FOREST BOTANY

Part - I

DIRECTORATE OF FORESTS
GOVERNMENT OF WEST BENGAL

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PREFACE

Botany is one of the core subjects of forestry. Scientific management of plant resources of forests requires a forest manager to familiarize himself with the fundamentals of the plants – their internal and external structure, diverse physiological functions, interaction with the environment in which they grow, their uses and other aspects related to plant life. As part of the JICA project on 'Capacity Development for Forest Management and Training of Personnel' being implemented by the Forest Department, Govt of West Bengal, these course materials on Forest Botany have been prepared for induction training of the Foresters and Forest Guards. The object of this training manual is to present the basic aspects of Forest Botany.

The subjects covered in these materials broadly conform to syllabus laid down in the guidelines issued by the Ministry of Environment of Forests, Govt of India, vide the Ministry's No 3 -17/1999-RT dated 05.03.13. In dealing with some of the parts of the course though, the syllabus has undergone minor revision to facilitate better understanding of the subjects and to provide their appropriate coverage. The revised syllabus, with such modifications, is appended.

As the materials are meant for the training of frontline staff of the Department, effort has been made to present the subject in simple and easy language. However, as the subject unavoidably brings many scientific terms to make proper and precise presentation of the topics, it has been felt necessary to deal with and include such botanical terms in the lessons, particularly those on plant morphology.

The contents of the course materials have been compiled and edited by A Basu Ray Chaudhuri, IFS (Retd). Many books and literature including those available in internet have been made use of in preparing these course materials and references of such books and documents have been cited in the respective lessons. Shri A Basu Ray Chaudhuri is indebted to many forest officers who have helped in the preparation of these materials. A special word of thanks goes to Dr. Kana Talukder, IFS, CCF for helping with valuable suggestions and inputs.

Efforts that have gone into making of these course materials will be best rewarded if the frontline staff of the forest department find these materials useful in their day-to-day works.

Kolkata, 2015

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SYLLABUS

Forest Botany (17* hours) Excursion 1 day		
1. Basics	1.1 External morphology (bark, branching pattern, phyllotaxy, leaf form, flower & inflorescence, fruit and seeds) -parts of a plant -roots types and functions -stem – functions -Leaf parts functions -Inflorescence types -Flowers-unisexual and bisexual-parts and functions -fruits simple, aggregate and multiple -seeds dispersal germination 1.2 anatomy -cells and tissues -heartwood and sapwood -annual rings 1.3 physiology -photosynthesis -transpiration -translocation -respiration 1.4 taxonomy -binomial nomenclature -species, genus, family 1.5 vegetative propagation 1.6 ecology -basic concepts - plant succession -eco-system -related energy in ecological system, food chain and -food web, -ecological balance*	13* hours (4* hours practical in laboratory)
2. Economic botany	-local names of 47* timber and NW FP species, their description*, distribution*, economic importance and uses. -Preparation of herbarium sheet for 10 important species (to be done during tour)*	4 hours
3. Field botany	During JFM fieldwork, the trainees will learn to identify the local species from the villagers and learn their local names and uses. -it is sufficient if the trainee assimilates local and common names of 50 important species. However, the course material should give the botanical names. During on the job training RFO/DFO should test their field knowledge Teach the trainees the local and botanical names of the important species. Identification of plants from morphology will be continued during Saturday excursions and tours/with villagers during collaborative walk during PRA exercise.	

* These are modifications to the MoEF-prescribed syllabus, indicating revision/addition of topics and change in lesson hours.

CONTENTS

Time 1 hour

Lesson Plan

Objective:

- To know about scope of the subject Botany
- To know about the groups of plants
- To study Plant Morphology – The Root

Backward Linkage: Nil

Forward Linkage:

- Plant Morphology and Physiology discussed in subsequent lessons

Training Materials Required:

- Copy of lesson 1 to be circulated beforehand

Allocation of time:

- Scope of Botany – 5 mts
- Groups of plants – 8 mts
- Plant morphology – diversity of plant life – 5 mts
- Parts of a flowering plant – The root – 32 mts
- Discussion/ Miscellaneous – 10 mts.

1. Scope of Botany

The subject of Botany deals with the study of plants. The scope of this study includes –

- Internal and external structure of plants ranging from the simplest to most complex form.
- Diverse physiological functions – respiration, manufacture of food, conduction of food and water, mode of reproduction etc.
- Adaptation to diverse conditions
- Distribution in space and time
- Relationship with other plants
- Classification in natural groups
- Evolution from lower and simple forms to the higher and more complex ones
- Uses.

