigold may be transplanted with tomato which attracts the natural enemies in large numbers. The ETL of this pest in tomato is 8 egg/15 plants. For the control of the pest *Trochogramma brasiliensis* can be used @ 50,000/ha at a interval of a week at least 6 times. Use of Ha-NPV @ 250LE/ha + 0.25% boric acid gives satisfactory result.

(7) Diamond-black moth – *Plutella xylstella* Lepidoptera : Fam. Ponomeutidae.

The caterpillars damage leaves of cabbage, cauliflower, rapeseed and mustard. This pest has become resistant to insecticides. Mustard is used as trap crop. About 80 to 90% pest are attracted to mustard. For control of this pest in cabbage Neem seed Kernal extract 4% can be sprayed at the head formation stage at the interval of 15 days twice or thrice.

(8) Mustard Aphid

(9) Painted bug

Insect Pests of fruits and Fruit trees

(1) Mango hopper :

Amritodus atkinsoni Fam. Cicadellidae. It is a major pest of mango. Adult and nymph both suck the sap from leaves, inflorescence and tender shoots. They also secrete honey dew which causes the development of black fungus sooty mould. For the control of the pest, spraying of Cypermethrin (500 ppm), Carbaryl (0.1%) or Neem seed Kernal extract 4% can be done at the time of fruit setting. Parasites *Aprotocetus* sp, *Ganatocerus* sp. *Polynema* Sp. and predators *Cryspa, Lacciperda, Maidada nominensis* are identified as bioagents. Proper spacing of 10m x 10m and pruning is helpful in pest management.

(2) Fruit fly : *Dacus dorsalis*

It is a major pest of mango and guava. The female deposits eggs inside the fruit 3 to 4 mm deep. After hatching of eggs maggots start feeding on the pulp as a result fruits decay and ultimately drop down. The population of the pest reaches at peak in March-April, May-June and September-October. Spraying of Deltamethrin 0.0025% and then Fenthion 0.05%, Dimethoate 0.04% or Carbaryl 0.1% at the interval of 12 to 15 days is recommended for mango. For guava 0.03% Phosphamidon can be used. Poison baiting is also helpful for controlling the pest.

(3) Mealybug : *Drosicha mangiferae* Fam. Margarodidae (on mango)
Dysmicoccus brevipes (on pineapple)
Maconcellicoccus hirsutus (on grape)

Host - All Common fruits.

Damaging stage – Numph + Female adult only by sucking. For control of mango mealy bug, digging of soil around the tree and mixing of 5% Malathion dust is beneficial. Use of greese band and cellophone band on the trees is also effective. Spraying of 0.03% Monocrotophos can be done if other methods fail. For control of pineapple mealy bug, use phorate @1.75kg/ha. For grape mealy bug, use of Dichlorvos is effective. A predator Lady bird beetle predator Australian Origin *(Cryptolaemus montrouzievi)* @ 1200 beetles/ha can be used for effective check of the pest.

(4) Fruit sucking moth :

Otheis fullonica, Ophideres materna (Lepidoptera: Noctuidae)

Damage : Only by Adult (not larvae). These pests are minor pest of citrus, mango, grapes and apple. The adult moths cause damage They pierce the fruits and make punctures for sucking juice. The site of attack is infected by fungus and bacteria with the result whole fruit turns yellow and drops off the tree.

Managements : Destruction of alternate host plants from vicinity.
Disposal of fallen fruits which attract pest.
In small scale bagging of fruits can be done.

Poison baiting – gur 1 kg + Vinegar 60g + lead arsenate 60g + water 10 litres. This solution should be applied in a wide mouth bottle 1 bottle per 10 trees. Bottle containing bait should be tied to the trees.

(5) Citrus Psylla :

Diaphorina citri Fam. Psyllidae : It spreads greening disease (Gracillicutes gram negative bacteria). It is serious in Punjab. The main cause of damage are nymphs & adults which crowd on terminal shoots and buds and suck plant sap. Leaves curl up and drop and shoot may even die.

Control: Infested plants may be sprayed with dimethoate (1ml/litre of water) or phosphomidon (1ml/2 litre of water) or demeton (1ml/litre of water)

Natural enemies : *Coccinella septempunctata L.*
Chrysopa sp.
Chilomenes sexmaculata.

(6) Lemon butterfly : *Papilio demdeus* – Lepidoptera : Papilionidae

The caterpillars are responsible for damage. They cause severe defoliation by eating. The damage is very severe to young plants, they may become completely devoid of leaves and ultimately die. The peak period for infestation is April to May and August to October.

Control :
1. Hand picking of caterpillars on smaller plants and their destruction.
2. Spraying of quinalphos (1ml./litre of water)

or fenvralcrate, cypermethrin or decamethrin @ 0.2 to .3ml/litre of water)

Natural enemies – *Trichogramma evanescens* (egg parasite)
Erycia nymphalidaephaga (Parasite of caterpillars)

(7) Anarbutterfly – (Pomegranate fruit borer)

Lepidoptera : Lycaenidae; *Virochola isocrates*

Pomegranate, guava, Ber, loquat, Sapota and tamarind are attacked but most destructive to pomegranate.

The caterpillars cause damage. They bore into fruits and feed on seeds. They plug the entry holes by their anal ends. The infested fruits drops prematurely or when the mature fruits are opened seeds are found eaten up.

Control : Bagging of fruits with cloth bags, butter paper or polythene on small scale is very effective.
Spraying of phosphamidon (3ml/10 litres of water) at interval of 15 days at least 5 times is recommended.

(8) San Jose Scale :

Quadraspidiotus perniciosus Hemiptera : Diaspididae

Plants beloning to the family Rosaceae such as apple, plum, pear, peach are severely attacked, though it is serious pest in temperate regions on nearly 700 different specieis of fruits.

Damage is caused by nymphs and female scales which suck up the sap from twigs, branches and fruits though all parts above the ground are attacked. Large number of insects may cause death of the plant.

Management –
1. Orchard sanitation. Infested pruned material should be burnt.
2. The plants in nursery can be protected by applying Carbofuran granules @0.75 – 1.0 g a.i. per plant.
3. 2% miscible oil can be sprayed during Feb. and March.
4. Use of natural predators like *Aphytis procila, Chilocorus bijugus, Coccinella septempunctata* is beneficial

9. Woolly aphid : *(Eriosoma lanigerum)*

Hemiptera : Aphididae

It is a serious pest of apple, pear and crab-apple. Infested plants have pale green leaves and whitish cottony patches on stem and branches. The characterstic galls or knots are formed on roots and other underground parts.

Management :

1. Use of resistant root stock like Golden Delicious Morton stocks 778, 779, 789 and 793 and Mailling Merton (MM) root stocks like MM 106, MM 109, MM 111.
2. A parasite *Aphelinus mali*, very effectively controls the pest.
3. Spraying of 0.05% Chlorpyriphos or fenitrothion.
4. Use of phorate or Carbofuran grnules in soil.

10. Apple root borer :

Dorystenes hungelii Coleoptera : Cerambycidae

The grubs are responsible for damage. They bore the roots of apple. A number of other fruits like Cherry, peach, pear, walnut are attacked. The eggs are laid 8-12 mm below the soil. The emerged grubs go 100 to 250mm down into the soil and feed m organic matter and roots of the plant. As a result of their feeding young plants die and older become weak and can not tolerate strong wind. Sandy soil are suitable for pest.

Management

1. Avoid sandy soils for planting.
2. Inter-culture under the tree helps in killing grubs
3. If infestation has occurred, treat the soil with phorate granule @100g. ai/tree. Chlorpyriphos may also be used for soil treatment.

❄❄❄

13. Plant Pathology : An Introduction

The term Plant pathology or Phyto-pathology has been derived from three greek words.

Phytopathology = Phyton + Pathos + logus

Phyton	Pathos	logus
↓	↓	↓
Plant	Ailments	Knowledge

Disease is a malfunctioning alteration of one or more ordered processes of energy utilization in a living system, caused by the continued irritation of a primary factor or factors.

Ancient Indian writer Surapal gave a detailed account on plant diseases in his book Vraksha Ayurveda. In this book he has classified plant diseases into External and Internal diseases. Theophrastus, the ancient Greek Philosopher in his book ''Enquiry into plants'' had included some of his observations regarding plant diseases.

Dutch worker *Leenwenhock* invented the microscope in 1675 and through it observed and described bacteria in 1683. this lead to the beginning of a new era in Biology. Italian botanist Micheli (1729) was the first to study fungi and observe fungal spores. A research paper on Bunt or Stinking smut of wheat was published by French botanist Tillet in 1755. In his paper Tillet proved that wheat seeds with black powdery mass on their surface had greater potential to cause diseases than healthy seeds. Thus it was concluded that Bunt was an infectious disease having some relationship with fungi. Prevost in 1807 proved that wheat bunt disease was caused by a fungus. He also discovered the life-cycle of the Bunt fungus. In 1853 Anton de Bary (1831-1888) confirmed the findings of Prevost. De Bary through his extensive studies on the late blight disease of potato conclusively proved that microorganism play an important role in plant diseases. Besides this De Barry also discovered the heteroecious nature of the rust fungus. He also described the life-cycle of Downey mildew fungus and provided informations about the role of enzymes in host-pathogen relationships. Because of his great contributions *De Bary* was given the title *"Father of mycology."* Julius Koon in 1858 wrote the first book on plant pathology in which he provided valuable informations regarding the role of fungi in plant disease development. ***Julius Koon*** is therefore called the ***Father of Modern Plant Pathology.***

German scientist Brefeld, who was a co-worker of De Bary, developed techniques of Artificial culture of microorganisms in between 1875 and 1912. These techniques made the study of infectious microorganisms easier.

In the latter half of Nineteenth century France had extensive cultivation of grapes for manufacturing wine. Downey mildew of grapes was introduced into Europe from America in 1878. ***Prof. Millardet*** of France discovered ***Bordeaux mixture*** for the control of this disease. At that time *Bordeaux mixture* was successfully used to control late blight of Potato and downey mildew disease of Grapes.

In 1876 Louis Pasteur and Robert Koch reported that Anthrax disease in Catle was caused by a bacterium. American scientist Prof. T.J. Burill (1878) discovered that Fire blight disease in apple and pear was of bacterial origin. His fellow American scientist E.F. Smith till the end of 1895 had conclusively proved the importance of bacteria as plant pathogens.

Swedish scientist ***Erikson*** in 1894 reported about of the existence of ***Physiological races*** in Rust fungus.

Ward (1903) and Salmon (1903, 1904) discover Physiological specialization in Cereal rust and powdery mildew. According to E.C. Stakman of U.S.A. due to continuous evolution of races & biotypes of the rust fungus their pathogenic capacity also keeps changing and so does the resistance capacity of the host.

Blakeslee in 1904 discovered ***Heterothallism in fungi*** and informed that in the life-cycle of fungus dissimilar nuclei participate. Heterokaryosis i.e. coming-together of dissimilar nuclei in a single fungal cell was discovered by Burgeff (1912 & 1914). Hansen and Smith for the first time demonstrated about the development of physiological races as a result of heterokaryosis. Flor (1955) proposed the Gene to gene hypothesis to explain disease resistance and susceptibility.

Needham in 1743 reported plant parasitic nematodes in wheat gall. In 1875 Berkebey and Schacht discovered the root knot nematode and cyst nematode of beet.

Cobb (1913-1932) studied the structure of many plant parasitic nematodes and classified them.

Adolf Meyer for the first time in 1836 discovered the viral disease tobacco mosaic. He proved that sap derived from diseased plant leaves has the potential to cause infection in healthy plants.

F.F. Smith in 1891 through his studies on Peach yellow disease concluded that it was an infectious disease whose transmission from diseased to healthy plants occurs through Grafting and Budding. Ivanowski in 1892 found that the agent causing tobacco mosaic could not be filtered through a chamberland filter although bacteria got easily filtered through it. Thus viruses were found to be smaller than bacteria.

Beijernick in 1898 proved that tobacco mosaic disease was not caused by a microorganism rather it originated from *Contagium Vivum fluidum* which he later called ***VIRUS***. In 1935 ***Stanley*** treated the sap obtained from Tobacco mosaic virus infected leaves with $(NH_4)_2\ SO_4$ and obtained crystalline protein. For this he was awarded Nobel Prize. Bowden & Pirie in 1936 proved that the crystalline powder of Bushy stunt virus of tomato contained Protein and nucleic acid. After the invention of ***Electron microscope*** by ***Knoll & Ruska*** (1932), *Kanschietal* in 1939 using this microscope studied the shape and size of the virus particle. Geirer and Schramm in 1956 proved that nucleic acid of the virus particle was the actual disease inciting agent. Viroid is only a naked nuclic acid molecule. The term 'viroid' was by T.O. Diener. Viroid is devoid of any protein coat and its RNA has a high molecular weight.

Potato Spindle tuber was the first disease reported to have been caused ***by a viroid.***

Virus = Nucleic acid (DNA or RNA) + Protein (outer cover)

Lipo-virus = Nucleic acid + Protein + lipid (e.g. Influenza virus)

Animal virus = DNA + Protein
(or Bacteriophage)

Plant Virus = RNA + Protein

Viroid = nucleic acid only

Plant viroid = RNA only

DNA = Deoxyribose nucleic acid

Plasmid/Episome : Extrachromosomal fragments found in bacterial cells.

Virus, viroid and plasmids all contain nucleic acid and lack their own metabolic potential.

Japanese scientist Doi et al in 1967 explained that diseases like witches broom of Potato, mulberry dwarf and Aester yellows etc. which were earlier thought to be of viral origin were actually caused by MLOs (Mycoplasma-like Organisms). Mycoplasma are larger than viruses but smaller than bacteria. They are devoid of Cell wall and cytoplasm is enveloped by a lipo-protein plasma-membrane. It is highly resistant against the antibiotic Penicillin but is sensitive to Tetracyclin antibiotic. ***Tetracyclin*** is therefore used to control mycoplasma. Mycoplasma was first isolated from sheep infected by Pleuro-pneumonia and therefore called PPLO (Pleuro-pneumonia like organisms). Most of the yellow diseases of plants are caused by Mycoplasma.

K.R. Kirtikar was pioneer worker on plant pathology in India. Kirtikar was the first Indian scientist who collected many Fungi and identified them. ***E.J. Butler*** of Imperial Research Institute, Pusa (Bihar) before 1910, did detailed studies of Fungi and diseases caused by them. He wrote a book *''Fungi and Diseases in Plants''*. He is therefore called the ***Father of Modern Plant Pathology in India.*** J.F. Dastur (1886-1971) was the first Indian plant pathologist to study in detail on fungi and plant diseases. B.B. Mundkur developed resistant varieties to control cotton wilt disease. The credit for identifying and classifying the smut fungi found in India also goes to Mundkur. He established the Indian Phytopathological institute and started the publication of Indian Phytopathology in 1948. ***Dr. Karam Chand Mehta*** *(K.C. Mehta)* of Agra College discovered *diseases cycle* of cereal rust in India. ***Prof. Jaichand Luthra and Sattar*** developed *Solar treatment* technique of seeds to control *loose smut* disease in wheat. *M.J. Thirumalachar* performed extensive studies on rusts and smuts in India. Thirumalachar on joining 'Hindustan Antibiotics' developed antibiotics like Oreofungin and Streptocyclin which lead to their successful use in plant-disease control in later years.

Technical terms : An Introduction

1. **Blight** : A non-restricted tissue disintegrating symptom characterized by general and rapid killing of leaves, flowers & stem.

2. **Hyperplasia** : Excessive development due to increase in the number of cells.

3. **Hypertrophy** : Excessive growth due to increase in size of cells.

4. **Hypersenstivity** : Excessive sensitivity of plant tissues to certain pathogens. Affected cells are killed quickly, blocking the advance of obligate parasites.

5. **Parthenogenesis** : Formation of embryo without fertilization.

6. **Rogueing** : Removing of unwanted (virus infected) plants from a field of crop.

7. **Obligate parasite** : A parasite that in nature can grow and multiply only on living organisms.

8. **Facultative parasite** : An organism that is usually saprophyte under certain conditions may become parasite.

9. **Facultative saprophyte** : An organism that is usually parasite but may also live as a saprophyte.

10. **Damping off** : Destruction of seedling near the soil surface, resulting in the falling of seedling on the ground.

11. **Mildew** : A plant disease caused by a fungus in which the mycelium and spores are seen as a whitish growth on the host surface.

12. **Virulent** : Strongly pathogenic

13. **Incubation period** : Period between infection and appearance of symptoms induced by parasitic organisms.

14. **Ination** : Deformity caused by viral infection.

15. **Eradication** : Control of plant diseases by eliminating the plants that carry the pathogen.

16. **Necrosis** : The death of cells or of tissues.

17. **Alternate host** : One of the two kinds of plants on which a parasitic fungus (e.g. black rust of wheat caused by *Puccinia graminis tritici*) must develop to complete life-cycle.

18. **Autaceious fungus** : A parasitic fungus which completes its entire life cycle on the same host (e.g. *Melampara lini*)

19. **Agar** : A gelatin-like substance obtained from sea weed (red algae *Gracilaria, Gelidium* etc.) and used to prepare culture media on which microorganisms are grown for study.

20. **Smut** : A disease caused by Ustilaginaceae characterized by masses of dark, powdery spores.

21. **Sooty mould** : The sooty envelope formed by the fungal mycelia on the surface of leaves and fruits.

22. **Witche's broom** : Broom like growth.

23. **Mycorrhiza** : Symbiotic relationship between roots of higher plants and fungal mycelia which is essential for the growth of these plants.

24. **Fungistatic** : A compound which prevents fungal growth without killing the fungus.

25. **Rust** : A disease of grasses and other plants giving a rusty appearance to the plant and caused by uredinales (rust fungi).

26. **Canker** : A necrotic or sunken lesion on a stem, branch or fruit of a plant (e.g. citrus canker caused by *Xanthomonas citri*)

27. **Plasmogamy** : Fusion of cytoplasms of two cells.

28. **Physiologic race** : One of a group of microorganisms like in morphology but unlike in certain cultural, physiological, pathological or other characters.

29. **Physiological specialization** : the existence of a number of physiologic races or forms within a species or a pathogen.

30. **Latent virus** : A virus that does not induce symptoms in its host.

31. **Latent infection** : The stage in which a host is infected with a pathogen but does not show any symptoms.

32. **Gummosis** : Production of gum by plant tissue.

33. **Masked symptoms** : Virus induced symptoms which are not visible under certain environment conditions but get to be expressed under certain conditions of temperature and pressure.

34. **Spot** : Disease symptom in which certain restricted tissue disintegrating areas are produced on leaves, stem and fruit.

35. **Hustorium** : A projection of hyphae into host cells which acts as a penetration and absorbing organ.