2. Main groups of plants

There are two main divisions of plant kingdom – (1) **cryptogams** and (2) **phanerogams**. **Cryptogams** are lower plants which **never bear flowers or seeds**; they are regarded as flowerless or seedless plants. **Phanerogams** are higher plants which **always bear flowers and seeds,** and are regarded as flowering or seed bearing plants.

2.1 **Cryptogams** comprise **three** groups, namely

- **Thallophyta** – lower cryptogams; the plant body is not differentiated into root, stem or leaf. Examples are Algae, Bacteria, Fungi, Lichens (associations of algae and fungi).
- **Bryophyta** – higher cryptogams; plant body may be thalloid (primitive) or leafy (advanced); have root-like (not true roots) structure called rhizoids.
- **Pteridophyta** – the highest group of cryptogams; plant body is differentiated into root, stem and leaves, but there is no flower and seed formation. Common examples are ferns.

2.2 **Phanerogams** have two main characteristics –

- Formation of pollen-tube to facilitate fertilization
- Production of seeds for reproduction

Phanerogams are divided into two groups –

(1). **Gymnosperms** (gymnos – naked, sperma – seed) – They are naked seeded plants, that is, those in which seeds are not enclosed in the fruit. They have simple and unisexual (either male or female) flowers. Common example is conifers.

(2). **Angiosperms –** They are closed-seeded plants; seeds are enclosed in the fruit.

Angiosperms comprise two big groups –

- **Dicotyledons –** Bigger group of angiosperms in which the embryo of the seed bears **two cotyledons.** Other characteristics are
  - Flower commonly bears five petals or multiple of this number
  - Root system has tap root
  - Leaves have reticulate (net like) venation
- **Monocotyledons -** Smaller group of angiosperms in which embryo of the seed bears only one cotyledon. Other characteristics are
  - Flower commonly bears three petals or multiple of this number;
  - Root system has fibrous roots;
  - Leaves have parallel venation.

3. Plant Morphology

Morphology deals with the study of forms and features of different plant organs such as roots, stems, leaves, flowers, seeds and fruits.

3.1. A few terms relating to diversity of Plant life

3.1.1. Habitat- The habitat is the natural home of a plant. Each habitat is characterized with a particular type of a climate, a particular type of soil and typical flora.

3.1.2. Habits- The nature of the stem, the height of the plant, its duration and mode of life determine the habit of a plant. Following terms are commonly used to indicate habits of plant.

- **Herbs-** Small plants with soft stem.
- **Shrubs-** Medium–sized plant with a hard and woody stem, often much branched and bushy.
- **Trees-** Tall plants with a clear, hard and woody stem.
- **Creepers-**Plants with soft stem and only creep on the ground
- **Climbers-** Plants with soft stem that climb neighbouring objects
- **Twiners-** Plants that bodily twine round some supports.
- **Lianes-** Plants that climb large trees, reach their tops and often spread over neighbouring trees. They are very thick and woody, perennial climbers.

3.1.3. Duration of life- Life of an individual plant is limited in duration. Herbs have a short span of life. They are of following types-

- **Annuals-**Herbs that live for a few month or at the most a year are called annuals
- **Biennials-** Those herbs which live for two years are said to be biennials. They take the first year for vegetative growth and produce flowers and fruits in the second year.
- **Perennials-** Some herbs continue to grow from year to year. The aerial parts of such plants die down every year after flowering or in winter, but a fresh life begins after a few showers of rain when the underground stem puts forth new leaves. Shrubs generally live for a few years. Trees however have the longest longevity.

4. Parts of a flowering plant

The plant body is normally differentiated into the underground root system and the aerial shoot system. The root system comprises **main root** and **lateral roots** and the aerial shoot system has distinct organs like **stem, branches, leaves** and **flowers.** Of these various parts, roots stem, branches and leaves are known as **vegetative parts** and the flowers are called **reproductive parts**. All the systems have the respective functions which they play during the life cycle of a plant.

4.1 Root

The root is the descending axis of the plant. The root system normally lies under ground and consists of the main root and the lateral roots. Root-ends are protected either by root caps or root pockets.

4.1.1. Types of roots

Roots are of two types- (1) Tap roots (Normal or main) and (2) Adventitious root

- **Tap root**- The root that develops from the radicle (a little root being the part of axis within the embryo) is called normal root. The direct prolongation of the radicle forms the **primary root.** When the primary root becomes stronger and persistent, it forms **tap root.** As tap root grows it produces lateral branches known as the secondary roots and the later in turn produces the tertiary roots.
- **Adventitious root-** Roots that grow from any part of the plant body other than the radicle are called adventitious roots. Adventitious roots are of following types-

1. Fibrous roots of monocotyledons- When the primary root does not persist, a cluster of slender roots are seen to grow from the base of the stem; such roots are called fibrous root.
2. Foliar roots- Roots that develop directly from the leaves
3. True adventitious roots-Roots that develop from the nodes and inter nodes of the stem.

4.1.2. Regions or parts of the root

The root either belonging to a tap root system or adventitious root system shows the following distinct regions or zones.

- **Root cap region**- The apex of the root is protected by a thin cushion or cap of tissue known as root cap. Its function is to protect delicate root tip as it makes way through the soil.
- **Growing region or zone of elongation**- This region lies just behind the root cap region. In this region growth of roots takes place by cell divisions and cell elongation. According to some authors, this region consists of two zones, namely, (a) zone of cell division, and

  (b) zone of cell elongation.
- **Root hair region**-This region lies just above the growing region and is covered by unicellular root hairs. The root hairs absorb water and solute from the soil besides providing a little anchorage.
- **Permanent region-** All the remaining portions of the root beyond the root hair zone come under this region. Function of permanent region is to conduct the substances absorbed by root hair besides providing anchorage.

4.1.3. Modified roots

Both tap roots and adventitious roots may undergo modification to carry out some special functions.

4.1.3.1. Modified tap root (for storage of food) - These roots are fleshy and swollen due to accumulation of food. Modified tap roots are of four types.

- Fusiform Root- The tap or primary root is swollen in the middle and tapering at both ends, e.g. Radish
- Conical Root- The root is broad at the base and gradually tapers towards the apex like a cone, e.g. Carrot.
- Napiform Root-The root is considerably swollen at the upper part becoming almost spherical and sharply tapering at the lower part, e.g. Turnip and Beet.
- Tuberous or Tubercular Root-The root is thick and fleshy but does not maintain any particular shape; e.g. Mirabilis, Ruellia tuberose, Tapioca, some species of Dahlia etc.

4.1.3.2. Modified branch Root (for respiration)

Pneumatophores or breathing roots – These are modified branches of tap root system growing from underground roots of the plant but rising up above the soil. They have pores to allow entry of atmospheric air for respiration. Many plants growing in estuaries and salt lakes develop pneumatophores.

4.1.3.3. Modified Adventitious Root

(a)) For Storage of Food

- **Tuberous roots-** This is a swollen root without any definite shape, as in sweet potato. These roots arise from the nodes of the prostrate stem.
- **Fasciculated roots –** When several tubercular roots occur in a cluster of fascicle at the base of the stem, they are said to constitute fasciculated roots; e.g. Dalhia, asperagous etc.
- **Nodulose roots-** When the slender root becomes suddenly swollen at or near the apex, it is said to be nodulose ; as in mango, ginger (amada) turmeric (holud) etc.
- **Moniliform or beaded roots-** Roots are alternately swollen and constricted at regular intervals presenting a beaded appearance; e.g. Indian spinach (Basella;pui) ,Momordica (kakrol), Wild vine (amal lota), Dioscorea alata etc.
- **Annulated roots-** The root has a series of ring-like swellings on its body. e.g. Ipecac.

(b) For mechanical support

- **Prop or Stilt Roots –** In many species of Ficus (e.g banyan), india-rubber plant, screwpine, Rhizophora etc. adventitious roots are produced from the main stem and often from the branches. They grow vertically or obliquely downwards and penetrate the earth. Gradually they become stouter and act as pillars to support the weight of the main stem and the branches of the plant.

- **Climbing Roots –** These roots develop from nodes and internodes and allow the plants to climb up walls or any other support. Examples are Piper betel, long peeper, black peeper, pothos etc. These roots act like foothold for the climber plants to climb up the support.
- **Clinging roots –** They are special kinds of short attaching roots. Developing from the stem these roots penetrate into cracks and crevices in the bark of supporting plant for additional fixation, e.g Hedera helix, epiphytic orchids like Vanda roxburghii.

(a) For vital functions

- **Assimilatory Roots –** Branches of Tinospora (Gulancha) climbing on neighbouring trees produce long slender hanging roots which develop chlorophyll and turn green in colour. These green roots are assimilatory roots as they do carbon assimilation (absorb carbon dioxide from air and produce carbohydrate food).