36. **Biotype** : A subgroup within a species usually characterized by the possession of a single or a few characters in common.

37. **Toxin** : A compound produced by a microorganisms and being toxic to a plant or animal.

38. **Bacteriostatic** : A chemical or physical agent that prevents multiplication of bacteria without killing them.

39. **Bacteriophage** : A virus which infects specific bacteria and kills them.

40. **Scorch** : Burning of leaf margins as a result of infection or unfavourable environmental conditions.

41. **Blotch** : A disease characterized by large and irregular spot or lesions on leaves, shoots and stems.

42. **Exudate** : Liquid discharge from plant tissue.

43. **Heterotrophic** : An organism depending on an outside source for organic nutrients.

44. **Host** : A plant that is invaded by a parasite and from which the parasite obtains its nutrients.

45. **Etiolation** : yellowing of the plant due to deficiency of light.

46. **Scab** : A rough, crust like diseased area on the surface of a plant organ. A disease in which such areas are formed.

47. **Gall** : A swelling produced on a plant as a result of infection by certain pathogens.

48. **Yellows** : Yellowing and stunting of host plant.

49. **Antigen** : A substance (usually a protein, lipid or carbohydrate) which after entering into a body activates the production of antibody.

50. **Antibiosis** : the phenomenon in which a substance produced by one microorganism is harmful to another organism.

51. **Antibody** : A protein produced by specific stimulation when a foreign antigen enters into the blood of an organism. Antibodies get attached with the antigens and makes them ineffective or harmless.

52. **Race** : A genetically distinct mating group within a species; also a group of pathogens with distinct pathological or physiological characterstics.

53. **Phytoalexin** : A substance that inhibits the development of a fungus on hypersensitive tissue, formed only when host plant cells come in contact with the parasite.

54. **Foliocellosis/Frenching** : A disease caused due to deficiency of Zn in fruit trees (specially belonging to *citrus* family) in which new leaves develop inter-veinal chlorosis, get reduced in size and branches are also not properly developed. The plant has a bushy appearance and the branches show die-back symptoms. It is also called leaf mottle disease.

55. **Exclusion** : control of plant disease by excluding the pathogen or infected plant material from disease free areas.

56. **Pleomorphism/polymorphism** : Having various forms in a life cycle – The rust fungus is allomorphic as it produces five different types of spores in its life-cycle.

57. **Hetoroecious fungus** : Passing different stages of life history in different hosts.

58. **Epidemic disease** : A wide spread & severe outbreak of a disease.

59. **Rhizoids** : A short, thin hypha produced by a thallus that grows towards the substrate.

60. **Saprophyte** : In organism which lives on dead and decaying organic matter.

61. **Downey mildew** : A plant disease in which the mycelium & spores of the fungus appear as a downey growth on the host surface.

62. **Mosaic** : Symptom of certain viral diseases of plants characterized by intermingled patches of normal and light green or yellowish colour.

63. **Wilt** : Loss of rigidity and dropping of plant parts wholly or partially.

64. **Rugose** : Rough and crinkled leaves produced as a result of viral infection e.g. Rugose mosaic of Potato.

65. **Russetting** : Brownish roughened areas on fruit skin produced as a result of excessive cork formation.

66. **Rickettsia like Organisms** : RLOs a prokaryotic microorganism having a cell wall and obligate intra-cellular parasite.

67. **Susceptibility** : The inability of a plant to resist the effect of a pathogen.

68. **Susceptible** : A plant or species which is incapable of resisting the effect of a pathogen.

69. **Pathogen** : An disease causing agent in plant.

70. **Resistance** : The ability of an organism to overcome, completely or partially the effect of a pathogen.

71. **Vector** : An insect able to transmit a pathogen.

72. **Disinfectant** : A physical or chemical agent that frees a plant or organ from infection.

73. **Immunity** : The state of being exempted from infection by a given pathogen.

74. **Ring spot** : A circular chlorotic area with a green centre; symptom of many viral diseases.

75. **Virion** : A complete virus particle.

76. **Viroid** : A naked nuclueic acid which resembles virus but is devoid of protein coat.

77. **Carrier** : A plant or an organism which carries an infections agent but does not show symptoms of disease produced by the agent.

78. **Lesion** : A localized area of discoloured, diseased tissue.

79. **Rot** : The softening, discolouration and disintegration of a succulent plant tissue as a result of fungal or bacterial infection.

80. **Disinfestant** : An agent that kills or inactivates pathogens in the environment or on the surface of the plant, prior to infection.

81. **Antagonistic symbiosis** : Parasitic symbiosis in which one organism benefits from another.

82. **Endemic disease** : A disease which regularly occurs on a particular area of earth or country.

83. **Shot hole** : A symptom in which small diseased fragments of leaves fall off and leave small holes in their place.

84. **Heterothallic fungi** : Fungi producing compatible male and female gametes on the physiologically different mycelia.

85. **Vein claering** : Distruction of chlorophyll in the vein tissue, as a result of infection by a virus or other pathogen.

86. **Vein banding** : Bands of green tissue along the veins while the tissue between the veins become chlorotic.

87. **Die back** : Progressive death of shoots and roots generally starting at the tip.

88. **Anthracnose** : A leaf spot or fruit spot type of disease caused by fungi that produce their sexual spores in an acervulus.

89. **Infection** : Establishment of the pathogen in the host.

90. **Infections disease** : A disease caused by a pathogen which can spread from a diseased to a healthy plant.

91. **Quarantine** : Control of export and import of plant to prevent spread of diseases or pests.

92. **Syndrome** : A set of symptoms which charactersize a disease.

93. **Transmission** : Transfer of pathogen such as viruses from one plant to other.

94. **Conjngation** : A type of sexual reproduction in which morphologically similar gametes fuse.

95. **Culture** : Growing microorganisms on a prepared nutrient medium.

96. **Homothallic fungus** : Fungi producing compatible male and female gametes on the same mycelium.

97. **Pustule** : Small blister like elevation of epidermis.

98. **Chlorosis** : Yellowing of green tissue due to chlorophyll destruction.

Rust in India

In our country, out of the major two rusts infesting crop wheat, leaf rust and stripe rust, the former is more harmful. The three types of host related with this disease are as follows :

(i) **Alternate host** : This host is required to complete the life-cycle e.g. *Barberis* is the alternate host of stem rust whereas *Thalictrum* is the alternate host of leaf rust. In India however alternate hosts have no importance in the life-cycle of rust fungus. Yellow rust has no alternate host in India.

(ii) Collateral host : Besides agricultural crops the uredial and conidial stages of the rust pathogen survive on Grass hosts e.g. Bromus sp and Agropyron are the collateral host of yellow rust. Brome grasses serve as collateral host for leaf rust and similarly *Bromus* sp (In Northern India) and Brija minor (in Southern India) are collateral hosts for Black rust.

(iii) Primary host : The host on which the rust pathogen produces its telial & resting stages is the Primary host. Dr. K.C. Mehta and his team have identified three hosts on which uredial spores are produced.

(a) Continued available host

(b) Self growing wheat plants.

(c) Grass host e.g. Bromus etc.

Mehta and his associates undertook research surveys from the foothills to the higher attitudes of Himalayas and concluded that Rust fungus perpetuates in hills of Northern India. L.M. Joshi, a student of Dr. Mehta reported that although the rust pathogen perpetuates in Northern India but its main source was the coastal areas of Indian Ocean and Bay of Bengal.

According to Dr. K.C. Mehta wheat crop occupies maximum time of the year in hilly areas of Sindh. The short period of 2-3 months when the wheat crop is not available in the fields, the pathogen survives through its uredial stages on wild wheat and other grassy hosts.

Predisposing factors

(a) Nearness of hills.

(b) Speed and direction of wind

(c) Amount of moisture and sunlight

(d) Suitable hosts.

There are four stages in the life cycle of rust organism. These have been represented by roman digits in the given table. The functions of these four stages had been well understood before 1927.

Stages	Name	Remarks
I II III IV	Aecial Uredial Telial Basidial	Functions already Understood.
O	Pycnial	Number 'O' has been assigned to this stages as the function of this stage was not known before 1927.

Craigie in 1927 discovered the function of Pycnial stage and reported that plasmogamy occurs in this stage. Craigic for the first time reported Heterothallism in Rust fungus. Among these five stages only uredial (II) and telial (III) are found on wheat. Pycnial (O) and Aecial (I) stages are present or Berberis and Mahonia whereas Besidial stage is produced on the inactive substratum on which teleutospores are produced.

Physioligical Specialization :

Erikson (1893) reported that *Puccinia graminis* was not a composite pathogen. He classified it into five formae specialis or varieties. These varieties differed from each other with respect to the shape of uredospore and other morphological characters such as colour and roughness. The term f. sp. has been placed between gaminis and tritici which indicates that triticum is a special form of Triticum allies. This very property of the organism is called Physiological specialization.

Later Stakman (1915) reported that even *puccinia graminis* f. sp. tritici was not a composite organism. He concluded that the special form of *Puccinia graminis tritici* was again made up of several forms which he called 'Biotypes'. He again observed that even a Biotype was not a composite organism and was composed of several 'races'.

Biotypes – represented by Arabic numerals i.e. 1, 2, 3, 4

Races – represented by roman letter a, b, c, d,

Example : the complete name of fungus causing Black rust/stem rust is as follows :

Puccinia graminis f. sp. *tritici* 16d.

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14. *Chemicals used in Disease Control*

Certain chemicals are toxic to pathogen. Such chemicals check the growth and development of pathogens and kill them. Based on the nature of the pathogen against which these chemicals are used, the latter have been classified into fungicides, bactericides, nematicides, viricides etc.

Fungicides :

Fungicide = Fungus + caedo = Latin words

Fungus ↓ Means ↓ Fungus

caedo ↓ Means ↓ to kill

Chemical or physical agents (Heat, UV rays etc.) having the potential to kill fungal pathogen come under this category. Although the term fungicide is generally used for chemical agents only.

Certain chemicals temporarily check the growth of fungal pathogen and do not kill them. Such chemicals are called **fungistatic** chemicals. Chemicals which check the production of spores in fungi are called **antisporulant** although all such chemicals which protect the plants from fungal pathogen come under the broader definition of fungicide.

Types of Fungicides :

(A) Sulphur fungicides : Sulphur since ancient times has been used as a fungicide. e.g. – Elemental Suphur and lime sulphur

(B) Copper Compound fungicides : The fungicidal nature of bone stone, copper sulphate was first of all discovered by **Prevost** (1807) against Bunt disease.

(B_1) Bordeaux Mixture : Prof. ***Millardet*** of France in 1882 accidentally discovered Bordeaux mixture from the mixture of copper sulphate and lime. This he successfully used to control downey mildew of grape. Millardet first of all prepared Bordeaux mixture by mixing copper sulphate, lime and water in the ratio 8:15:100 (8kg of $CuSO_4$ + 15 kg lime

+ 100 litre water). But this mixture was extremely powerful and caused foliar injury. Bordeaux mixture is now prepared in following concentrations

(a) 4 : 4 : 50 = 0.8% (4 pounds copper sulphate + 4 Pounds lime + 50 gallon water)

(b) 5 : 5 : 50 = 1.0% (5 pounds copper sulphate + 5 pounds lime + 50 gallon water)

Nowadays 5:5:50 (1.0%) ratio is often used.

Thus Bordeaux mixture contains three ingredients :

(i) Copper sulphate/Blue stone = $CuSO_4 \cdot 5\,H_2O$

(ii) Quick lime

(iii) Water

The following reactions take place in Bordeaux mixture

$CuSO_4.\ 5H_2O + CaO \rightarrow Cu\ (OH)_2 + CaSO_4$

Because of the lime content High volume spray is used for the application of Bordeaux mixture.

(B_2) Burgundy mixture/Soda-Bordeaux mixture : In this mixture lime is replaced by sodium carborate or washing soda or soda ash, the rest composition being similar to Bordeaux mixture. In ancient Europe because of the non-availability of Quick lime Mason in 1887 used Sodium carbonate in its place. This he did in the city of Burgundy and therefore the name Burgundy mixture.

Burgundy mixture =	Copper Sulphate +	Sodium Carbonate +	Water
	↓	↓	↓
	5 or 6lb	$6\frac{1}{4}$ or $12\frac{1}{2}$ lb	50 gallon
	↓	↓	↓
	$CuSO_4\ 5H_2O$	Na_2CO_3	H_2O

(B_3) Chestnut compound/Cuprammonium fungicide :

Use of chestnut compound as a fungicide was first of all done by Bewlery in 1921 against Damping off disease of seedlings.

Chestnut Compound or Cupprammomium Fungicide	=	two parts by weight of crystalline $CuSO_4$	+	11 parts by weight of $(NH_4)_2\ CO_3$

(B_4) Chaubattia Paste : This was first of all used at the Government Fruit Research Centre, Almora. This was used as a wound dressing fungicide against diseases of apple and pear such as Black

stem, brown stem etc.

Chaubattia Paste =	Copper Carbonate +	Red lead +	Lanolin/raw linseed oil
	800g $CuCO_3$	800g	1000 ml.

(C) Thiocarbamate Fungicides : The importance of Thiocarbamate in the field of Fungicides is comparable to the discovery of DDT as an insecticide. Though ***Spergon*** was the first Organic fungicide to be used commercially. In 1931 ***Tisdale*** first observed about the possible use of Thiocarbamate as a Fungicide. Thiocarbamate has been grouped into three categories :

(C_1) Thiuram disulphides : Among its different compounds only tertramethyl thiuram disulphide is used as a fungicide. This product is called ***Thiuram/thiram.*** It was included in the list of fungicides in 1934 basically as a ***seed protectant.*** But later on it was started using as a ***Foliage protectant*** and in certain conditions for ***soil treatment*** also. Its general formulation for its use as spray is 80% W.P. and 50% colloidal suspension. For seed treatment usually 50% powder is used. For better results 250 g.a.i. of Thiram is dissolved in 100 litre water and the seeds are soaked in it. For soil treatment 10-15 kg a.i. is used.

(C_2) Metallic dithiocarbamates :

(i) Ferbam : It is a *Fe (Iron)* containing fungicide.

It was developed by Tisdale and Williams in 1931. Its commercial use as a fungicide started in 1943. In temperate countries it is used against disease of apple and other fruits. For spray its formulation is 0.2 – 0.3% a.i. Its effect decreases on mixing with copper, lime and mercury.

(ii) Ziram : It is a ***Zinc*** containing fungicide. This is the most stable among the group of Dithio-carbamate fungicides. It has been found to be an effective fungicide to control diseases caused by Fungi Imperfecti in fruits and vegetables and also early blight of potato. It provides additional advantage in soil deficient in Zn. For spray purpose formulations of 0.2 – 0.3% a.i. and 50% W.P. are available in market.

(C_3) Ethylene bisdithiocarbamates :

(i) Nabam : Nabam is a sodium containing fungicide. Because of its phytotoxicity and instability it is not usually used in fields. Although it gives better results on mixing $ZnSO_4$ and lime.

(ii) Zineb : It is a ***Zn***-containing fungicide. Except certain sensitive plants Zn is usually not harmful for crops. It is used to control many diseases in plants. It is used for *soil treatment* to control Damping off and other soil-borne diseases. It has nematicidal property and is used to control *Meliodogyne spp.*

(iii) Maneb : This fungicide is similar to Zineb but in Maneb Zn is replaced by *Mn* i.e. it is *Mn-containing* fungicide. It was included in the list of fungicides in 1950. It is very effective against Foliar diseases especially Blight diseases of potato and tomato.

(iv) Mancozeb : It contains both Zn and Mn.

(v) Vapam/Metham-sodium : It is a *soil Fumigant* which was enlisted in 1954. It is used in partial sterilization of soil for the control of *Soil Fungi* and *nematodes*. It also acts as a herbicide.

S (Sulphur) is an important component in the structural formula of thiocarbamate fungicide.

S.No.	Fungicides	Metal constituent	Remark
1.	Thiuram/Thiram	No metal	used for Seed treatment+Soil treatment Foliage Protectant
2.	Ferbam	Fe	Used for Spraying
3.	Ziram	Zn	Used for Spraying
4.	Nabam	Na	–
5.	Zineb	Zn	Soil treatment+Nematicide
6.	Maneb	Mn	Effective for foliar disease control
7.	Mancozeb	Zn + Mn	Effective for foliar disease control
8.	Vapam	Na	Soil Fumigant + Herbicide

(D) Other Organic Fungicides :

(D_1) Glyodin : Wellman and Mecallan (1946) discovered about the fungicidal property of glyoxalidine derivatives which is now available under the trade name Glyodin in market. In temperate countries this fungicide is used to control Apple scab and other fruit diseases.

(D_2) Dodine/Cyprex : Dodine as a protectant fungicide became available in 1959. It does not harms bees. It can be safely mixed with ordinary fungicides and insecticides. It also has some eradicant property. Dodine is used to control Apple Scab and other foliar and fruit diseases.

(D_3) Quinone Compounds :

(i) Chloranil seed treating fungicide became available in the market under the trade name *'Spergon'* in 1940. Because of its disintegration in light, it is not used for foliar application.

(ii) Dichlone : After the success of Chloranil, Dichlone as a seed treating fungicide was launched in market in 1943 under the trade name *'Phygon'*. Besides its *seed protectant* property it is also used as a foliar protectant.

(D_4) Captan : As a protective fungicide captan was enlisted in 1949. It has been proved successful in the treatment of many diseases of fruits, vegetables and ornamental plants. Alongwith its use as a ***seed treatment*** fungicide it is also used to reduce post harvest losses caused by fungi in storage. Captan is also used for ***soil drenching*** @ 0.5% for protection against damping off.

(D_5) Folpet : Its physical and chemical properties are similar to captan and is sold under the trade name 'Phaltan?

(D_6) Difoltan : It is quite similar to Folpet and captan.

(D_7) Karathane (Dinocap) : It was first of all enlisted in 1954 to control *powdery mildew* disease in plants. Because of its solubility in oil, it is not used in oil based spray. It is a good substitute of sulphur and therefore used to control powdery mildew in sulphur – sensitive or Sulphur shy plants. Upto a certain extent it is also successful in controlling ***mites.***

(D_8) : Pentachloronitrobenzene (Quintozene) : It was enlisted in 1930 for the control of Soil borne pathogens and dry rot of potato.

Later on it came to be used to control *Rhizoctonia, Selerotium* and other soil fungi. It is persistant in soil and cucurbits and tomato plants are sensitive to it. PCNB (Penta Chloro Nitro Benzene) is a *nematicide* also. It has mainly *antisporulant* and *fungistatic* property.

(D_9) Organic Tin Compounds : TPTA (Triphenyl Tin acetate) was enlisted under the trade name Brestan whereas TPTA and TPTH (Tripheryl tin hydroxide) under the trade name Denter. TPTA also has insecticidal property. It was enlisted in 1954 to control Potato blight.