Prop roots of Ficus benghalensis (Source: http://www.floridata.com/)

Climbing roots - Adventitious roots of *Philodendron* (family Araceae) enable this species to cling tightly to the bark of a woody stem. (Source: http://www.botgard.ucla.edu/)

- **Sucking Roots, Parasitic Roots or Haustoria –** In some parasitic plants like species of Cuscuta (Swarnalata), small adventitious root-like structures, i.e rootlets called haustoria or sucking roots develop from stems of the parasites. These roots penetrate the tissues of the host plant and suck the latter. The parasite thus lives by sucking the host plant with the help of sucking roots.
- **Epiphytic Roots –** Certain plants, commonly orchids, grow on branches of trees. These plants, known as epiphytes, do not suck the host plant as parasites do. The epiphytes develop aerial roots of special kind which hang freely in the air. Such hanging root is provided with an outer cover of spongy tissue called velamen. With the help of velamen the hanging root absorbs moisture from air. These roots also serve as assimilatory organs by virtue of chloroplast present below the velamen coating.
- **Reproductive Roots –** Sometimes the roots produce adventitious buds which help in propagation as in many species of Agave. Vegetative reproduction by root-cutting are common in Ipomea batatas, Trichosanthes dioica etc. These roots are called reproductive roots.
- **Mycorrhizal or saprophytic roots –** These roots are infested with fungal mycelia. Plants growing in humus have mycorrhizal roots and such plants are called mycorrhizal saprophytes, e.g Pinus sp. Betula sp.etc. Mycorrhizal saprophytes draw nutrition from humus soil with the help of fungal mycelia.

4.1.4 Functions of Root

Functions may be broadly classified into two categories – (1) Mechanical and (2) Physiological. Besides, roots have special functions which they perform by adaptation to modified forms which have been discussed earlier.

4.1.4.1 Mechanical Function – Roots serve the mechanical function of **fixation**, that is, fixation of the plant to the soil. The tap root that goes deep into the soil and the lateral roots spreading out in all directions provide anchorage and support to the plant. In case of monocotyledons, the fibrous roots provide the anchorage.

4.1.4.2 Physiological Function

- **Absorption** – This is the most important physiological function. With the help of root- hairs the roots absorb water and necessary organic salts.
- **Conduction –** The roots take part in the process of conduction of water and mineral salts upwards to the stem and ultimately to leaf.
- **Storage –** The roots store certain amount of food in the mature or permanent region. As the roots grow, this stored food is utilized.

Source of Lesson Materials:

1. A.C.Dutta ,1987, A class-book of Botany, Oxford University Press.
2. J.N.Mitra et.al.2014, studies in Botany, volume one, Moulik Library, Kolkata
3. http://www.floridata.com
4. http://www.botgard.ucla.edu

Time 1 hour

Lesson Plan

Objective:

- To study plant morphology - the stem
  - The bud
  - Kinds of stem
  - Functions of the stem
  - Modifications of the stem
- To study types of branching of stem

Backward Linkage:

- Plant morphology dealt with in lesson 1

Forward Linkage:

- Plant Morphology and Physiology discussed in subsequent lessons
- Field botany during tour

Training Materials Required:

- Copy of lesson 2 to be circulated beforehand
- Specimens of plant parts wherever possible

Allocation of time:

- Description of stem and bud–5 mts
- Kinds of stem –8 mts
- Functions of stem–5 mts
- Modifications of stem –25 mts
- Branching of stem–12 mts
- Discussion/Miscellaneous- 5 mts

1. The Stem

The stem is the ascending organ of the plant. It develops from the **plumule** (part of the axis within the embryo which lies between the cotyledons) and is the direct prolongation of plumule upwards. Sometimes, the stem is sub-aerial or underground. The stem bears branches (there are exceptions like palms, cycas etc.) leaves and flowers. The stem along with branches, leaves etc. is called **shoot**. While young, the stem is green in colour.

1.1 Nodes and Internodes

The place on the stem or branch where one or more leaves arise is known as **node**, and the space between two successive nodes is called the **internode**. The angle formed between a leaf and the internode is called axil.

1.2 The Bud

A bud is a young undeveloped (condensed) shoot. It has a short stem and a number of tender leaves arching over the growing apex. In the bud the internodes have not developed and the leaves are crowded together over a conical mass. The bud that grows in the axil of a leaf is known as **axillary bud** and that which grows at the apex of a stem or branch is called **terminal bud**.

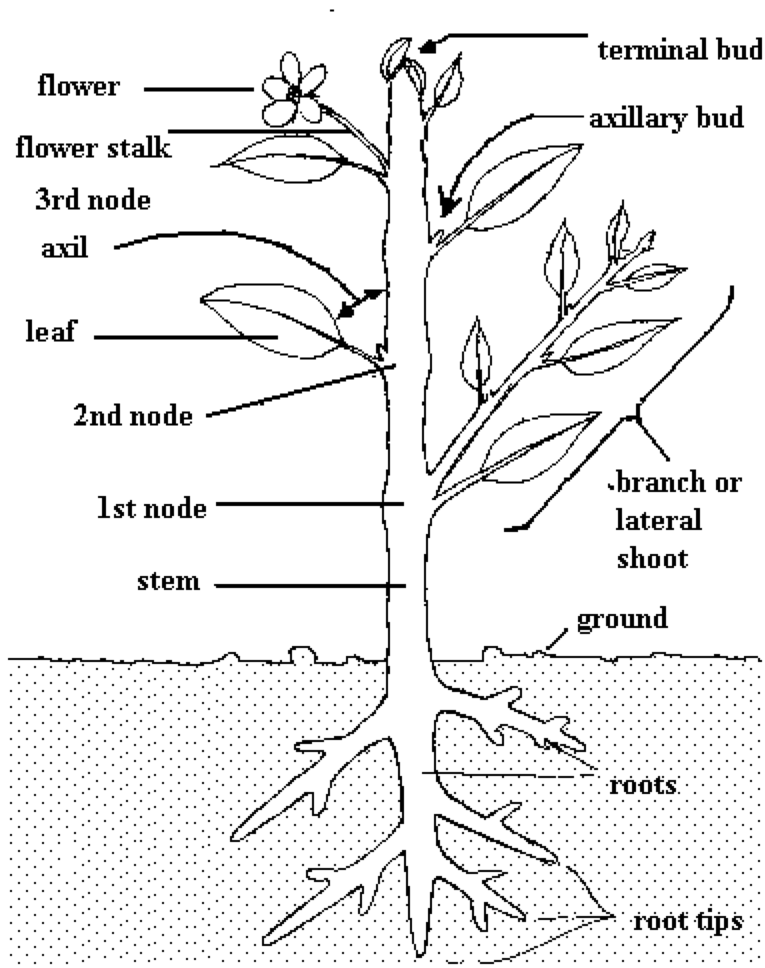


Fig.2.1.Parts of a Plant

(Source:http://www.uq.edu.au/_School_Science_Lessons/UNBiol1.html)

1.2.1 Kinds of buds

- **Normal Bud**s - Axillary buds and terminal buds are known as **normal buds.**
- **Accessory Buds –** Buds that develop sometimes by the side of the axillary bud are called

Accessory buds.

- **Adventitious Buds –** Those buds which develop from any part of plant body other than apex of the axis and axil of a leaf are known as adventitious buds. They are of different types –
  - **Epiphyllous –** Buds developing on leaves, e.g *Bryophyllum calycinum*;
  - **Cauline –** Buds developing on stems, when the main stem of the plant is cut off, e.g *Duranta repens*
  - **Radical –** Buds developing on roots, e.g *Trichosanthes dioica, Ipomea batatas*.

1.3 Kinds of Stem

Aerial Stems may be (a) **strong (erect)** or (b) **weak.**

1.3.1 Types of strong stem

- **Excurrent** – The tree takes a pyramidal form, e.g species of Abies, Pinus, Polyalthia longifolia;
- **Deliquescent** – The tree takes a dome shaped form, e.g. Mangifera indica (Mango)
- **Caudex** – The unbranched, erect, cylindrical stem, e.g Palms
- **Culm** – Joined stems with solid nodes and hollow internodes, e.g Bamboo
- **Scape** – In some herbaceous plants, particularly monocotyledons, the suppressed underground stem produces an erect unbranched aerial shoot known as **scape.** It comes out through the cluster of leaves and bears at its apex a solitary flowers or a cluster of flowers.