(D_{10}) Oils : Nowadays oil-mist spray is used to control Sigatoka disease of Banana. Fungicidal property of oils is only due to physical reasons.

(E) Antibiotics :

(E_1) Streptomycin : Streptomycin at 100 ppm or more concentration has been found to be effective against bacterial seed-borne pathogen. But as there is greater possibility of development of resistant strains in bacteria, streptomycin is mixed with Oxytetracyclin (terramycin). This mixture or combination is called *Agrimycin*. Streptomycin is effective against both Gram-positive and gram-negative bacteria. It does not possess fungi-toxic property.

(E_2) **Cycloheximide** : It is obtained as a byproduct in the production of Streptomycin. Its trade name is Actidione. It is active against Phycomycetic fungus *Pythium debaryanum* but is ineffective against bacteria. Cycloheximide is a *systemic* fungicide and is easily absorbed by roots & leaves. Its effect persists for about 5 weeks after spray. But its production is expensive and there is little difference between effective concentration and phytotoxic concentration. It can also cause mutagenic effect in plants.

It is therefore not used for disease control in agricultural crops.

(E_3) **Griseofulvin** : It was first isolated in 1939 from *Penicillium griseofulvum*. It is obtained as a byproduct of several species of *Penicillium*. It is a systemic fungicide. Griseofulvin does not check the germination of spore but affects the growth of hyphae. Thus it is not a true fungicide. It does not harm bacteria. Griseofulvin is active against Powdery mildew.

(E_4) **Aureofungin** : It is a broad-spectrum systemic antifungal antibiotic. It is used for seed treatment to protect from rot in storage.

(E_5) **Blasticidin-S** : It is produced from *Streptomyces griseochromogenes*. It is effective against many species of bacteria and certain fungi including *Pyricularia oryzae*. Because of its *growth inhibition* property, it is also used as a Chemotherapeutant.

(E_6) **Kasugamycin** : It is obtained from the culture broth of *Streptomyces kasugaensis*. It is selectively active against *Pyricularia oryzae* and *Pseudomonas* spp. Kasugamycin is more effective as an eradicant than as a protectant.

(F) Systemic Fungicides :

(F_1) **Oxathiin** : Oxathiin was developed by Von Schmeling and Kulka in 1966.

(i) **Carboxin or DMOC/DCMO** : Its trade name is *Vitavax*. It is a proven chemical against *Basidiomycetes fungi* (Smuts and Rusts).

Fungi such as *Verticillium albo-atrum* and *Monilia cineraria* f. *americana* can also controlled by carboxin as they are sensitive to this systemic fungicides.

Vitavax is used for seed dressing and soil drenching in order to control *Loose smut of cereals* (internally seed borne) and *Rhizoctonia disease* of cotton and sugarbeet.

This chemical is not very stable & completely degrades in soil within 10-30 days. Vitavax is used to control Loose smuts *(Ustilago nuda, Ustilago avena)* and bunts.

(ii) Oxycarboxin/DNOCD/DCMOD : Its trade name is *Plantvax*. It is used in controlling diseases related to fungi imperfecti. The diseases caused by members of fungi imperfecti are – Early blight of potato, Alternaria leaf spot of crucifers, leaf blight of wheat, Leaf spot of groundnut, stripe disease of barley, leaf spot of rice (Helminthosporium) blast of rice, Ripe fruit rot end Dieback of chillies, *Wilt* of pigeon pea, wilt of cotton, wilt of linseed, fusarium *wilt* or Panana disease of banana, *Wilt* of sugarcane.

(F_2) Pyrimidine derivattives –

(i) *Methyrimol* - It is effective against powdery mildew of cucurbits, cinarea, chrysanthemum and sugarbeet.

(ii) Ethirimol – It is like methyrimol and effectively controls powdery mildew of Crucifers.

(F_3) Benzimidazole : It comes under the name of ***Benomyl*** or ***Bavistin*** or ***Benlate***. It is a *superior systemic fungicide* which acts as a good *eradicant* and *protectant*. It has ovicidal action against *mites* eggs. Benzimidazole is effective against certain fungal diseases of crops such as rice blast, diseases caused by *cercospora*; verticillium of cotton, powdery mildew and black spot of rose, but has less effect on Helminthosporium spp. & Phycomycetes.

(F_4) Chloroneb : It is almost completely *fungistatic* and relatively non-fungicidal in action. It is easily absorbed by plant roots and its concentration is more in root and lower part of the stem. It is therefore used in supplemented seed treatment and soil treatment to protect plants from seedling disease during planting. Chloroneb is active against *Rhizoctonia* spp. It can be mixed with most of the pesticides and organomercurials used in seed treatment.

(F_5) **Thiabendazole (TBZ)** : Although TBZ was enlisted as an *antihelminthic* but it is a broad spectrum systemic fungicide. This fungicide is transported from the roots to the leaves of plant and sometimes in the reverse direction also. It does not undergo disintegration in plant tissues. It is effective against Blue and green moulds of citrus fruits. When applied @120g/100kg it successfully controls seed borne bunt, *Fusarium nivale* and *Septoria nodorum*. Verticillium wilt can be successfully controlled if soil treatment is undertaken @30kg/ha.

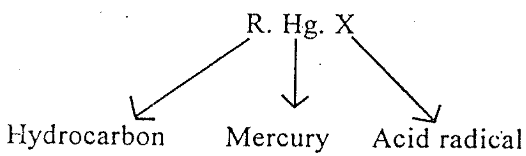
(F_6) **Terrazole/OM-2424** : It is an effective fungicide for the control of seed and seeding disease of Maize, Cotton, Sorghum, Soybean, bean, potato, tomato and *cucumis*.

(F_7) **Organo-phosphorus compounds** : This group includes compounds like Hinozan, Kitazin, Inazin etc. which are active against blast disease at a concentration of 400-500 ppm concentration. It becomes toxic at higher concentrations. It is extensively used in Japan. Among them Kitazin is an effective fungicide because of its excellent systemic behaviour.

(G) Organo–mercurial Fungicides :

Mercuric chloride is an effective Fungicide and bactericide. Because of its high toxicity it is not used to control plant diseases.

The general formula of organomercurial derivative is



The examples of Organo-mercurial fungicides are –

Agrosan GN, Agrox, Aretan/**Agallol**, ***Ceresan***, Mergamma, Parrygen, Panogen, Puraturb, Semessan. Because of their highly toxic nature great care is taken in their use. The treated seeds should never be used for human or animal consumption. Dry seed dressing contains 0.6-15% Hg whereas liquid dressing contains 0.6-2.0% Hg. Organomercurials mixed with Y-BHC or dieldrin is used to control insects attacking young seedlings.

(G) **Formaldehyde** – It was for the first time used in Germany for seed treatment during the last decade of 19th Century. Because of its lesser toxicity it was used as a substitute for $CuSO_4$. Inspite of this, use of Formaldehyde for seed treatment has several harmful effects.

Fungicides and their name

S.No.	Common Name	Other name
A.	**Metallic salts**	
A1	Copper Oxychloride	**Blitox**, Cupravit, Cuprox, **Fytolan**, Cupramar, Basic Copper Chloride, Coxysan
A2	Copper Sulphate	Blue vitriol, Bluestone
A3	Cuprous Copper Oxide	Fytomix, Perenox, Fungimar
B.	**Non-metallic Salts**	
B1	Sulphur dust	Brim Stone
C.	**Organo mercurials**	
C1	Ethyl mercury chloride	**Ceresan**, Granosan
C2	Methoxy ethyl mercury chloride	**Aretan, Agallol** (3%mercury equivalent) Agallol forte (6% mercury equivalent) Baytan.
C3	Phenyl mercury acetate + Ethyl mercury chloride in equal proportion	**Agrosan** G.N.
C4	Phenyl mercury salicylate	Mercusol, Merculine
D.	**Carbamate**	
D1	Benlate	Benomyl
D2	Carbendazim	Bavistin (Benzanidazole group)
E.	**Thiocarbamate**	
E1	Maneb	Dithane M-22, manzate, Manesan
E2	Mancozeb	**Dithane** M-45, Fore, **Indofil**
E3	Nabam	Chem Bam, Dithane D-14, Parzate
E4	Zineb	**Dithane Z-78**, Hescathane
F.	**Dithiocarbamates**	
F1	Ferbam	Fermate, Hexaberb, Tribungol
F2	Thiram/Thiuram	Arasan, Thiride, Mercuram
F3	Ziram	Cuman, Ziride, Zitox
G.	**Others**	
G1	Fentin Acetate	Brestan
G2	Captan	Merpan, Orthocide

G3	Fentiazon	Celditon
G4	Hinosan	Edifenphos
G5	Karathane	Arathane, **Dinocap**
G6	PCNB	**Brassicol**, Tritisan
G7	Plantvax	**Oxycarboxin**
G8	Vitvax	**Carboxin**
G9	Methan N sodium (Nematicide)	**Vapam, Metham**
H.	**Antibiotics**	
H1	Aureomycin	Acronize, Chlortetracycline
H2	Terramycin	Oxytetracycline, Biostat PA
H3	Streptomycin	**Agrimycin**
H4	BLA-S	Blasticidin
H5	Kasumin	Kasugamycin
* Plant	Growth Regulator	
	Ethephon	**Ethrel**

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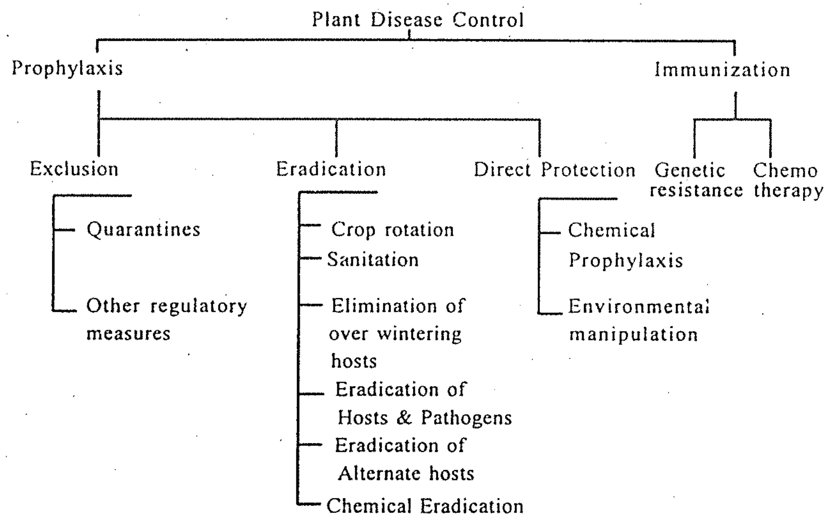
15. *Plant Disease Control*

Till the appearance of disease symptoms the pathogen has taken command over the plant. In order to avoid such a situation it is essential to protect plants from disease i.e. protective and preventive measures should be undertaken. Therefore it is said prevention is better than cure.

Classification of Plant Disease Control Methods



The control measures for plant diseases have been classified into two categories.

(A) Prophylaxis (B) Immunization

(A) Prophylaxis : include methods which protect the plant from the attack and infection by the pathogen or from the environmental factors which favour disease development. These methods have further been divided into three sub-categories.

(A_1) Exclusion : Method which prevents a disease from entering into a new area. For example – Quarantine and Inspection, embargo, certification etc.

(A_2) Eradication : This measure is taken for the elimination of the pathogen after its establishment on the host. It includes crop rotation, sanitation, elimination of alternate and over wintering hosts, elimination of pathogen from the seeds, tubers etc.

(A3) Direct protection : The principle behind this measure is that noncompliance with it can result into infection. Fungicidal seed treatment methods are either eradicant or protective in nature. Spraying and dusting of fungicide on plant comes under direct protection. Other examples are – Controlling environmental factors in green houses and warehouses, altering the time of sowing & harvesting in order to make it favourable for the host and unfavourable for the pathogen, protecting plants from cold, frost, heat etc. and maintaining nutrient elements.

(B) Immunization : Immunization deals with development of disease resistance in plants. The host thus becomes capable of defending itself from the pathogen. Such characters are developed through selection and hybridization. Temporary immunization of plants can also be brought about by Chemotherapy. The host plant absorbs the chemotherapeutant and homogeneously circulates it in their body.

On studying the different methods of plant disease control three conclusions are derived –

(i) Direct action against the pathogen or the attack on the pathogen or exclusion.

(ii) Genetic modification of the host to resist disease or strengthening of the host.

(iii) The alteration in the environment to make it unfavourable for disease development or to modify the environment.

General Principles of Plant Disease control

(1) Avoidance of the pathogen
(2) Exclusion of the inoculums
(3) Eradication of the pathogen
(4) Protective measures
(5) Development of resistance in the host.
(6) Therapy of diseased plant.

Among these principles the first five are preventive measures and are adopted on the cooperative basis whereas the sixth one is curative measure.

(1) Avoidance of the pathogen : It includes the following measures

(a) Selection of Geographical area : A geographic area is selected on the basis of the favourable temperature and humidity requirement for a particular crop. Most of the species of fungi and

bacteria develop & grow more & have more pathogenicity in humid areas in comparison to dry areas. For example – Smut and ergot disease of bajra are more in humid areas where the flowering stage prolongs in the rains for several days.

(b) Selection of field : Many soil borne diseases are controlled by proper selection of the field. It is quite possible that a particular field soil contains a pathogen species. In that case the particular crop is not sown in that field for several years. The causal organism of Red rot of sugarcane *Colletotrichum falcatum* survives in the soil for several months. Water drainage is also taken care of while selecting the field.

(c) Choice of the time of sowing : The susceptible stage of plant growth and the favourable environment for pathogen should not match at the same time.

(d) Disease escaping varieties : Certain varieties of crop due to their growth characteristics are able to escape from disease. This disease escaping characteristics of the crop is not genetic rather it is due to growth habits and time of maturation. Early maturing variety of pea is capable of escaping powdery mildew and rust.

(e) Selection of seed : To avoid seed borne diseases, healthy and disease free seeds are essential.

(f) Modification of cultural Practices : Cultural practices such as – distance between the plants, time and frequency of irrigation, transplantation time and method, mixed cropping, amount and property of fertilizer and compost etc. can be changed to reduce losses caused by the disease.

(2) Exclusion of Inoculum : It includes the following methods :

(a) Seed treatment : The pathogens present on the surface of seeds, tuber & graft etc can be excluded by chemical treatment. This helps in avoiding entry of the pathogen in new area.

Physical methods - *Jensen* for the first time used heat to control internal infection of potato tubers by late blight fungus *(Phytophthora infestans)*. It was observed that heat treatment of potato at 40^0C for 4 hours results into death of the internal mycelium. The **hot water treatment** method of Jensen was developed in 1887 which was used to control loose smut disease of wheat, barley and Oats. Until the development of systemic fungicide hot water treatment was the only method to control loose smut. Hot water treatment is also effective in the control of nematodes.

Solar energy treatment to control loose smut was first developed by *Luthra*. In this method seeds are first rinsed or soaked in water for 4-5 hrs. before drying them in scorching sun.

Hot air treatment for the control of virus in propagating stocks was first developed by ***Kunkal*** in Peach yellow.

Chemical methods :

Seed treatment with fungicide before transplanting is done with following objectives :

(i) To control disease caused by seed borne infection

(ii) To protect germinating seeds or seedlings from the attack of soil borne pathogens.

Chemicals used in Seed treatment

Chemical Seed Treatment

- Inorganic
  - Non metals → Sulphur dust
  - Metals
    - Mercurials e.g. Mercuric chloride, Mercurous chloride, Carbonate
    - Non-mercurials e.g. Basic copper carbonate, Red cuprous oxide etc.
- Organic
  - Mercurials e.g. Agrosan GN, Ceresan, Ethyl mercuric chloride, Phemyl mercuric acetate, Phenyl mercuric Urea, etc.
  - Non-mercurials e.g. Thiram, Oxanthiins, Carboxins, Chloranil, Systemic fungicides

Chemically treated seeds are kept dry during storage. Such seeds should undergo treatment at least one week before sowing. But seeds treated with liquid chemicals are not stored and the treatment is therefore performed just before sowing.

Seed dressing with organomercurials is potent enough to control many diseases except loose smut disease of wheat and barley. Therefore organomercurial is called a broad spectrum seed treating fungicide. Systemic fungicides are suitable to control loose smut of wheat & barley.

Types of seed treament :

On the basis of nature and purpose seed treatment has been divided into three categories –

(i) Seed disinfection : This type of seed treatment is for the eradication of such pathogens which are internally seed borne i.e. they are established in the seed coat or deep tissues in the seed. Examples – Loose smut of wheat & barley, strike disease of barley, Rhizoctonia disease of tomato. Earlier only physical measures like hot water or solar energy treatment was used for the eradication of such diseases but nowadays systemic fungicides like Plantvax/oxycarboxin, vitavax, carboxin, Benlate/Benomyl, Bavistin etc. are used for the purpose.

(ii) Seed Disinfestation : Distruction of fungal or bacterial pathogens present on the seed surface is called seed disinfestations. The fungicides used in this process are either in powder or wettable form. Many externally seed borne diseases such as – covered smut of barley or oat, Loose and grain smut of Jowar, Wheat bunt etc. can be controlled by seed disinfestations. The fungicides used in seed disinfestations are as follows :

Cesesan, Panogen, Copper sulphate, copper carbonate etc. These fungicides loose their effect when the seeds are sown in soil. Due to this these are not considered good seed protectant.

(iii) Seed Protection : Protection of seeds from soil borne pathogens during the process of seed germination is called seed protection. Pre-emergence Damping off disease in many vegetables can be controlled by seed protection. Organo-mercuric fungicides act as seed protectants. Other fungicides used as seed protectants are – Captan, thiram, Arasan, Semasan, Agrosan GN, Agallol, Aretan, Folpet etc.

(a) Systemic Fungicides are used for seed disinfection, seed Disinfestation and seed protection.

(b) Inspection and Certification : Crops grown for seed production are regularly inspected so that seed borne disease could be effectively controlled. Such disease free seeds are certified.

(c) Plant Quarantine : A plant quarantine can be defined as a legal restriction on the movement of agricultural commodities for the purpose of exclusion, prevention or delay in the establishment of plant pests and diseases in areas where they are not known to occur.

(d) Eradication of Insect Vectors : Insects serve as vectors for many diseases. Eradication of such insect vectors is essential for the control of pathogens. Examples of some diseases and their insect vectors are as follows :

S.No.	Insect – Vector	Name of transmitting disease/pathogen
1.	Aphids *(Myzus persicae)*	Potato leaf roll virus
2.	Leaf hopper	Maize streak virus, Rice dwarf disease virus; Tungro virus of rice.
3.	White flies *(Bemisia tabacci)*	Yellow mosaic of beans; Vein clearning of bhindi; tomato leaf curl
4.	Thrips	Tomato spotted wilt virus
5.	Mites	Wheat streak mosaic virus

(3) Eradication of the Pathogen : It includes the following principles –

(a) Biological control of plant pathogens : Decomposition of organic matter in the soil leads to intense microbial activity. Among them certain microorganisms have the potential to kill pathogens. In our country Root-knot nematodes and Black scurf of potato have been successfully controlled by organic soil amendments. Organic soil amendments come under biological control methods. This technique is helpful in controlling many soil borne diseases.

(b) Crop rotation : Crop rotation is essential for controlling soil borne diseases and pathogens.

(c) Removal and Destruction of Diseased Plant Organs

The following methods are brought into use –

(i) Roguing
(ii) Eradication of Alternate and Collateral hosts.
(iii) Sanitation of Fields

(d) Heat and Chemical treatment in diseased plants : This method is used to kill the resting structures of pathogen present on the host surface. This method is very effective in controlling diseases of fruit trees.

(e) Soil treatment : The main objective of this method is to inactivate pathogens and nematodes present in the soil. For this, different chemicals, heat, flooding and fallowing etc. like physical and chemical

methods are used. For controlling nematodes volatile soil fumigants are mainly used. Chemical treatment is performed by any one of the following methods :

(i) Drenching of soil with solution or suspension
(ii) Broadcasting of dusts, powders or granules
(iii) Furrow application
(iv) Soil fumigation

(4) Protective Measures :

(a) Chemical treatment : The main objective of chemical spray, dusting and seed treatment is to form a protective poisonous layer on the host surface or to kill the parasites already present on the host surface.

(b) Chemical control of Insect vectors : Certain viral diseases are transmitted only through insect vectors. Therefore it becomes essential to kill these insect vectors.

(c) Modification of Environments : Hot and humid conditions are favourable for diseases and pathogens. Ploughing, frequency and amount of irrigation etc. change the environment upto a certain extent.

(d) Modification of Host nutrition : Host nutrition also affects diseases. Excessive nitrogen in plant promotes leaf diseases whereas excess of Ca and K makes the plant disease resistant. Balanced nutrient management in crops can help in reducing the intensity of many diseases.

(5) Development of Resistance in Hosts

Development of resistance in hosts is brought about by following methods –

(a) Selection and Hybridization for disease resistance

(b) Through chemotherapy – when systemic fungicides and antibioties are applied to plants in form of foliar spray or through roots., their toxic effects persists on crops.

(c) Through host nutrition :

(6) Therapy of Diseased Plants : Diseased plants are cured through following methods –

(a) Chemotherapy
(b) Heat therapy
(c) Tree-surgery – The diseased branches of trees are removed or the disease parts scrapped and fungicidal paste is applied on the wounded

areas. This helps in checking infection. Important diseases of apple – Black stem, Brown stem and Pink disease etc. are controlled through surgery.

Soil treating chemicals : It is used for controlling such soil borne diseases which attack on seeds or seedlings. The examples of such chemicals are – Formaldehyde, Captan, Thiram, Zineb, Organo-mercurials, PCNB, Ethylene dibromide, vapam etc.

Seed treating chemicals : It is used for controlling seed borne diseases. Seed borne diseases are of two types –

(a) **Externally seed borne diseases :** For controlling these diseases, Chemicals such as Formalin, TMTD, Copper carbonate, Captan, Organo-mercurials (Agrosan GN and Ceresan) are used for seed treatment.

(b) **Internally seed borne diseases :** For controlling internally seed borne disease, hot water treatment and solar treatment are used.

Systemic Organic Compounds are effective chemicals for controlling both externally and Internally seed borne diseases.

Examples of Systemic fungicides : Oxanthin derivatives (Plantvax and Vitavax), Benlate, Bavistin, Demosan

For controlling air borne diseases, Foliar application of chemicals is more effective.

The common copper fungicides are : Perenox, Perelan, Blitox, Cuprokyt, Cuprosan, Fytolan. Its use is comparatively better than that of Bordeaux mixture.

Use of Organo-sulphur compounds such as Thiram and Dithiocarbamates (Zineb, Ziram) is a safer alternative for tender and sensitive foliage.

BACTERIAL DISEASES

Common Name	Particular Bacteria
1. **Citrus Canker**	*Xanthomonas citri*
2. Black rot of crucifers	*Xanthomonas compestris*
3. Bacterial blight of rice	*Xanthomonas oryzae*
4. Angular leaf spot of cotton or **Black arm disease**	*Xanthomonas malvacearum*
5. Leaf spot of chilli	*Xanthomonas vesicatoria*
6. Red stripe of sugarcane	*Xanthomonas rubriliniens*
7. Bacterial wilt of solanaceous plants/Brown rot of Potato/**Ring diseases** of Potato	*Pseudomonas solanacearum*
8. Fire blight of Apple and Pear	*Erwinia amylovora*
9. Soft rot of carrot	*Erwinia crotovora*
10. Scab disease	*Streptomyces scabies*

MYCOPLASMAL DISEASES

Host Plant	Name of mycoplasmal diseases
1. Rice	Yellow dwarf disease
2. Safflower	**Phyllody**
3. Seasamum	**Phyllody**
4. Brinjal (Egg plant)	**Little leaf**
5. Citrus	**Greening disease**
6. Sugarcane	**Grassy shoot, white leaf**
7. Potato	Purple top; witches broom
8. Coconut	Lethal Yellowing

Note : Greening disease of citrus is actually a bacterial disease and causal organism is Gracilicutes gram negative bacteria. Previously it was considered as mycoplasmal disease.

VIRAL DISEASES

Host plant	Name of Viral diseases
1. Wheat	Mosaic streak
2. Maize	Mosaic; **vein enation**
3. Barley	Mosaic, Yellow dwarf
4. Bajra	Mosaic
5. Jowar	Yellowing
6. Rice	**Tungro diseases; Grassy stunt**
7. Sugarcane	**RSD** (Ratoon stunting Diseases)
8. Potato	**Potato necrosis;** Potato severe mosaic, Leaf roll; super mild

	mosaic
9. Tomato	**Leaf curl :** Mosaic; Black ring spot
10. Chilli	**Leaf curl :** Mosaic
11. Bhindi	**Yellow vein mosaic** (YVM)
12. Onion	Yellow dwarf
13. Urd	Leaf crinkle
14. Pigeon Pea	Sterility mosaic
15. Groundnut	**Clump disease;** mosaic; chlorosis
16. Tobacco	Leaf curl; yellow net vein (ynv); Ring spot
17. Banana	**Bunchy top**; mosaic, Banana streak
18. Citrus	**Tristeza** and **Quick decline**
19. Papaya	Distortion ringspot, mosaic, leaf curl.

Diseases cuased by Nematodes

Names of disease and hosf plants	Particular nematode
1. Ufra disease of Rice	*Ditylenchus angustus*
2. Ear Cockle of wheat	*Anguina tritici*
3. Root lesion disease of chillies, coffee, cotton, tea, rice	*Pratylenchus* spp.
4. Plants affected by Golden nematode / sugarbeet nematode Host Plants – Potato, Brinjal, Sugarbeet, Beet	*Heterodera rostochiensis*
5. Plant affected by **Burrowing nematode** Host Plants – banana, rice, citrus	*Radopholus similes*
6. **Root knot disease**/Root gall disease Hosf plant – coffee	*Meliodogyne exigua*

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16. Disease-details Table

Crop/Disease	Pathogen	Symptoms & Feature	Control measures
(1) RICE			
(i) Blast (Rich man's disease)	*Pyricularia oryzae*	Brown spindle.eye boat shaped lesion on leaf, neck rotting, discoloured nodes, partially filled grains; Heavy dose of nitrogen, high atm ospheric relative humidity (RH) = 86 – 98%) and night temp. of 20°C for few hours favour for disease/	Seed treatment with Agrosan GN,Ceresan/ Thiram @ 2g per kg of seeds; spray Zineb or mancozeb @ 0.25%; Grow resistant varieties – Tulsi, Rasi, Swarnadhan, IR-64 Nitrogen - management of field.
(ii) Bacterial leaf bligh (BLB) Or Bacterial leaf spot. (Poor man's disease)	*Xanthomonas oryzae*	'Kresek' occurs in early stage (Plant withers and dries up); In later stage blighting starts from the tip of the leaves to the base (downward), Straw turned yellow, partially filled grains, Yellowing **Bacterial Ooze** appears on the surface which dries up into bead-like incrustations (i.e. **Ooze test**); Problem under poor and N-deficient soil conditions.	Use disease free certified seeds, water drainage time to time; seeds treatment with Streptocycline 0.015% + ceresan 0.05%; 3-4 sprays of 75g Agrimycin-100 + 500g copper Oxy chloride in 500 lit. Water/ha; Hot water treatment; use resistant varieties-Ajay, PR-10; Nitrogen management of field.
(iii) Tungro (Leaf Yellowing) (BLB & RTV are the Killer disease of Rice)	Rice Tungro Virus (RTV) vector-Rice green leaf hopper	Yellowing from tip & margin on older leaves, stunted growth, empty glumes & poor panicles with dark-brown colouration, Interveinal chlorosis.	Spray systemic insecticide Diazinon @1.5 kg a.i./ha; Rogue out diseased plants, slurry treatment of seeds with furadan 75% W.P. @0.13-g/kg seeds; use resistant varieties – Vikramarya.
(iv) Brown spot	***Cochillobolus miyabeanus (Helminthosporium oryzae)***	Many dark-brown elliptical spots on leaves; infects coleoptile of seedling and causes blighting; infected kernel shriveled.	Seed treatment with ceresan or Agrosan GN @2 g/kg of seeds, grow varieties like Bala, Krishna, Sabarmati, IR-204; Spray dithan M-45 @0.25% at 10-12 days interval.

(v) False Smut	*Claviceps oryzae sativae (Ustillaginoides virens)*	Infected kernels transformed into a large velvety, yellow olive green and more than twice in diameter than normal grains, Infected grains covered with powdery spore mass.	
(vi) Khaira disease	Zn-deficiency	Usually in nursery; chlorotic/Yellow patches at leaf base on both sides of midrib; restricted root growth and usually main roots turn brown.	Spray 5 kg Zn SO_4 + 2.5 kg lime per hectare at 10 DAS in nursery or $ZnSO_4$ @ 5 kg + Urea 2% in 1000 litre of water/ha at the sowing time.
(vii) Sheath blight	***Rhizoctonia solani***	Minor disease	—
(viii) Bakanae disease or Foot rot	***Gribbrelia fuglkuroi***	Minor disease	—
(ix) Udbatta disease	Fungal	Minor disease	—
(x) Ufra disease	***Ditylenchus angustus (nematode)***	Minor disease	—
(xi) Yellow dwarf	Mycoplasma	Minor disease	—
(xii) Pan Sukh	Dry physiological disease	Minor disease	Drain excess water; apply (NH_4) SO_4 @ 15-20 kg/ha.
(xiii) Grassy Stunt	Viral	Minor disease	—
(2) WHEAT			
(i) Rusts (a) Brown rust or Leaf rust (LR)	***Puccinia recondita tritici***	Round oval uredial pustules mainly on leaves and scatterd & Irregular; most widespread disease & most damaging in our country	Avoid late sowing, use high dose of K, Spray Zineb or mancozeb @0.2% Grow varieties like Sonalika, chhoti Lerma, UP-2003, HD-2285, UP-368, Girija, RH-124; Development of resistant variety through Conv-ergent breeding by using resistant genes viz., Yr, Lr & Sr is being tried.
(b) Yellow rust (YR) or Stripe rust	***Puccinia striiformis***	Lemon Yellow pustules in rows or long paralleles streaks; the pustules of yellow rust are smaller than those of Leaf rust;chiefly on leaves.	
(c) Black rust or Stem rust (SR)	***Puccinia gramimis triticl***	Elongated uredial pustules on stem, leaf sheath, leaves and earheads but stem is often most severally affected.	

(ii) Kernal bunt or Partial bunt	***Neovossia indica***	Called cancer of Wheat; grains partly converted into black sooty powder; gives rotten fish smell due to trimethylamine	Since it is soil borne, seed borne & air borne, hence only one solution is to grow resistant variety and seed treatment with mercury fungicide.
(iii) Loose smut	***Ustilago triticl (Ustilago nuda triticl)***	Early emergence of heads; Production of black powder in place of grain; Before ear-emergence only Sonalika is detected by yellowing flag leaves & withering; It can be distinguished at ear emergence; Internally Seed-borne. Factors conducive for spread : Wind for spore dispersal; Light rainfall at flowering time; Openness of the flowers; suitable temp. around 18-20°C for germination of chlamydospores; Atmosphere should not calm and quiet. Max infection at when plant raised at 21°C; No infection at 29°C.	Seed treatment with vitavax @2.5g/kg of seed, solar heat treatment; Hot water treatment, Raise windbreak plantation to restrict its spread.
(iv) Ear Cockle	***Arguina triticl*** (nematode)	Leaf blades generally twisted; infected ears shorter and remain green longer; awans more spreading; affected grains transformed into one or more small galls.	Floatation of Seeds in 20% salt solution; Rogueing; use clean seeds.
(v) Tundu disease or Yellow ear rot or Sehum disease	***Corynebacterium tritici (bacteria)*** + ***Anguina tritici (nematode)***	Curling of affected plant leaves; bright yellow **slimy ooze** (due to bacteria) on leaves and inflorescence; **Agglutinized Inflorescence;** seeds not formed; grains transformed into small hard galls.	Floatation of Seeds in 20% salt solution; Rogueing; use clean seeds.

(vi) Molya disease or cereal root eelworm	*Heterodera avenae (Cyst nematode)*	Stunting, Pale Yellow sparsely growing seedlings; roots showing knots containing nematode cysts.	Crop rotation.
(vii) Flag smut	*Urocystis tritici*	—	—
(viii) Hill bunt	*Tilletia foe-tida or Tilletia caries*	—	—
(3) BARLEY :			
(1) Covered Smut	*Ustilago hordei*	Smutted head; grains replaced by black agglutinised spore masses & Covered by persistent white pape-ry membrane. Factors for spread – (a) amo-unt of moistuse (b) suitable temp. (c) Depth of planting when seeds are planted deep; it take too long time to emerge at the surface. Its dispersal is only at time of harve-sting because chlamy-dospore sticks to seed.	Externally seed borne hence easy to control; Seed dressing with AgrosanGN @2.5g/kg Seeds.
(ii) Loose smut	**Ustilago nuda**	Same as of wheat	Same as of wheat
(iii) Powdery mi-ldew	***Erysiphe graminis var. hordei***	Cottony growth on both the leaf surface (but on lower surface in downy mildew); later on powdery deposits of conidia; necrosis at powdery spot' Ecto-phytic; Favourable con-dition Winter season. Cold and dry weather; control through S-fungicides.	Spray 'S'-Fungicide grow resistant variety.
(4) JOWAR :			
(I) Downey mildew	***Sclerospora sorghi***	Downy white growth on lower surface with yellowing on upper surface on young leaves i.e. chlorosis at downy spot; later on shredding of leaf & stunted growth; Endo-phytic; Favourable condition-Monsoon mainly cold & moist weather; control through Cu-containing fungicides like Bordeaux mixture (BM) Zineb etc.	Grow resistant variety. Seed treatment with Agrosan G.N./Cere-san@ 2.5g/kg seed spray maneb or Zineb @0.2%

(ii) Grain Smut	*Sphacelothec-a sorghi*	Grains transformed into elongated cylindrical structures consisting of black spore masses.	Seed treatment with finely powdered Sulphur @5g or Agrosan G.N. @2g/kg seed.
(iii) Leaf rust	***Puccinia purpurea***	Bright Purpled spot on leaf surface mainly on lower surface; more severe after flag emergence.	Grow resistant variety like CSH-1, 2 etc; spray Dithan Z-78 @0.2% at 10-12 days interval.
(iv) Anthracnose or Bed leaf spot (BLS)	***Colletotrichum graminicola***	Brown spots with whitish or purple centres on lower leaves; affects both seedling as well as matured plants.	Grow resistant varieties i.e. CSH-1, CSH-2 etc; Seed treatment with Agrosan G.N.: Spray Zineb @ 0.2% ; Weed out Johnson grass (Collateral host)
(v) Head smut	***Sphacelotheca relliana***	Part of Entire floral structure transformed into smutted galls.	
(vi) Long smut	***Tolyposporium ehrenbergii***	Few grains trans-formed into long cylindrical and slightly curved bodies	
(5) BAJRA			
(i)Downey mil-dew or **Green Ear disease (ERD)**	***Sclerospora graminicola***	Ear transformed into green leaf like or leafy whorl type structure. Essential factors for germinating oospores are (1) Good air supply (2) Low soil moistuoe (3) 20-25^{0}C temp; it means oospore req-uires weathering; More conducive is Light soil; According to **Sateulla & Thirumalachar** (1956) – at 15-20^{0}C and 90% RH (Moisture near saturtion) sporangia were formed. According to Wetson, asexual stage of it is not found in India.	Roguing of diseased Plant, Grow hybrid resistant varieties i.e. HB-3 Spray 0.2% Zineb.
(ii) Ergot	***Claviceps fusiformis***	First appear on the ears in the form of honey like pinkish liquid; Liquid turns brown & sticky; Sclerotia (ergot i.e. pinkish liquid) appears as brown to black later on and elongated structure.	Avoid late planting; Floating of seeds in 2% salt solution, spray Ziram @ 0.15% at boot leaf stage.