1.3.2 Kinds of weak stem

a) **Trailer –** trails over the ground without rooting at the nodes. Trailer stem is again of two kinds:

- **Procumbent or Prostrate-** Its stem including the apex lies flat on the ground, e.g. *Basella rubra , Ipomoea reptans* etc.
- **Decumbent-** The stem after trailing for some distance lifts its head, that is, while the stem lies on the ground the apex is turned upwards ,e.g. *Tridax procumbens*

b) **Creepers-** The plant grows horizontally on the ground, produces branches profusely spreading out in all directions, and gets rooted at each node, e.g. *Ipomea batatas* (Sweet potato).

c) **Climbers-**

- **Stem climbers or Twiners –** Long and slender stems of some plants climb up other plants or objects by twining round the support, e.g. Clitoria (Aparajita), Abrus (Kunch).
- **Lianes-** Long and woody perennial stem climbers which climb up tall forest trees, e.g. *Bauhinia vahlii*
- **Tendril climbers-** Plants which develop special type of climbing organs called tendrils, which help the plant to climb up other plant or object, e.g. Passiflora sp., *Gloriosa superba*

Fig.2.2.Gloriosa superba- leaf apex modified into tendril

(Source: http://www.botanicalgarden.ubc.ca/potd/2012/02/gloriosa-superba.php)

- **Root Climbers –** Several weak plants climb up suitable objects with help of adventious root which develop from the nodes of the stem, e.g. *Pothos scandens*, Piper betle
- **Hook climbers -** Hook – like structures develop from the flower stalks or due to modification of terminal leaflets, which help the plant to climb up.
- **Leaf climbers-** The leaf or part of the leaf is modified into tendril which acts as climbing organ, e.g. Clematis sp., Nepenthes sp.etc.
- **Rambler or scrambler –** The plant climbs neighbouring plants with the help of pickles and thorns, e.g. Baugainvillea, Climbing rose etc.

1.4. Functions of the stem

1) Normal Functions

- **Mechanical function-** Bearing the crown and weight of the entire plant, production and bearing of foliage leaves, branches and reproductive structures like flowers and fruits.
- **Physiological function-** Conduction of mineral salts and water from the roots and translocation of prepared food to various parts.

2) Special Functions

- Storage of water, e.g. Many Cactus sp.
- Storage of food- Food is stored in underground stems like Rhizomes, Tubers.
- Photosynthesis – Manufacture of carbohydrate food

- Self defense- Development of thorns, prickly stems, e.g. Duranta sp., Alangium sp., Rosa sp.
- Supporting organs- Examples are tendrils of species of Vitis, Passiflora etc.
- Propagation- Sub-aerial modified stems like runner, stolon, sucker help in vegetative propagation.

15. Modifications of Stems

Stems or Branches of certain plants are modified into various shapes to perform special functions. The special functions include –

- Perennation – Survival from year to year under unfavorable conditions.
- Vegetative propagation – Creation of new plants from vegetative parts.
- Storage of food and water.

1.5.1. How underground stems are different from roots

- Underground stems have nodes and internodes
- Presence of small dry, scale leaves and development of adventitious roots from the nodes.
- Presence of buds at the axils of such leaves
- Internal structures are like those of stems

1.5.2. Types of underground modified stems

1) Rhizome – It is a thick , prostrate , underground stem provided with (a) distinct nodes and internodes, (b) scaly leaves at the nodes, (c) a bud in the axil of each such leaf and (d) a terminal bud

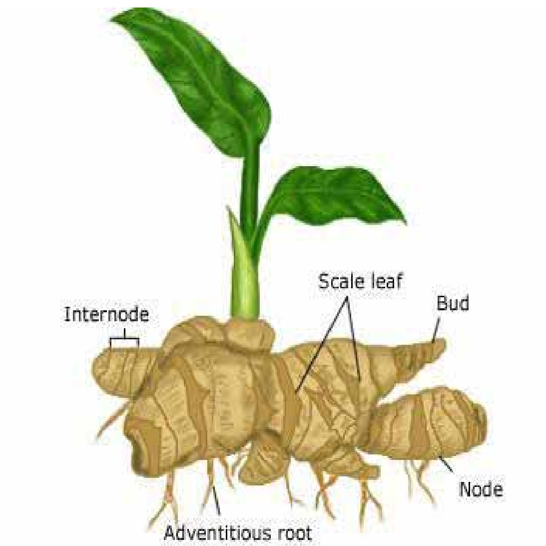


Fig.2.3. Rhizome of Ginger

(Source: http://www.tutorvista.com)