(iii) Smut	*Tolysporoium penicillaria*	Affected kernels green & larger in the beginning but later turns to black.	Remove smutted ears; spray vitavax @0.25% Follow three year crop rotation
(6) MAIZE			
(i) Whit bud of Maize	Zn-deficiency	Apical portion of leaf becomes white	Apply $ZnSO_4$ @ 20-25 kg/ha at sowing time.
(ii) Seed rot or sedling blight	*Pythium aphanidermatum; Fusarium monilliformis; Rhizoctinia spp.*		Seed treatment with captan or Thiram @2.0g/kg of seeds.
(iii) Black bundle	*Cephalosporium acremonium*	Decay of Vascular bundle; wilting of leaves & ultimately wilting of plants; black spots in the middle of vascular bundle i.e. black spot on the cut ends of the stalk.	Use resistant hybrids; seed treatment with Bavistin @2g/kg seed (systemic fungicide)
(iv) Bacterial Stalk rot	*Erwinia crotovorta var. zea.*	Basal inrternodes become soft, discolour and starts decaying; alcoholic smell in the field.	No water logging; injury to plant avoided; Roguing of affected plant.
(v) Charcoal rot	*Macrophomina phaseoil*	Shredding of the pith in the stalk, Black dot on the rind and inside the stalk; lodging of the crops in severe cases	Avoid water strees after the flowering of the crop.
(vi) Turcicum leaf blight	*Trichometasphaeria turcica (Helminthosporium turcicum)*	—	—
(vii) Maydis and carbonum leaf blight.	—	—	—
(viii) Banded leaf & sheath blight	—	—	—
(ix) Brown stripe downey mildew	—	—	—
(x) Pre-soaking stalk rots.	—	—	—

(7) GRAM			
(i) Fusarium wilt	*Fusarium Oxysporum f. sp. ciceria (4 races)*	Stunted growth; yellowing of leaves, withering of plants; Main root turns black	Use of resistant genotypes viz. Pusa-212, Phule G-5; Avrodhl; Seed treatment with Bavistin + thiram (2g + 1.5g/kg seedf); solorization of soil with polythene sheets or deep ploughing and exposure to solar radiation; Late & deep planting.
(ii) Sclerotinia blight	*Sclerotinia sclerotiorum*	Plants become yellow then brown and ultimately dry; All plant parts are affected except roots.	Soil treatment with captan @10 kg/ha; Grow resistant,varieties
(iii) Ascochyta blight	*Ascochytarabie (2 races & 1 biotype)*	-do-	Use resistant genotype viz Gaurav; seed treatment with Bavistin & thiram (1:1) or Hexacap @ 3 g/kg seed controls primary infection; spray Dithiaron, @0.1% Indofil M-45; captafol @0.2 & Captan @0.2% for excellent control.
(iv) Botrytis grey mould	—	—	resistant var-Dhanush.
(v) Leaf spot & root rot	*Alternaria circinans & Fusarium monilliformae*		
(8) ARHAR			
(i) Fusarium wilt	*Fusarium oxysporum f. sp. udum*	Most destructive soil borne fungal disease wilting of leaves & plants; lateral roots completely rotten; Tap root become black on the surface & move upward; wilting branches arrive from such blackened area; Black streaks on wood below the bark; disease spread in a circular fashion around the first wilted plant.	No chemical control (i) Follow mixed cropping. Viz Arhar + Tobacco & Arhar + Sorghum. Tobacco liberates chemical injurious to Pathogen & Sorghum's root exudates HCN which is toxic to Fusarium. (ii) Soil amendments with green manuring & use of oil cakes. (iii) Crop rotation with sorghum or tobacco or fallow for 1-2 years.

(ii) Sterility mosaic	Sterility mosaic virus (SMV) Vector-Mite *(Aceria cajani)*	Plants become light greenish bushy; no flowers & fruits	Roughing of Perennial & Self grown plants; only ICPL-151 is resistant in early maturity group; use of acaricide viz Tedion, Morest, Kelth-ane @1.0% Besides, seed dressing with carbofuran as 25% (Furadan 3G) and seed treatment with 10% Aldicarb or its soil application @1.5 kg a.i./ ha.
(iii) Phythophth-ora stem blight	***Phytophthora drechsleri f.sp. cajani***	Serious disease in high humidity and poorly drained soil i.e. state of W.B.; short duration varieties are more susceptible.	Seed treatment with Metalaxyl (1.75g a.i./kg seed) followed by 1 spray of Metalaxyl 25 WP (at 1000 ppm) 30 DAS; proper drainage & Planting on ridges.
(iv) Alternaria leaf blight		Serious in post-rainy season	Resistant genotypes are DA-2, DA-11 & Pant A-3.
(9) SOYBEAN			
(i) Yellow Mosaic	Yellow mosaic virus (YMV) Vector-white fly ***Bemisia tabacci***	Yellow mosaic mottling of leaves accompanied with crinkling & reduction in size; stunted plants & few pod setting.	Use resistant variety; spray metasystox 25 EC @1 kg/ha in 1000 lit. of water at 10 days interval; Roguing of diseased plants.
(ii) Anthracnose (pod blight)	***Colletotrichum truncatum***	Pod becomes yellowish & later turns to brown; seed formation seriously affected	Use resistant variety viz Bragg. Spray Zineb @0.25%
(10) GROUNDNUT			
(i) Tikka disease & rust or Cercospora leaf spot & rust (CLS)	***Phaeoisariopsis personata*** (***Cercospora*** personata & ***Cereospora arachidicola) Rust-Puccinia arachidis***	Small dark brown spots and Pre-mature leaf shedding. In case of personata, brown spots are regular & not more than 0.6 mm in diameter but of arachidicola, there are irregular spots.	Spray Bavistin @0.05% + Dithan M-45 @0.2% 2-3 times at 2-3 weeks intervals starting from 4-5 weeks after planting.
(ii) Collar rot & dry root rot	***Aspergillus niger*** (collar rot)	Attack at seedling stage at the base; black spores are seen at root	Seed treatment with 5g thiram or 3g or Dithane M-45 or 2g Bavistin Per kg kernels; crop rotation
(iii) Stem rot	***Sclerotium rolfsii***		Seed treatment same as of collar rot.

(iv) Bud necrosis	Vector-Thrips Tomato Spotted wilt virus (TSWV)	—	Spray 400 ml. Rogor or 360 ml Methyl demeton/ha; Adopt cultural methods like early planting closer spacing, & intercropping with millet crops; Tolerant varieties are kadiri-3, ICGS-II, ICGS-44.
(11) SESAME			
(i) Phyllody	Mycoplasma vector-leaf hopper	Green leafy floral parts and profuse branching	Spray Metasystox : 1 ml/lit. water
(ii) Leaf curl	Nicotiana virus 10; vector aphid	Downward curling of leaves	Soil application of phorate granules @10 kg/ha; spray Metasystox @1ml/lit. water
(12) RAPE & MUSTARD			
(i) Alternaria blight	***Alternaria brasicae***	Causes average loss 36%; it causes 10-70% damage while aphid pest causes damage 35-73%; concentric black spots on leaves, stems & pods.	Collect & burn disease debris; remove weeds like coriander; spray captafol (Difoltan, Foltaf) @1.5 kg/ha or Dithane M-45 @ 2 kg/1000 lit. Water at 15 days intervals starting from 40-45 DAS; Hot water treatment of 50°C for 10 minutes of seeds.
(ii) White rust.blister	***Albugo candida***	White or yellow pustules of variable sizes & shapes on lower surface of leaf; infection covers all parts except roots.	Clean cultivation; remove and burn affected plants; spray zineb @0.2%, captafol (Difoltan, Foltaf) or copper oxyflouride (Blitox 50 @ 1.5 kg/ha) at 15 days interval.
(iii) Downey mildew	***Pernospora brassicae***	Yellow & irregular spots on upper surface & white growth on under surface of leaf; malformed inflorescenece.	Spray 0.2% Zineb at 10 days interval.
(iv) Sclerotinia rot & club roots	—	—	Use long term crop rotation; control of cruciferous weeds; lime sulphur @1 kg/m^2.

(13) SUNFLOWER			
(i) Alternaria blight or Leaf spot	***Alternaria hellianthi***	Small oval spots on leaves	Spray Mancozeb (Indofil M-45) Zineb (Indofil Z-78) @0.25%.
(ii) Rust (iii) Root & collar rot	***Puccinia hellianthi*** ***Sclerotium rolfsii*** ***Rhizoctonia bataticola***	—	Seed treatment with Brassical followed by Thiram and Mancozeb reduces root and collar rot
(iv) Downey mildew	***Plasmopara halatedil***	—	Seed treatment with APRO 35 SD (metaloxyl Comp) @ 6g/kg seed
(14) Cotton			
(i) Bacterial blight or Angular Leaf spot or Black arm (ALS)	***Xanthomonas malvacearum***	Major disease of cotton; angular and water soaked lesions on leaf & stem.	Spray Streptocycline + copper oxychloride; seed treatment with agrimycin 100; destroy debris.
(ii) Fussarium wilt	***F. Monilliform f sp. vasinf-ectum***	Vascular tissue becomes brown; only scattered plant affected	Grow resistant variety like American cotton; apply K + O.M.
(iii) Anthracnose	***Colletotrichum indicum***	Dark brown spots on the stem below soil surface and on roots; circular & water soaked spots on bracts and spread to bolls.	Seed treatment with ceresan/Agrosan G.N. @2.5 g/kg Seed; spray Blitox @0.2%
(iv) Myrothecium leaf spot	***Myrothecium roridum***	—	Spray carbendazin 0.1% or copper oxychloride (0.2%)
(v) Tirak	Physiological	Premature defective openings of bolls & shedding of leaves	Late sowing, apply extra water at flowering & fruiting in sandy soil.
(vi) Root rot/Dry root rot/Sore shin	***Rhizoctonia bataticola*** ***Macrophomina phaseoli*** ***Rhizoctonia solani***	—	Mixed cropping with Moth (Phasaolus aconitifolium)
(vii) Grey mildew or Dahiya disease	***Ranulariaareola***	Serious only in desi cotton; cloudy weather followed by rains and temp. 24-26°C favours this disease.	Dusting of 'S' or spray 0.1% carbendazim or 0.2% kalthane.

(viii) Stenosis (small leaf)	virus	Extreme stunting of the aerial organs.	—
(ix) Verticillium wilt	—	—	—
(14) SUGARCANE			
(i) Red rot	***Collectotrichum falcatum***	Red rot inside the stalk; red area traversed by white band; alcoholic smell from field.	Setts treatment with 0.25% Agallol or Aretan (1:100) solution; avoid ratooning; use healthy setts; Heat treatment.
(ii) Grassy shoot disease (GSD) or (Albino)	Mycoplasma	Excessive tillering, sprouting of lateral buds	Use healthy setts, Hot water treatment or Most hot-air therapy or aerated stem (50°C for 1 hr.)
(iii) Ratoon Stunting disease **(RSD)**	Ratoon stunting virus (RSV)	—	Heat treatment, application of 'S'
(iv) Sett rot or Pineapple disease (v) Rind disease	—	—	—
(16) Potato			
Late blight	***Phytophthora infestans***	Bright brown & irregular patches starts from leaf tip or leaf margin; later on turned in brownish black patches; Ground leaves show symptom first; in favourable condition entire vegetative parts are killed within a day hence called blight; in unfarourable environment infected area becomes brittle & detached; continuous high humidity and relatively low temp. are favourable condition. In Indo gangetic plains only mode of survival is infected tubers stored at low temp.	Healthy seed material, high ridging to reduce Infection, delayed harvesting because of high temp & the above parts is dried away. Due to labour intensive Bodeaux mixture is not used; Blitox 50 is not also used; spray Mancozeb/Zineb @ 2.0 – 2.5 kg.10 lit. of water/ha; 2-3 sprays at 15 days interval; tuber treatment with mercuric chloride (1:1000 in water) ; Use resistant variety like kufri Alankar, kufri Jyoti & Kufri chandramukhl developed by CPRI, Shimla.

(ii) Early blight	*Alternaria solani*	Concentric ring or target board appeared on leaf lamina; spots irregularly distributed; No any particular favourable condition hence it is widely distributed; collateral host is Tomato.	Spray Zineb/Maneb @0.2% Sort out infected tubers.
(iii) Black scurf	***Pellicularia filamentosa (Rhizoctonia solani)***	Surface of tuber covered with black in-crustations (Sclerotia of pathogen), growing tips of tuber sprouts are killed.	Tuber treatment with mercury chloride (1: 1000); soil treatment with Brassicol @20-30 kg/ha as furrow application.
(iv) Wart	***Synchytrium endobioticum***	Appearance of tumours or warts on tubers, stems & stolons.	Grow resistant variety.
(v) Black heart	*Oxygen* starvation (Physiological)	Particularly of tubers at the bottom of deep piles kept for a long period; the tissue of the cut tuber turns pink on exposure, later turning dark brown or black.	Provide proper storage conditions with adequate ventilation.
(vi) Charcoal rot	***Macrophomina phaseoli***	The roots become brown & rot; the bark of stem becomes ash-coloured ; black sunken areas are formed around the stem end of the tuber.	Eearly harvesting; tuber treatment with Agallol/ Aretan grow resistant variety.
(vii) Black leg & soft rot	***Erwinia carotovara***	—	—
(viii) Scab	***Streptomyces scabies***	—	—
(17) TOBACCO:			
(i) Tobacco mosaic	Virus	Mosaic mottling, blistering & puckering of young developing leaves.	Strict sanitary measures; spray 1% tannin acid; Roguing.
(ii) Damping off	*Pythium aphanidermaum*	Seedlings rot at collar region	Preseeding application of Metalaxyl MZ @2.16 kg/ha followed by 2-3 post-emergence application.

(iii) Tobacco Leaf curl (TLC)	Tobacco leaf curl virus (TLCV) Vector-whitefly	Okra & castor support the growth of vector but are non-hosts of TLCV while clusterbean, Seasame, sunnhemp & chillies are alternative hosts of TLCV.	Clean the alternative hosts & other weeds.
(iv) Frog eye leaf spot (v) Black shank			
(18) TOMATO			
(i) Tobacco mosaic	Virus	Same as of tobacco	
(ii) Late blight		Same as of Potato	
(iii) Early blight		Same as of Potato	
(iv) Leaf curl	Virus	Curling of leaves, thick & leathery leaf	Spray systemic insecticide Dimethoate 0.1% at one week interval before fruit ripening.
(vi) Blossom end-rot (Buck eye-rot)	***Physiological due to Ca deficiency, uneven moisture supply***	Black, sunken, necrotic lesions, Water-soaked at the blossom end of green or ripening fruits.	Folior spray of Ca SO_4 @ 0.4.0.5% avoid irregularity in moisture supply; spray captafol 0.3% at 10 day interval.
(vii) Cracking	Physicologial due to B-deficiency of heavy rain/ irrigation after a long dry spell	Radial and concentric cracking at the upper side of fruit.	Spray Borax @0.2% in soil @15-20 kg/.ha.
(19) Brinjal (Egg plant)			
(i) Phomopsis blight : fruit rot	***Phomopsis vexans***	Soft & watery soaked on fruit; blight of foliage; fruit rot.	Seed treatment with carbendazim @1 g/kg of seed; Dip seedling in 0.5% carbendazim @ 1 g/ kg of seed; Dip seedling in 0.5% carbendazim for 30 minutes before transplanting followed by 2 spraying of 0.05% Bavistin at interval of 10-15 days after one month after transplanting; Crop rotation.

(ii) Little Leaf	Mycoplasma	Tinny Yellow leaves & bushy growth	Roguing: apply thimet 10G @10kg/ha in nursery
(iii) Wilt	***Pseudomonas solanacearum***	Vascular bundle (V.B.) becomes brown	Crop rotation, grow resistant variety.
(iv) Damping off	***Pythium sp.***	Rotting of seedling	Rotation of seedbed; hot water treatment; Drench nursery with captan.
(v) Broom rape (Orobanche)	Flowering root parasite		
(20) OKRA/ BHINDI :			
(i) Yellow Vein mosaic (YVM)	Virus (YVMV) vector – white-fly	Yellowing of leaf vein and ultimately dries; vector persist on wild host (i.e. Hibiscus tetraphyllus)	Removal of wild host plant; spray malathion; grow resistant variety like Pusa Savani spray sulphax W.P. @ 2 kg/ha.
(ii) Powdery mildew	***Erysiophe cichoracearum***	White powdery coating	Spray Sulphax w.p. @2 kg/ha
(iii) Damping off			
(21) CHILLIES			
(i) Damping off	***Pythium aphanidermatum Phytophthora sp.***		
(ii) Wilt	***Fusarium annum***		
(iii) Anthracnose (Ripe rot dieback)	***Collectotrich-um capsici***		
(iv) Leaf curl	Virus		
(22) CABBAGE (All Brassica spp.)			
(i) White blister	Same as of Rapeseed		
(ii) Browning of Cauliflower	Boron (B) deficiency	Brown curd, hollow stem	Apply Borax @ 10-15 kg/ha in soil or spray 0.2-0.3%.
(iii) Whiptail of cauliflower	**Mo-deficiency**	Thick, green & leathery leaf and no curd.	Apply 1-2 kg Sodium or Aluminium molybdate.

(iv) Club-root (Finger & toe disease)	***Plasmodiophora brassicae***	Club-shaped roots (spindle-shaped or spheroid growths)	Seedling treatment with mercuric chloride in @ 125 ml per 100 seedling.
(v) Black rot	***Xanthomonas compestris***	Blackening of V.B.; Blighting from leaf margin to midrib in V-shaped	Hot water treatment at 50°C for 30 minutes; roguing.
(23) APPLE			
(i) Scab	***Venturia inaequalis***	Scattered, circular brown spots with dendritic margin on undersurface of leaves; dark brown spots on fruits.	Pre-blossom spraying with lime sulphure (1:60) or Benomyl at fortnightly interval.
(ii) Bitter rot	***Glomerella cingulata***	White powdery growth	Remove affected fruits; apply Bordeaux mixture (4 : 5 : 50)
(iii) Powdery mildew	***Podosphaera leucotricha***	Rotting of premature fruits & continue upto storage	Spray Bordeaux mixt-ure, Karathane E.C. (0.05% or carbendazim (0.05%).
(iv) Black canker	***Sphaeropsis malorum***	Cankerous, elongated corky lesion on stem; bark cracks, peels off	Only control is Pruning
(24) MANGO			
(i). Malformation'	***Fusarium monilliformae var. subglutin-ana (Previously considered mite, Virus & Physioligical)***	Vegetative and floral malformationl bunchy top appearance;more around cities or settlement than in open country-side due to particulate type of pollution.	Pruning; spray captan; single spray of NAA or planofix in the conc. Of 200 ppm by deblossom-ing at bud burst stage.
(ii) Anthracnose	***Colletotrichum gloeosporiodi-des***	Dark brown spots on leaves	Spray 1% Bordeaux mixture or Metalaxyl
(iii) Black tip	B-deficiency near brick-kiln	Basal end of fruits rots and turns black	Spray Boarax @ 0.6% thrice in a year; Brick kiln about 15m high or orchard away from brick-kiln.
(iv) Fruit drop	Deficient nutrient for-many of the developing embryos may also be imp-ortant factor leading to post-fertilization drop.	Fruit drop is a contin-uous process; occurs primarily at 2 periods; first drop at from fruit set to 20 days after and 2nd drop when develop-ing fruits are 28-35 days of after pollination & fertilization.	Apply 400 ppm & NAA at 30 days followed by GA_3

(25) GAUVA			
(i) Fruit canker (Grey blight)	*Pestalotia psidiia*	Generally occurs on green fruits & rarely in severe form raised cankerous spots on fruits & leaves; fruit becomes hard, mal-formed & mummified.	3-4 spraying of 1% Bordeaux Mixture (BM)
(ii) Anthracnose	*Collectotrichum psidii*	Causes dieback, twig blight, winter tip or fruit spots.	Spray Difoltan 0.3% followed by Dithan Z-78 0.2% at one month interval.
(iii) Gauva wilt	Still unresolved Scanty infor-mation on its etiology.	Wilting in two forms viz dieback or slow wilting & quick wilting. In dieback, plant starts dying from the top down words whereas in quick wilt, plants die immediately after the infection is noticed.	Conrtrol measures are not clearly understood; guava sp. Psidium cattliennam; P. Molle P. quidanense, P. frie drichallanum & Phillip-ine guava are resistant to wilt and may be used as root stock
(26) PAPAYA			
(i) Ring spot or Papaya ringspot or Distortion ringspot	Ringspot virus (RSV) Papaya ringspot virus (PRSV) Distortion ringspot virus (DRSV) Tran-smission by mechanical sap. Inocula-tion and aphid vectors.	ELISA test confirmed that the mosaic virus of India belongs to papaya ringspot virus (PRSV); PRSV is a serious disease, infected leaf rolls upwards along the margins distinct round spots on main stem which turns into elongated streaks in advance stages, elongated dark green streaks on leaf petiole & upper half of the stem; malformation in winter; yellow spots & yellow rings with solid green center on matured green fruit.	No reistant variety to PRSV. Spray malathion to control aphid vector *(Aphis gossypill A. craclvora, Myzus persicae)*
(ii) Leaf curl	Viral	Curling, crinkling and distortion of leaf.	Uprooting of infected plants at early stage.
(iii) Papaya mosaic	Viral	Faint chlorotic spots on leaf surface followed by vein clearing, puckling & mottling of young leaves; in extreme cases leaf blade distorted & modified into shoe string; identical to Ringspot.	Same as of ringspot

(vi) Stem & Foot (Collar) rot	*Pythium aphanidermat-um*	Water soaked patches & swollen collar of the stem.	Good drainage & spray 1% Bordeaux mixture (BM)
(27) BANANA			
(i) Panama wilt	***Fusarium oxysporum var. cubense***	Progressive browning & falling of leaves. Black streaks on under ground stem, Serious on Rasthali group of banana & Cavendish group is not suscepti-ble.	Use disease free suckers; crop rotation; eradicate affected plants.
(ii) Bunchy top	Virus (BBTV) Banana Bunchy top virus Vector ***Pentalonia nigronervoga***	Leaves shot & narrow; bunched together at top	Use virus free sucker; roguing.
(iii) Konkan disease or Banana bract mosaic	Viral (Banana bract mosaic virus –BBMV)	Disease of Nendran banana in Kerala; spindle shaped pattern in unusually red coloured pseudostem; darkstreak on petiole base) reddish streaks on bracts & undersized fruit.	
(iv) Banana Streak disease	Banana Steak virus (BSV) Vector : Mealy bug ***(Planococcus citri)***		
(v) Sigatoka or Leaf spot	***Mycophaerella musicola***	Prevalent in humid tropics or coastal regions.	
(vi) Cigar-end disease	***Stachylidium theobromae***		
(vii) Black finger	***Macrophomina musae***		
(28) CITRUS :			
(i) Citrus Canker	Xanthomonas compestris pv citri	Most serious disease of acid lime; small brown raised corky outgrowths on leaves, twigs, fruits	Prune & burn; use only disease free planting material spray 1% B.M.
(ii) die-back or wither tip or twig blight	***Collectotrichum gloeosporiodies Diplodia natelansis Fusarium sp.***	Dieback of young twigs; black dots on dead tissues.	Prune & apply Bordeaux paste paint to cut ends; spray with Zn-Cu lime.

(iii) Gummosis (Broom rot)	***Phytophthora palmivora***	Ruptured lengthwise bark, exudes gum	Spray 0.1% aurofungin
(iv) Greening	Gracillicuts gram negative bacteria (previously considered mycoplasma) Vector-***Diaphorina citri***	Yellowing of midribs & lateral veins of leaves;	Drenching with tetracycline; spray B.P. 101 (500 ppm)
(v) Tristeza	Citrus tristeza virus (CTV) vector-***Toxoptera citricida***	Gradual decline in vigour	Use resistant root stock viz. Rangpur line.
(vi) Decline/chlorosis	Insufficient soil moisture and nutrition	Yellowing and gradual reduction in the size of the leaves; die back of the twigs followed by decline and gradual death	
(vii) Root rot	***Phytophthora palmivora Phytophthora citriphthora Phytophthora parasitica Phytophthora nicotianae var. parasitica***	Use of tolerant root stock; Drenching with Ridomil and Foltaf.	
(viii) Pink disease	***Pellicularia salmonicolor***		

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17. *Objective model Question*

1. Match List-I (Crop species) with List-II (Serious disease) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Rice	1. Green ear
B. Wheat	2. Bacterial leaf blight
C. Maize	3. Stalk rot
D. Bajra	4. Alternaria leaf blight

CODES :

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

2. Which of the following pairs of wheat rusts and alternate hosts are correctly matched?
(1) Puccinia graminis tritici.........Berberis vulagaris
(2) Puccinia recondita tritici.........Thalictrum spp.
(3) Puccinia striiformis.............Phalaris minor.
Select the correct answer using the codes given below:
CODES :
(a) 1, 2 and 3
(b) 1 and 2
(c) 1 and 3
(d) 2 and 3

03. Match List-I (Crop disease) with List-II (Pathogen) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Tikka disease of groundnut	1. Erysiphe graminis f.s.p. hordei

B. Powdery mildew of barley 2. Puccinia striiformis
C. Yellow rust of wheat 3. Plasmopara viticola
D. Downy mildew of grapes 4. Cercospora personata

CODES :

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

4. Which one of the follwing pairs of crop and disease is correctly matched?
   (a) Cabbage — Early blight
   (b) Cucumber — Club root
   (c) Potato — Black ward
   (d) Tomato — White rust
5. Which one of the follwing pairs is NOT correctly matched?
   (a) Karnal bunt of wheat — Neovossia horrida
   (b) False smut of rice — Ustilaginoidea virens
   (c) Hill bunt of wheat — Tilletia foetida
   (d) Ear cockle of wheat — Anguina tritici
6. Plant pathogenic viroids contain
   (a) RNA only
   (b) RNA and protein coat
   (c) DNA and protein coat
   (d) DNA only
7. Loose smut of wheat is a/an
   (a) externally seed-borne disease
   (b) externally seed-borne and soil-borne disease
   (c) air-borne disease
   (d) internally seed-borne disease
8. Which of the following are the sources of survival of the wilt pathogen of sugarcane in India?
   (1) Ratoon of infected crop
   (2) Diseased plant debris
   (3) Setts of diseased crop
   (4) Collateral hosts

Select the correct answer using the codes given below:
CODES:
   (a) 1, 2, 3 and 4
   (b) 2 and 3
   (c) 3 and 4
   (d) 1, 2 and 3
9. Which one of the following is the correct order in which they appear during biocontrol operations?
   (a) Parasite, Release, Mass rearing, Parasitism
   (b) Mass rearing, Parasite, Release, Parasitism
   (c) Release, Mass rearing, Parasite, Parasitism
   (d) Parasite, Mass rearing, Release, Parasitism
10. The following major events occur during the pathogenesis of a host by a pathogen:
   (1) Landing of inoculum
   (2) Recognition
   (3) Germination of the propagules
   (4) Penetration
   (5) Establishment
   (6) Development of symptom

   The correct sequence of these events in disease development is
   (a) 1, 2, 3, 4, 5, 6
   (b) 1, 3, 4, 2, 5, 6
   (c) 1, 2, 4, 3, 5, 6
   (d) 1, 3, 2, 4, 5, 6
11. Mycoplasma is sensitive to
   (a) penicillin
   (b) tetracyclin
   (c) calixin
   (d) streptomycin
12. Whorl application of granular insecticide provides effective control measure against:
   (a) spotted bollworm
   (b) maize stem borer
   (c) stem borer of paddy
   (d) mango stem borer

13. Match List-I (Principles of disease control) with List-II (Practices) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Exclusion	1. Spraying a common fungicide
B. Avoidance	2. Chemical seed treatment
C. Eradication	3. Isolation in time and space
D. Protection	4. Plant quarantine

CODES :

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

14. Which one of the following insecticides is capable of controlling mites as well?
(a) Endosulfan
(b) Toxaphene
(c) Cypermethrin
(d) Monocrotophos

15. The safest method of disposing off the left over pesticide is, disposal by:
(a) pouring in the drain
(b) pouring in a pond
(c) pouring in a moving stream
(d) burying in the soil

16. Which of the following types of manually operated sprayers are suitable for spraying 4 to 5 metre tall plantations?
(1) Hand compression sprayer
(2) Knapsack sprayer
(3) Foot sprayer
(4) Rocking sprayer
Select the correct answer using the codes given below:
CODES :
(a) 1, 2, 3 and 4
(b) 2 and 4

(c) 1, 2 and 3
(d) 3 and 4

17. Which of the following protective measures are necessary for a person manually dusting pesticide on crop in uncertain wind conditions?
(1) Wearing plastic aprons
(2) Use of plastic gloves
(3) Use of plastic shoes
(4) Use of goggles
(5) Use of nose filters
Select the correct answer using the codes given below:
CODES :
(a) 1, 2, 3, 4 and 5
(b) 1, 2, 4 and 5
(c) 2, 3 and 4
(d) 1, 3 and 5

18. If one gram of a pesticide formulation containing 50% active ingredient is mixed with one litre of water, what will be the concentration of the active ingredient in the spray fluid?
(a) 0.5 ppm
(b) 5.0 ppm
(c) 50 ppm
(d) 500 ppm

19. Assertion (A) : Philosophy of pest control based on eradication of pest spices is the antithesis of integrated pest control.
Reason (R) : Eradication of pest spices leads to an unstable biotic community.

20. Assertion (A) : The broad spectrum insecticide needs to be used for all agricultural crops.
Reason (R) : Broad spectrum insecticide kills a large variety of insects.

21. Consider the following statements regarding enzymes in living plants:
(1) They are specific.
(2) They are sensitive to heat.
(3) The reactions caused by enzymes are reversible.
(4) They exist in a colloidal state.
Of these statements
(a) 1 and 2 are correct
(b) 1, 3 and 4 are correct

(c) 2, 3 and 4 are correct
(d) 1, 2, 3 and 4 are correct

22. Which one of the following plant nutrients is useful in increasing resistance to diseases and insect pests?
(a) Calcium
(b) Phosphorus
(c) Nitrogen
(d) Potassium

23. Parts of cell walls in plants are given in List-I and their distinctive components are given in List-II. Match the two lists and select the correct answer using the codes given below the lists:

List-I	List-II
A. Primary wall	1. Hemicellulose
B. Secondary wall	2. Lignin
C. Middle lamella	3. Lipids and proteins
D. Plasma lemma	4. Pectin

CODES :

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

24. During the conversion of each molecule of glucose into pyruvic acid through the glycolytic cycle
(a) one Molecule of ATP is consumed and two molecules of ATP are generated
(b) two molecules of ATP are consumed and two molecules of ATP are generated
(c) one molecules of ATP is consumed and four molecules of ATP are generated
(d) two molecules of ATP are consumed and four molecules of ATP are generated

25. Which is the correct chronological sequence of the following discoveries related to mechanism of photosynthesis?
(1) Calvin's cycle
(2) Hatch and Slack cycle
(3) Hill reaction
(4) Red drop
Choose the correct answer using the codes given below:
(a) 3, 4, 2, 1
(b) 4, 3, 2, 1
(c) 3, 4, 1, 2
(d) 4, 3, 1, 2

26. Match List-I (Plant growth regulators) with List-II (Possible precursors) and select the correct answer using the codes given below the lists:

List-I	List-II
A. ABA	1. Tryptophan
B. Ethylene	2. Terpenoids
C. GA_3	3. Fatty acids
D. IAA	4. Carotenoids

CODES :

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

27. Which of the following chemicals are responsible for the induction of female flower?
(1) Ethephone
(2) GA_3
(3) NAA
(4) Morphactine
Select the correct answer using the codes given below:
CODES:
(a) 1 and 4
(b) 2 and 4
(c) 1 and 3
(d) 3 and 4

28. The main function of maleic hydrazide is considered to be that of a/an
(a) antiauxin

(b) antagonist to gibberellin
(c) inhibitor
(d) growth retardant

29. Khaira disease of rice can be controlled by spraying
(a) copper sulphate
(b) manganese sulphate
(c) borax
(d) zinc sulphate

30. Which of the following are features of CO_2 metabolism of succulent plants with CAM?
(1) Nocturnal stomatal opening
(2) Night-time transpiration
(3) Night-time CO_2 uptake
(4) Decrease in acidity during the night
Select the correct answer using the codes given below:
CODES:
(a) 2, 3 and 4
(b) 1, 2 and 4
(c) 1, 3 and 4
(d) 1, 2 and 3

31. There is a definite relationship between the extent of accumulation of a particular metal ion and the extent of stomatal opening. The metal ion in question is
(a) calcium
(b) magnesium
(c) potassium
(d) sodium

32. The photosynthetic pigment which ocurs in red and blue green algae is
(a) chlorophyll
(b) carotenoid
(c) cytochrome
(d) phycobilin

33. Evidence for universal nature of flowering hormone has emerged from experiments involving
(a) defoliation
(b) reciprocal grafting
(c) night interruption
(d) application of hormones

34. Substitude adenine compounds which promote cell division in plant tissues would include
(a) cytokinins
(b) gibberellins
(c) morphactins
(d) triacontanols

35. When meristems of plants become dormant, there is
(a) inhibition of auxins
(b) inhibition of cytokinins
(c) inhibition of gibberellins
(d) accumulation of abscissic acid

36. Which of the following pairs are correct matched?

1.	Internal necrosis of jack fruit	Boron deficiency
2.	'Black tip' of mango	Air pollution (fumes from brick kilns
3.	'Cavity spot' of carrot	calcium deficiency

Select the correct answer using the codes given below:
CODES :
(a) 1, 2 and 3
(b) 1 and 2
(c) 1 and 3
(d) 2 and 3

37. Coffee rust is caused by
(a) Uromyces hobsoni
(b) Hemileia vastatrix
(c) Cronartium ribicola
(d) Ravenelia emblicae

38. The plant disease primarily responsible for the "Great Bengal Famine" of 1943 was
(a) blast disease of rice
(b) bacterial blight of rice
(c) udbatta disease of rice
(d) brown leaf spot of rice

39. Pectinolytic enzymes of plant pathogens play a major role during pathogenesis in diseases like
(a) rusts
(b) downy mildew

(c) wilts, damping-off and root/footrots
(d) powdery mildew

40. Which one of the following insects is a gregarious pest?
(a) Sorghum shoot fly
(b) Spotted bollworm
(c) Migratory locust
(d) Rice caseworm

41. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I (Crops)	List-II (Smut diseases)
A. Barley	1. Grain smut
B. Paddy	2. Whip smut
C. Sorghum	3. False smut
D. Sugarcane	4. Flag smut
	5. Covered smut
	6. Stinking smut

Codes :

	A	B	C	D
(a)	5	3	2	6
(b)	5	3	1	2
(c)	1	4	2	6
(d)	1	5	4	6

42. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I (Disease)	List-II (Casual organism)
A. Wart disease of potato	1. Phytophthora parasitica
B. White rust of crucifers	2. Albugo candida
C. Blister blight of tea	3. Uncinula necator
D. Panama disease of banana	4. Synchytrium endobioticum
	5. Exobasidium vexans
	6. Fusarium oxysporum f.s.p. cubense

Codes :

	A	B	C	D
(a)	2	4	3	1
(b)	4	2	5	6
(c)	1	2	3	6
(d)	2	4	5	3

43. Which one of the following is the correct mode of infection in Ergot of bajra (pearl millet)?
(a) Shoot infection
(b) Local infection of blossom
(c) Seedling infection
(d) Systemic infection

44. Which one of the following is truly diagnoses the infestation by the shorghum shootfly?
(a) Formation of 'dead heart' in the early seedling stage of sor ghum which can be easily pulled out
(b) Formation of 'dead heart' and a bunchy top during the later seedling stage of sorghum
(c) Formation of 'dead heart' which can not be easily pulled out during the later seedling stage of sorghum
(d) Formation of silvery shoot during the early seedling stage of sorghum.

45. Tomato leaf curl virus is transmitted by
(a) aphid
(b) whitefly
(c) grasshopper
(d) butterfly

46. Which one of the following pests is controlled through the application of a grease band around the tree trunk?
(a) Mango mealy bug
(b) Trunk borer of mango
(c) Codling moth on apple
(d) Woolly aphis on apple

47. Identify the correct sequence in which fungitoxic activity of the following were reported:
1. Dithocarbamates
2. Bordeaux mixture

3. Captan
4. Oxathin derivatives

Codes :

(a) 1, 2, 3, 4
(b) 2, 1, 4, 3
(c) 2, 1, 3, 4
(d) 1, 2, 3, 4

48. The quantity of endosulphan 35% EC required for treating an area which needs 1000 litres of spray fluid at 0.05% (a.i.) strength is

(a) 35 x 0.05 / 1000 litres
(b) 2.5 x 1000 / 1000 litres
(c) 1000 x 0.05 / 35 litres
(d) 35 x 1000 / 0.05 litres

49. Which one of the following tissues is most suitable for tissue culture to produce virus-free plants of potato?

(a) Leaf tissue
(b) Pollen
(c) Embryo tissue
(d) Meristem tip tissue

50. The size (in micrometers in diameter) of droplets produced by high volume sprayers should most appropriately be

(a) 200 to 500
(b) 100 to 150
(c) 81 to 100
(d) 30 to 40

51. Consider the following statements :

The rate of application of spray fluid per unit area is regulated by the

(1) operating pressure
(2) size of nozzle apperture
(3) swath width
(4) speed of the operator

Of these statements

(a) 1, 2 and 3 are correct
(b) 3 and 4 are correct
(c) 1, 2 and 4 are correct
(d) 1, 2, 3 and 4 are correct

52. Spraying of one hectare of cotton crop is done using 500 litres of spray fluid prepared from 2 kg. of carbaryl 50% water dispersible powder. The concentration of active ingredient of carbaryl in the spray fluid is

(a) 1%
(b) 0.2%
(c) 0.1%
(d) 0.5%

53. Assertaion (A): Low volume (LV) sprays are more eco nomic than high volume (HV) sprays.

Reason (R) : Less quantity of pesticide is required per unit area for LV sprays when compared to the HV sprays.

54. Assertion (A) : Integrated pest management is a part of sus tained agriculture.

Reason (R) : Integrated pest management protects the crop against harmful pests with minimum pollution hazard to the environment and leads to increased food production.