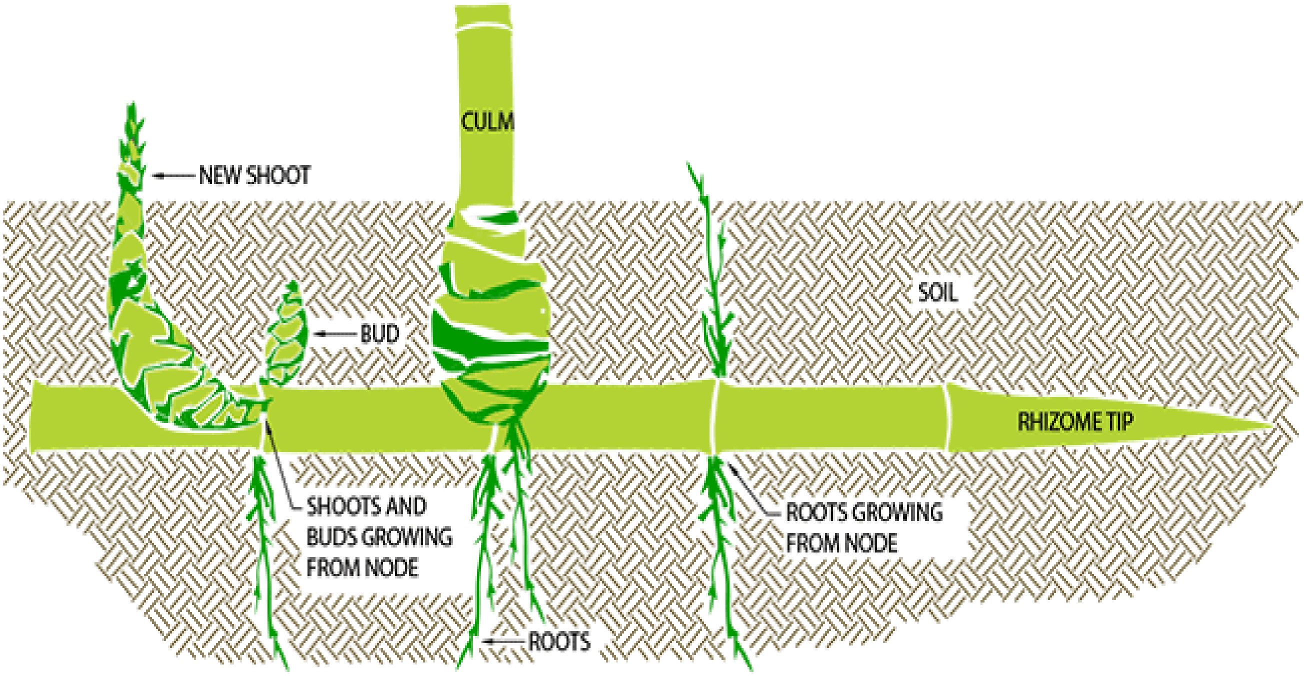


Fig.2.4. BambooRhizome

(Source: www.bamboobotanicals.ca)

1) Tuber- It is the swollen end of a special underground branch. The branch arises from the axil of a leaf, grows horizontally and ultimately swells up at the apex owing to deposit of food matters. The shape of a tuber is round or oval. It bears on its surface a number of "eyes" or buds which grow up into new plants, examples are *Solunum Tuberosum* (Potato), *Cyperous rotundus* etc.

Fig.2.5. Solunum tuberosum (Source: http://www.forestryimages.org)

3) Corm – This is a condensed form of rhizome. It consists of a stout, solid, fleshy, underground stem growing in the vertical direction. It is round in shape, often flattened from top to bottom. A heavy deposit of food material the corm often grows to a big size. It bears one or more buds in the axils of scale leaves, and some of these buds grow into daughter corms. Adventitious roots develop from the base and sometomes also from the sides. Corm is found in

Amorphophallus (B. OL), taro (Colocacia, B. KACHU) etc.

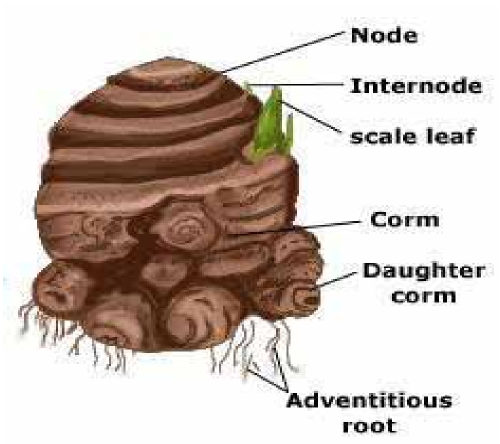


Fig. 2.6. Corm of Colocasia
(source: http://www.tutorvista.com)

4) Bulb – it is a modified shoot consisting of a shortened convex, or slightly conical stem, a terminal bud (single, often large) and numerous scale leaves with a cluster of fibrous roots at the base. The scale leaves commonly surround the short stem in concentric manner (**Tunicated bulb**). The inner scales are fleshy, storing water and food, and the outer ones protect the stem. The terminal bud grows into aerial shoot. Examples are onion, garlic etc.