55. Assertion (A) : Epyphytotic of late blight of potato in 1845 forced man to realise the importance of plant diseases.

Reason (R) : In 1845 there was famine in Ireland and many people died of hunger and disease.

56. Match List-I (Symptomps) with List-II (Causes) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Khaira disease of rice	1. Phophorus deficiency
B. Browning of cauliflower	2. Molybdenum deficiency
C. Purple colouration of maize leaves	3. Potassium deficiency
D. Firing of tobaco leaves	4. Zinc deficiency

Codes :

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

57. The uptake of oxygen and production of carbon dioxide in light by photosynthesising tissue is called
(a) respiration
(b) photo respiration
(c) ground respiration
(d) salt respiration

58. The link between glycolysis and citric acid cycle is the oxidative decarboxylation reaction to form
(a) pyruvate
(b) acetyl CoA
(c) oxaloacetate
(d) citrate

59. Indole acetic acid belongs to which one of the following groups of plant growth hormones?
(a) Gibberellins
(b) Auxins
(c) Kinins
(d) Vitamins

60. In plants, growth rate, protein synthesis and potassium uptake are stimulated by
(a) cytokinins
(b) enzymes
(c) auxin
(d) ethylene

61. The growth hormone which overcomes genetic dwarfism in certain plants and causes elongation of intact plant is
(a) gibberellin
(b) auxin
(c) abscisic
(d) cytokinin

62. Match List-I (Diseases) with List-II (Casual organisms) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Citrus canker	1. Pseudomonas solanacearum
B. Black rot	2. Agrobacterium tumefaciens
C. Brown rot	3. Xanthomonas compestris pv.
D. Crown gall	4. Xanthomonas compestris pv. citri

CODES :

	A	B	C	D
(a)	4	3	1	2

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

63. Which of the following pairs are correctly matched?

(1) Brown spot of rice	Helminthosporium oryzae
(2) Karnal bunt of wheat	Neovossia indica
(3) Bunt of rice	Neovossia horrida
(4) Hill bunt of wheat	Ustilago tritici

Select the correct answer using the codes given below:
CODES :
(a) 2, 3 and 4
(b) 1, 2 and 4
(c) 1, 3 and 4.
(d) 1, 2 and 3

64. Loose smut of wheat can be effectively controlled by
(a) crop rotation
(b) soil treatment with non-systemic fungicides
(c) seed treatment with systemic fungicides
(d) spraying the crop with fungicides

65. Which one of the following correctly defines the period between inoculation and appearance of the first disease symptom?
(a) Penetration period
(b) Latent period
(c) Incubation period
(d) Infection period

66. Match List-I (Casual agent) with List-II (Disease caused) and Select the correct answer using the codes given below the lists:

List-I	List-II
A. Virus	1. Sesamum phyllody
B. Mycoplasma	2. Potato spindle tuber
C. Fungus	3. Yellow vein mosaic of okra
D. Viroid	4. Downy mildew of bajra

CODES :

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

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

67. The two important diseases of sugarcane would include
(a) little leaf and bacterial wilt
(b) red rot and grassy shoot
(c) red rot and bunt
(d) bakanae disease and stem canker

68. Which one of the following statements correctly defines economic threshold level?
(a) The pest population level at which control measure should be taken to prevent the pest population from reaching economic injury level
(b) The lowest pest population density that will cause economic damage
(c) The optimum pest population density that will cause economic damage
(d) The pest population level at which application of pest control measures will be uneconomic

69. Which one of the following statements correctly defines the "alternate host" of a pathogen/parasite?
(a) A host on which a parasite attacks simultaneously with the main host
(b) A host which grows in alternate season or year
(c) One of the two kinds of hosts on which a parasitic fungus develops to complete its life cycle
(d) A host on which, the parasite does not attack in normal conditions

70. Which one of the following is the best method of controlling ear cockle disease of wheat?
(a) Application of solar heat
(b) Mechanical separation of infected seed by floatation
(c) Application of balanced dose of fertilizer
(d) Treatment of seed with pesticide

71. What is the chronological order in which the following organizations were established by Govt. of India?
1. Locust warning and control organization
2. Directorate of Plant Protection, Quarantine and Storage

3. Zoological Survey of India
Select the correct answer using the codes given below:
CODES :
(a) 1, 3, 2
(b) 3, 2, 1
(c) 3, 1, 2
(d) 2, 1, 3

72. Mycoplasma is sensitive to
(a) pencillin
(b) bavistin
(c) tetracycline
(d) calixin

73. Which of the following come under the category of cultural control of insects?
1. Change in sowing time
2. Destruction of collateral hosts
3. Killing effect of Sun's rays
4. Mixed cropping
CODES :
(a) 1, 2, 3 and 4
(b) 2 and 4
(c) 1, 2 and 4
(d) 1 and 2

74. Which one of the following can be classified as autocidal technique of insect control?
(a) Introduction of bio-agents
(b) Evolving resistant cultivars
(c) Use of insect growth regulators
(d) Release of sterile males

75. Which one of the following sprayers requires only one-third of the quantity of water while keeping the same quantity of active ingredient of the pesticide per hectare?
(a) Foot/pedal sprayer
(b) Mist blower
(c) Rocking sprayer
(d) Knapsack/backpack sprayer

76. Which one of the following sprayers would require the LOWEST volume of spray solution to cover a hectare of rice crop?
(a) Power sprayer

(b) Foot sprayer
(c) Knapsack sprayer
(d) Hand sprayer

77. The quantity of liquid insecticide with 25% active ingredient required for preparing 500 litres of the spray fluid of 0.25% strength is
(a) 1.25 litre
(b) 2.5 litre
(c) 5.0 litre
(d) 10 litre

78. Assertion (A) : Both nymphs and adults of an insect species have the same type of mouth parts.
Reason (R) : Such species lack completely metamorphosis.

79. Assertion (A) : For successful farming, pest must be controlled.
Reason (R) : All insects are crop pests.

80. Assertion (A) : The pump of a pneumatic or compression sprayer is required to be operated continuously while spraying.
Reason (R) : Initial operation of the pump develops certain amount of pressure on the spray fluid within the tank.

81. Entry of potassium ions into root hair in soils having a low potassium ion content in the soil is mediated through
(a) ion exchange mechanism
(b) mass flow phenomenon
(c) Donnan equilibrium process
(d) utilisation of metabolic energy

82. Consider the following statements:
According to cohesion theory for the ascent of sap, water moves from the roots through the stems to the leaves in tall trees because of
(1) forces of root pressure
(2) the gradient in decreasing water potentials from the soil, through the plant to the leaves
(3) forces of adhesion of water to cell walls, especially in the leaves
(4) forces of cohesion between water molecules
Of these statements
(a) 1, 2 and 3 are correct
(b) 2, 3 and 4 are correct
(c) 1, 3 and 4 are correct
(d) 1, 2 and 4 are correct

83. Which one of the following physiological processes requires close coordination of three different organelles such as mitochondria, chloroplast and peroxisome?
(a) Photosynthesis
(b) Photorespiration
(c) Respiration
(d) Protein synthesis

84. Which of the following are characteristic of C_4 plants?
(1) There are two CO_2 acceptors, namely PEP and RuBP.
(2) RuBP carboxylase is present in the mesophyll cells.
(3) The first stable product is a 4-carbon compound.
(4) Oxygen does not have any inhibitory effect on the process.
Select the correct answer using the codes given below:
CODES:
(a) 1, 2 and 4
(b) 1, 3 and 4
(c) 1, 2 and 3
(d) 2, 3 and 4

85. Which one of the following is a set of high energy products of the light reaction of photosynthesis that are used in dark reaction?
(a) ATP and plastocynine
(b) ATP and NADP
(c) ATP and (NADPH + H^+)
(d) Plastoquinone and ferridoxine

86. Which of the following pairs of hormones and bioassay techniques are correctly matched?

(1)	Cytokinin	Radish cotyledon test
(2)	Gibberellic acid	Rice second leaf test
(3)	Indole-3-acetic acid	Coleoptile curvature test

Select the correct answer using the codes given below:
(a) 2 and 3
(b) 1 and 2
(c) 1 and 3
(d) 1, 2 and 3

87. Which of the following statements about carotenoids are correct?
(1) Carotenoids present in coleoptile affect the destruction of auxin by light.
(2) Pollens generally carried by insects for pollination contain carotenes whereas carotenoid pigments are rarely detected in pollens of wind pollinated flowers.

(3) They cause a suitable drop in light intensity leading to a gradi ent of increasing auxin concentration from the lighted side to the darker side.

(4) They absorb blue light to produce phototropic curvature in oat coleoptile in phycomyces and also in certain blue-green algae.

Select the correct answer using the codes given below:

CODES :

(a) 2, 3 and 4
(b) 1, 2 and 4
(c) 1, 3 and 4
(d) 1, 2 and 3

88. Which of the following structures help the fungi to survive under adverse conditions?

(1) Zoospores
(2) Chalmydospores
(3) Sclerotia
(4) Conidiospores

Select the correct answer using the codes given below:

CODES :

(a) 3 and 4
(b) 2 and 4
(c) 1, 2 and 3
(d) 2 and 3

89. Modification of floral parts into leafy structures by pathogenic infection is called

(a) hyperplasia
(b) hypertrophy
(c) phyllody
(d) witch's broom

90. Match List-I (Diceases) with List-II (Diceases incitants) and Select the correct answer using the codes given below the lists:

List-I	List-II
A. Karnal bunt of wheat	1. Sclerospora graminicola
B. Late blight of potato	2. Tilletia indica
C. Flax rust	3. Phytophthora infestans
D. Downy mildew of bajra	4. Melamspora lini

CODES :

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

91. Consider the following statements:

"Gundhi bug" causes damage to paddy crop by

(1) sucking juice from the developing grains
(2) sucking juice from the leaves
(3) sucking juice from the culm
(4) affecting the quality and quantity of grain

Of these statements

(a) 2 and 4 are correct
(b) 1, 3 and 4 are correct
(c) 2 alone is correct
(d) 1 alone is correct

92. Two of the more important diseases of potato whose spread in India has been successfully restricted through plant quarantine measures include

(a) Brown rot and late blight
(b) Wart and golden nematode
(c) Ring rot and mosaic
(d) Bacterial wilt and charcoal rot

93. Severe incidence of red hairy caterpillar occurs under which one of the following sets of conditions?

(a) High temperature and high soil moisture
(b) High temperature and low soil moisture
(c) Low temperature and high soil moisture
(d) Low temperature and low soil moisture

94. Match List-I with List-II and Select the correct answer using the codes given below the lists:

List-I *(Pathogenic genera of fungi)*	List-II *(Symptoms and effects)*
A. Cystopas	1. Red rust
B. Protomyces	2. Green ear
C. Sclerospora	3. White rust
D. Taphrina	4. Leaf curl
	5. Stem gall

CODES :

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

95. Consider the following stages:
   (1) Spore germination
   (2) Embryo infection
   (3) Spore on flower stigma
   (4) Infected grains

   The correct sequence of these stages in the development of loose smut disease in wheat is
   (a) 3, 1, 4, 2
   (b) 1, 3, 4, 2
   (c) 1, 3, 2, 4
   (d) 3, 1, 2, 4

96. Which one of the following is the vector for yellow vein mosaic of bhindi (okra)?
   (a) Brown plant hopper
   (b) Green plant hopper
   (c) Aphids
   (d) White files

97. Consider the following steps:
   (1) Sampling
   (2) Surveillance
   (3) Control stretegy

   The correct sequence of these steps in the management of pests and diseases is
   (a) 1, 2, 3
   (b) 2, 1, 3
   (c) 2, 3, 1
   (d) 1, 3, 2

98. Which one of the following statements correctly defines systemic insecticides?
   (a) An insecticide which enters into the system of insects

   (b) An insecticide which is absorbed into the plant system
   (c) An insecticide which is absorbed and translocated in the sys tem of the plant
   (d) An insecticide that processes translaminar activity

99. Which one of the following groups consists of systemic fungicide?
   (a) Bavistin, Topsin-M, Captan
   (b) Plantvax, Emisan, Blitox
   (c) Vitavax, Bavistin, Calixin
   (d) Ziram, Plantvax, Blitox

100. Brodeaux Mixture was discovered by P.A. Millardet of France during the year, 1882 following his chance observation of a farmer's practice for protection against
   (a) Plasmopara viticola on grapevine
   (b) Uncinula necator on grapevine
   (c) Podosphaera leucotricha on apple
   (d) Venturia inequalis on apple

101. Which one of the following sprayers will cause more loss of spray droplets by drift?
   (a) Low volume sprayer
   (b) High volume sprayer
   (c) Ultra low volume sprayer
   (d) Duster

102. Which of the following would determine the quantity of spray needed per hectare while using manually operated knapsack sprayers?
   (1) Swath of spray
   (2) Walking speed of the person doing the spraying
   (3) Calibration of the sprayer
   (4) Type of nozzle

   Select the correct answer using the code given below:

   CODES :
   (a) 1, 2 and 4
   (b) 1, 2 and 3
   (c) 1, 3 and 4
   (d) 2, 3 and 4

103. Which of the following safeguards are necessary for a proper operation and maintenance of plant protection equipment?
   (1) Lubrication should be followed faithfully using the specified lubricant.
   (2) A multigrade motor oil should not be mixed with petrol as fuel for a 2-stroke engine.

(3) The oil and fuel should be poured separately into the tank.
Select the correct answer using the code given below:
CODES :
(a) 2 and 3
(b) 1 and 2
(c) 1 and 3
(d) 1, 2 and 3

104. Which one of the following remedies is to be suggested in case of failure of a manually operated sprayer to retain pressure?
(a) Tightening of loose nuts and clamps and replacement of gas kets
(b) Tightening of the lid of the tank, replacement of the gasket, if necessary
(c) Opening the nozzle and cleaning its various parts especially the orifice
(d) Straightening the plunger rod if found bent

105. Assertion (A) : When light falls on guard cells of stomata, their osmotic potentials become more negative and they open.
Reason (R) : Light causes an increase in the transport of K^+ ions from the accessory cells to the guard cells.

106. Assertion (A) : In zinc deficient plants concentration of indole-acetic acid in the tissues drops well before vis ible symptoms appear.
Reason (R) : Zinc is essential for the synthesis of tryptophan.

107. Assertion (A) : Respiratory quotient for respiration of materials rich in carbohydrates is usually about 1.
Reason (R) : Carbohydrate molecules have the same number of carbon atoms as the oxygen atoms.

108. Assertion (A) : $CoCl_2$ and $NiCl_2$ promote the vase life of chry santhemum flowers.
Reason (R) : $CoCl_2$ and $NiCl_2$ act as anti-ethylene compounds.

109. Assertion (A) : Vitamin C requirement of human body has to be met by exogenous sources such as fruit and veg etables.
Reason (R) : Vitamin C can neither be synthesised nor stored in the human body.

110. Assertion (A) : Seed treatment with chlorpyriphos is done in groundnut.

Reason (R) : It helps in controlling white grub.

111. Assertion (A) : Integrated pest management is the best way of controlling disease and pests of crop plants.
Reason (R) : This ensures that all the insects and pathogens are killed effectively.

112. Assertion (A) : Survey and surveillance is the backbone of inte grated pest control.
Reason (R) : Integrated pest control can be achieved by inte grating chemical, biological, cultural, regulatory and mechanical methods of pest control.

113. Which one of the following chemicals is used to treat seed potato to break its dormancy?
(a) Ethral
(b) Thiourea
(c) Indole acetic acid
(d) Naphthalene acetic acid

114. Tick, which disease is commonly found in Jowar fields?
(a) Wilt
(b) Blast
(c) Leaf spot
(d) Grain smut

115. Citrus species resistant to canker is:
(a) Citrus aurantifolia
(b) Citrus limonia
(c) Citrus paradisi
(d) Citrus karna

116. The "little leaf" disease of brinjal is caused by:
(a) Fungus
(b) Bacteria
(c) Nutrition
(d) None of the above

117. Mycorrhizal association is found in:
(a) Papaya
(b) Litchi
(c) Bael
(d) Ber

118. The most commonly used plant growth regulator for rooting of cut-tings is:
(a) IBA
(b) Cycocel

(c) Ethephone
(d) GA_3

119. The casual organism of 'red rot' a fungal disease of sugarcane, is present in:
(a) Soil
(b) Climate
(c) Seed (planting material)
(d) Virus

120. The most suitable chemical for seed treatment of wheat against 'Kernel bunt' is:
(a) B. H. C.
(b) Agrosan G.N.
(c) Vitavax
(d) Captan

121. The fruit-fly belongs to:
(a) Phycitidae
(b) Tephritidae
(c) Techinidae
(d) Coccinellidae

122. The insecticide act was passed by Parliament in the year:
(a) 1973
(b) 1965
(c) 1968
(d) 1972

123. The locust deposits its eggs:
(a) On lower surface of leaves
(b) In the soil
(c) In the tender parts of a twig
(d) In dry grasses

124. The rate of fumigation of EDB per quintal grain is:
(a) 1 ml.
(b) 3 ml.
(c) 6 ml.
(d) 10 ml.

125. Hopper burn is the result of attack of the following insect pest:
(a) Grasshopper
(b) Sugarcane leafhopper
(c) Brown planthopper
(d) Green leafhopper

126. Which of the following insecticide is safest for use?
(a) Methyl parathion
(b) Carbaryl
(c) Phosphomidan
(d) DDT

127. Who was the first Plant Protection Advisor to Govt. of India?
(a) Dr. Sardar Singh
(b) Dr. S. Pradhan
(c) Dr. M.L. Roonwal
(d) Dr. H.S. Pruthi

128. White grub is the pest of:
(a) Rice
(b) Wheat
(c) Groundnut
(d) Mustard

129. Integrated pest management refers to:
(a) It is the use of zero pesticides
(b) Use of zero tillage
(c) Use of zero fertilizers
(d) Management of all above judiciously

130. The deficiency of thiamine (B_1) in human body causes:
(a) Night-blindness
(b) Beri-Beri
(c) Pellagra
(d) Scurvy

131. Dissemination of plant pathogens take place only by:
(a) wind
(b) wind and water
(c) wind, water and soil
(d) wind, water, soil and insects

132. One of the factors causing malformation of mango is:
(a) Fungus
(b) Nematodes
(c) Virus
(d) Bacteria

133. The zinc deficiency in paddy plants causes:
(a) Blight disease
(b) Ergot disease
(c) Smut disease
(d) Khaira disease

134. Panama wilt is a disease of:
(a) Apple
(b) Banana
(c) Pear
(d) Peach

135. The most convenient and safer chemical to control stored grain insects in rural areas is:
(a) E D B
(b) Celphos
(c) D D T
(d) Naphthalene ball

136. Insects with sucking type of mouth parts need following group of insecticides for effective controll:
(a) Stomach poisons
(b) Systemic poisons
(c) Contact poisons
(d) Fumigants

137. Insecticides under Intergrated Control System are applied at which one of the following stage:
(a) General equilibrium level
(b) Economic threshold level
(c) Economic injury level
(d) Total loss level

138. Cynogas pump is a:
(a) Sprayer
(b) Duster
(c) Flame thrower
(d) Fumigator

139. Which one of the following is the richest source of Vitamin 'A':
(a) Banana
(b) Wheat
(c) Rice
(d) Mango

140. 'Aphids' in mustard can be controlled by the use of:
(a) Malathion
(b) Vitavex
(c) Thiram
(d) Dithane-Z

141. Which one of the following is NOT correctly matched:

	Crop	*Disease*
(a)	Potato	Blight
(b)	Wheat	Smut
(c)	Jowar	Ergot
(d)	Til	Phyllody

142. Which one is an insect trap crop:
(a) Arhar
(b) Paddy
(c) Bhindi
(d) Potato

143. The most abundant acid in grape is:
(a) Tartaric acid
(b) Citric acid
(c) Ascorbic acid
(d) Gallic acid

144. Which is the most effective light in photosynthesis:
(a) Blue
(b) Green
(c) Yellow
(d) Red

145. In glycolysis, conversion of a molecule of glucose to two molecules of Pyruvic acid results in a net gain of:
(a) 8 ATP molecules
(b) 38 ATP molecules
(c) 2 ATP molecules
(d) 36 ATP molecules

146. The number of ATP that forms during the Kreb's cycle of respiration will be:
(a) 8
(b) 15
(c) 22
(d) 30

147. Nematodes are:
(a) Symbiotic nitrogen fixers
(b) Blue green algae
(c) Insects
(d) Plant pathogens

148. Which one of the following is a growth retardant:
(a) 2, 4, 5-T
(b) Cycocel
(c) CEPA
(d) TIBA
149. The correct pair is:
(a) Rice-white grub
(b) Potato-white ants
(c) Sugarcane-weevil
(d) Gram-pod borer
150. Pollen besket is found in the hind legs of:
(a) Termite
(b) Honeybee
(c) Ant
(d) Butterfly
151. Why insecticidal spraying should be avoided when crops are in flowering stage:
(a) to prevent flower dropping
(b) to facilitate proper fruit setting
(c) to protect bees
(d) to prevent insecticidal residues
152. Which one is the anticoagulant:
(a) Zinc phosphide
(b) Aluminium phosphide
(c) Magnesium oxide
(d) Bromodiolone
153. Under intigrated system of insect control we integrate:
(a) Cultural and biological methods
(b) Biological and legal methods
(c) Physical and chemical methods
(d) All types of methods
154. The least toxic insecticides to human beings belong to the following group:
(a) organo chlorines
(b) organo phosphates
(c) carbamates
(d) synthetic pyrethroids
155. Yellow mosaic in soyabean is spread by:
(a) Seeds
(b) Soils

(c) Air
(d) White fly
156. Loose smut of wheat is controlled by:
(a) Seed treatment
(b) Soil sterilization
(c) Crop rotation
(d) Thiram spray on crop
157. Systemic insecticide used to control pests is:
(a) Endosulphan
(b) Chlorpyriphos
(c) Phosphamidon
(d) Quinophos
158. Canker disease of citrus is caused by:
(a) Bacteria
(b) Fungus
(c) Virus
(d) Nematodes
159. 'Tungru' is a viral disease of:
(a) Rice
(b) Citrus
(c) Wheat
(d) Tobacco
160. Which one of the following is not correctly matched:

	Crop	*Disease*
(a)	Mustard	Alternaria blight
(b)	Urd (Black gram)	Sterility mosaic
(c)	Soyabean	Yellow mosaic
(d)	Groundnut	Bud necrosis

161. Loss of electron is known as:
(a) Oxidation
(b) Reduction
(c) Catalysis
(d) Hydrolysis
162. What is the correct sequence in which the following events occur during pathogenesis or disease cycle?
(1) Penetration
(2) Colonization
(3) Infection
(4) Exit of pathogen

Select the correct answer from the codes given below:

(a)	1,	3,	2,	4
(b)	1,	2,	3,	4
(c)	3,	1,	2,	4
(d)	4,	2,	3,	1

163. Which one of the following is the cause of "spreading decline" of citrus?
(a) Citrus nematode (Tylenchulus semipentrans)
(b) Burrowing nematode (Radopholus similis)
(c) Fungal diseases
(d) Nutritional deficiency

164. The incidence of "White grubs" is heavy in:
(a) heavily water-logged fields
(b) dry fields having sandy-loam soil
(c) dry fields of heavy clay soil
(d) desert land having little vegetation

165. Which one of the following helps in maintaining the shape of nematodes?
(a) Pseudocoelomic fluid
(b) Cuticle and muscles
(c) Pseudocoelome
(d) Annulation of cuticle

166. Green leaf hopper of paddy is the primary vector of
(a) tungro disease
(b) sheath rot disease
(c) kresek disease
(d) ufra disease

167. Bacterial leaf blight of rice caused by Xanthomonas oryzae can be indentified by
(a) wilting of the plant
(b) yellowing of leaves
(c) 'ooze test'
(d) defoliation

168. White ear-head in paddy is caused by
(a) gall fly
(b) green leaf hopper
(c) yellow stem borer
(d) stink bug

169. Match List-I with List-II and select the correct answer using the codes given below the lists:

	List-I *(contribution)*	List-II *(Scientist)*
A.	A fungus is the cause of wheat-bunt disease	1. K.C. Mehta
B.	Modern techniques of growing microorganisms in pure culture	2. T.O. Diener
C.	Discovery of disease cycle of wheat rust in India before 1947	3. Prevost
D.	Introduced the term 'viroid'	4. Brefeld

CODES :

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

170. Which one of the following types of spraying is best done by manually operated knapsack sprayer having flat-fan nozzle?
(a) High volume
(b) Low volume
(c) Ultra low volume
(d) Semi-low volume

171. Domestic quarantine exists in India against
(1) Panama disease of banana
(2) Potato root eelworm
(3) San Jose scale
(4) Sugarbeet eelworm

Select the correct answer from the codes given below

Codes:
(a) 1 and 4
(b) 1 and 2
(c) 2 and 3
(d) 2, 3 and 4

172. The spray is classified as aerosol when average droplet size (volume median diameter) is
(1) 50 m
(2) 50 - 100 m
(3) 100 - 200 m
(4) 200 - 400 m

173. Match List-I with List-II and select the correct answer using the codes given below the lists:

	List-I *(Equipments)*	**List-II** *(Insecticides/pesticides)*
A.	High volume sprayer	1. Dusts
B.	Blowers	2. Wettable powder
C.	Back pack sprayer	3. Liquids
D.	Rocker sprayer	4. Emulsions

CODES :

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

174. Pneumatic sprayers have been used in pest control for many years. A pneumatic sprayer
(a) operates using wind or air
(b) contains poisonous pesticide
(c) is a knapsack type sprayer
(d) operates automatically

175. Solar energy treatment of wheat seed against loose smut was given by
(a) Jensen in 1889
(b) Swingle in 1892
(c) Luthra and Sattar in 1934
(d) Freeman and Johnson in 1909

176. Which one of the following equipments can be effectively used for spraying an orchard crop?
(a) Barrel pump
(b) Sikar pump

(c) Foot sprayer
(d) Heli sprayer

177. Match List-I with List-II and select the correct answer using the codes given below the lists:

	List-I *(Equipments)*	**List-II** *(Mode of Use)*
A.	Rotary duster	1. Ultra low volume (ULV) formulation
B.	Package duster	2. Small scale use
C.	Heli sprayer	3. Feeding brush
D.	Pedal pump	4. High volume (HV) spray

CODES :

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

178. In case of rotary type of duster the air current is developed by
(a) bellows
(b) fans
(c) self-propelling jacket
(d) self-propelling blades

179. Which one of the following can be classified as hydraulic energy sprayer?
(a) kanpsack mist blower
(b) controlled drip applicator sprayer
(c) knapsack sprayer
(d) wheel barrow sprayer

180. Assertion (A) : All pests are NOT insects.
Reason (R) : There are a number of helpful and productive insects.

181. Assertion (A) : A multigrade motor oil should be mixed with petrol used as fuel for a 2-stroke engine for mo torized knapsack sprayer.
Reason (R) : Multigrade motor oils are blended from different grades of lubricating oils and are

suitable for engines subjected to great temperature variations.

182. Assertion (A) : Smut diseases (loose and covered smut) of wheat are seed-borne and can be effectively controlled by treating the seeds with a systemic fungicide.

Reason (R) : Systemic fungicide used (at the recommended dose) have no adverse effect on seed germination.

183. Match List-I (Crop) with List-II (problems associated with the crop) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Mango	1. Poor fruit set
B. Grape	2. Malformation
C. Pineapple	3. Powdery mildew
D. Custard apple	4. Fasciation

CODES :

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

184. Which one of the following is the correct sequence in the ethylene biosynthesis pathway?
(a) Methionine, ACC, SAM, Ethylene
(b) Methionine, SAM, ACC, Ethylene
(c) ACC, Methionine, SAM, Ethylene
(d) ACC, SAM, Methionine, Ethylene

185. Rhizoctonia solani causes a tuber borne disease of potato, called
(a) Black scurf
(b) Charcoal rot
(c) Common scab
(d) Powdery scab

186. What is the correct sequence of the following historical plant disease epiphytotics?
(1) Coffee rust epiphytotics in Ceylon
(2) Potato late blight epiphytotics in Ireland
(3) Rice leaf spot (Helminthosporium) epiphytotics in Bengal.
Select the correct answer using the codes given below:
CODES :
(a) 1, 3, 2
(b) 1, 2, 3
(c) 3, 1, 2
(d) 2, 1, 3

187. Which of the following pairs is correctly matched?

(a)	White fly	Yellow mosaic of green gram
(b)	Aphid	Mango malformation
(c)	Thrip	Groundnut tikka disease
(d)	Brown plant hopper	Blast of rice

188. Consider the following stages in the life cycle of the fungus that causes black or stem rust of wheat:
(a) Telia
(b) Uredia
(c) Spermogonia
(d) Aecia
The correct sequence of these stages in the life cycle of the fungus is
(a) 1, 2, 3, 4
(b) 2, 1, 4, 3
(c) 2, 1, 3, 4
(d) 1, 2, 4, 3

189. Which one of the following is the cause of black heart of potato?
(a) Copper deficiency
(b) Boron deficiency
(c) Potassium deficiency
(d) Oxygen deficiency

190. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I (Diseases)	List-II (Genera of fungi)
A. Bunts	1. Plasmopara, Bremia
B. Downy Mildews	2. Neovossia, Tilletia
C. Rusts	3. Sphacelotheca, Tolyposporium
D. Wilts	4. Melampsora, Uromyces

CODES:

	A	B	C	D
(a)	2	1	5	4

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

191. Rice-wheat cropping system is prone to some serious diseases which can affect both the crops. Which one of the following rice diseases can seriously damage the wheat crop in India, if virulent strains of the pathogen are introduced?
(a) Blast
(b) Bacterial leaf blight
(c) Brown spot
(d) Foolish seedling disease

192. Which one of the following fungicides is ineffective against loose smut of wheat?
(a) Baytan
(b) Bavistin 50W
(c) Thiram
(d) Vitacax 75W

193. Which one of the following types of fungicides is of greatest importance in protecting plants from fungal pathogenes?
(a) Therapeutant fungicides
(b) Eradicant fungicides
(c) Protectant fungicides
(d) Systemic fungicides

194. Which one of the following sets of abbreviations correctly designates pesticide formulation in the solid state?
(a) SD, EC and G
(b) SD, EC and WP
(c) SD, G and WP
(d) EC, G and WP

195. Which one of the following pesticides in banned in India?
(a) Endrin
(b) BHC
(c) Malathion
(d) Endosulphan

196. Which of the following would cause development of insect resistance to insecticides?
(1) Sub-lethal dose of the insecticide applied
(2) Repetitive use of the same insecticide
(3) Host plant factors
(4) Rigours of abiotic factors
Select the correct answer using the codes given below:
CODES:
(a) 2 and 4
(b) 1 and 2
(c) 1, 2 and 3
(d) 1, 2, 3 and 4

197. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I *(Pesticides of plant origin)*	**List-II** *(Sources)*
A. Neem products	1. Azadirachta indica
B. Nicotine	2. Chrysanthemum cinerariaefolium
C. Pyrethrum	3. Derris elliptica
D. Rotenone	4. Nicotiana rustica

CODES :

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

198. Consider the following statements :
Microbial pesticides like Baccilus thuringiensis (Bt) and Nuclear Polyhedrosis Viruses (NPV) are well-suited to the integrated pest management programme because
(1) the development of resistance in insects against pesticides is nil.
(2) there is much less possibility of resistance development against such pesticides.
(3) they are safe and ecofriendly.

(4) they are inexpensive.

Of these statements

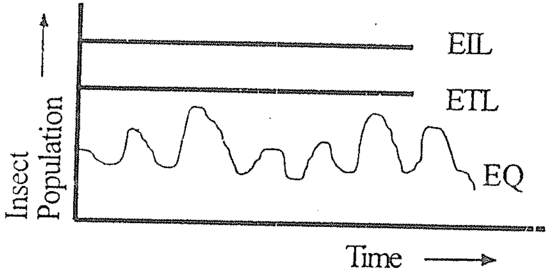
(a) 1, 2, 3 and 4 are correct

(b) 2, 3 and 4 are correct

(c) 3 and 4 are correct

(d) 2 and 3 are correct

199.



Equilibrium position (EQ), Economic Threshold Level (ETL) and Economic Injury Level (EIL) of an insect pest attacking a particular crop is shown in the above figure. The correct control strategy for this situation would be

(a) Spray insecticide at EIL

(b) Spray insecticide at ETL

(c) Spray insecticide below ETL

(d) None of the above as insecticide spray is not required.

200. Which one of the following is the most suitable substance for calibrating hand sprayer before taking up spraying with pesticides?

(a) Linseed oil

(b) Mustard oil

(c) Water

(d) Kerosene oil

201. Match List-I (Name of equipment) with List-II (Types) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Battery operated CDA sprayer	1. High volume sprayer
B. Knapsack power sprayer	2. Fumigation
C. Rocking sprayer	3. Low volume sprayer
D. Soil injector	4. ULV sprayer

CODES :

	A	B	C	D
(a)	3	4	2	1

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

202. What is the amount of Bavistin 50 W required to be added to 1000 litres of water to make a spray mixture of 0.05% a.i. concentration?

(a) 0.5 kg.

(b) 1.0 kg.

(c) 1.5 kg.

(d) 2.0 kg.

203. Assertion (A) : CCC leads to stunting of plant growth.

Reason (R) : CCC inhibits endogenous synthesis of gibberellins.

204. Assertion (A) : Calcium carbide is used to hasten the ripening of mango.

Reason (R) : Calcium carbide releases acetylene which promotes fruit repening.

205. Assertion (A) : Tobacco mosaic virus (TMV) has a very wide host range.

Reason (R) : TMV has an efficient aphid vector.

206. Assertion (A) : Aircraft spraying may be done from greater heights than dusting.

Reason (R) : Spray droplets fall faster than dust particles.

207. Which of the following is a ripening hormone:

(a) Ethylene

(b) Cytokinin

(c) Auxin

(d) Gibberellin

208. The attack of pea stem fly is maximum in:

(a) September

(b) November

(c) January

(d) February

209. Powdery mildew disease is a serious problem in which of the following crops:

(a) Capsicum

(b) Okra

(c) Cucurbits
(d) Pea

210. The maximum CO_2 concentration is found at high intensity of :
(a) 2500-5000 foot candles
(b) 6000-7500 foot candles
(c) 1000-2000 foot candlles
(d) 2150-2450 foot candles

211. Which of the following is controlled by Gibberellin acid :
(a) Fruit fall
(b) Ripening of fruits
(c) Vegetative growth
(d) Prevention of the loss of flowers

212. Auxin is :
(a) An Enzyme
(b) A Vitamin
(c) A Hormone
(d) A Protein

ANSWER

01.	c	19.	a	37.	b	55.	a
02.	b	20.	a	38.	d	56.	d
03.	c	21.	d	39.	c	57.	b
04.	c	22.	d	40.	c	58.	b
05.	a	23.	d	41.	b	59.	b
06.	a	24.	d	42.	b	60.	a
07.	d	25.	d	43.	b	61.	a
08.	a	26.	c	44.	a	62.	d
09.	d	27.	c	45.	b	63.	d
10.	-	28.	a	46.	a	64.	c
11.	b	29.	d	47.	c	65.	c
12.	a	30.	d	48.	c	66.	b
13.	c	31.	c	49.	d	67.	b
14.	d	32.	d	50.	a	68.	a
15.	d	33.	b	51.	d	69.	c
16.	d	34.	a	52.	b	70.	b
17.	a	35.	d	53.	a	71.	-
18.	d	36.	-	54.	a	72.	c

73.	c	110.	a	145.	c	179.	c
74.	d	111.	a	146.	d	180.	b
75.	b	112.	b	147.	d	181.	a
76.	a	113.	b	148.	b	182.	b
77.	c	114.	d	149.	d	183.	b
78.	a	115.	-	150.	b	184.	-
79.	c	116.	d	151.	c	185.	a
80.	d	117.	b	152.	a	186.	d
81.	d	118.	d	153.	d	187.	a
82.	b	119.	c	154.	d	188.	a
83.	b	120.	b	155.	d	189.	d
84.	b	121.	b	156.	a	190.	a
85.	c	122.	c	157.	c	191.	-
86.	d	123.	b	158.	a	192.	c
87.	-	124.	b	159.	a	193.	c
88.	d	125.	c	160.	d	194.	c
89.	c	126.	b	161.	a	195.	a
90.	b	127.	-	162.	a	196.	d
91.	d	128.	c	163.	b	197.	b
92.	b	129.	a	164.	b	198.	d
93.	a	130.	b	165.	a	199.	b
94.	d	131.	d	166.	a	200.	a
95.	d	132.	a	167.	c	201.	b
96.	d	133.	d	168.	c	202.	b
97.	b	134.	b	169.	c	203.	a
98.	c	135.	b	170.	a	204.	a
99.	c	136.	b	171.	c	205.	b
100.	a	137.	b	172.	a	206.	c
101.	c	138.	d	173.	b	207.	a
102.	a	139.	d	174.	a	208.	-
103.	d	140.	a	175.	c	209.	d
104.	b	141.	c	176.	c	210.	-
105.	a	142.	c	177.	b	211.	a
106.	-	143.	a	178.	b	212.	c
107.	a	144.	d				
108.	-						
109.	a						

अत्त दीपो भवथ