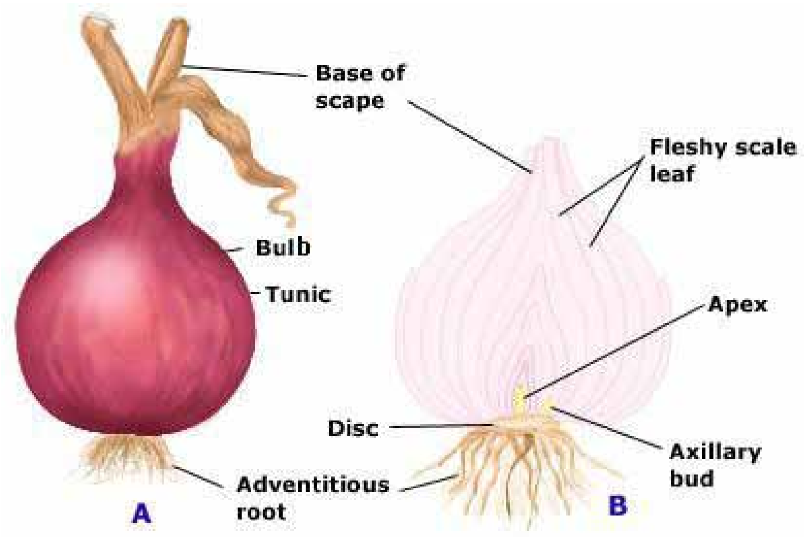


Fig.2.7 A Tunicated bulb of Onion , 2.7 B. Longitudinal section

(Source: http://www.tutorvista.com)

1.5.3 Sub-aerial modifications of Stems

Certain plants undergo sub-aerial modification of stems for the purpose of vegetative propagation. There are **four types** of sub-aerial modification.

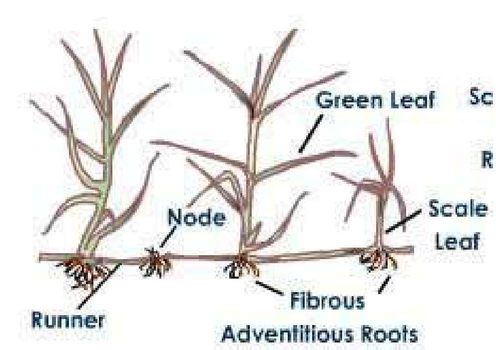


Fig. 2.8. Runner of Grass
(Source: http://www.tutorvista.com)

(1) Runner – It is a slender, prostrate branch that arises from the axillary bud of a mother plant. With long internodes it creeps on the ground and strikes roots at the nodes and grows into a new plant. A mother plant thus can produce many such runners that spread on ground on all sides. Examples are wood-sorrel (*Oxalis*), Indian pennywort (*centella*), Marsilea (B. SUSHNISHAK), strawberry (*Fragaria*) etc.

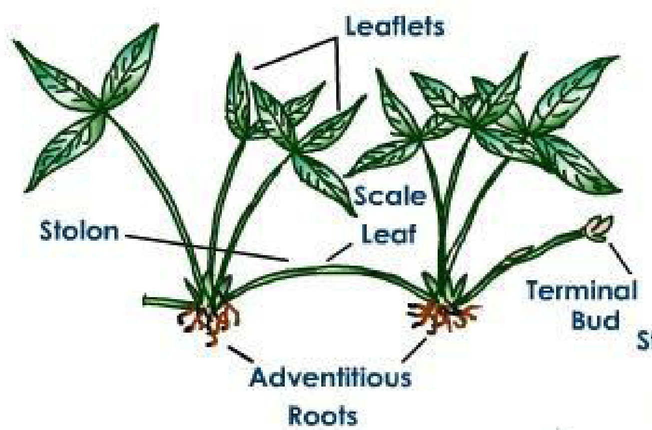


Fig. 2.9. Stolon of Strawberry
(Source: http://www.tutorvista.com)

(2) Stolon – It is a slender lateral branch that originates from the base of the stem of the mother plant. It bends down on or into the ground, strikes roots and develops a bud which soon grows up to a new plant. The stolon may continue to grow for varying distances, striking roots and producing a bud at each node. When it straightens out and creeps on the ground, the stolon resembles a runner.

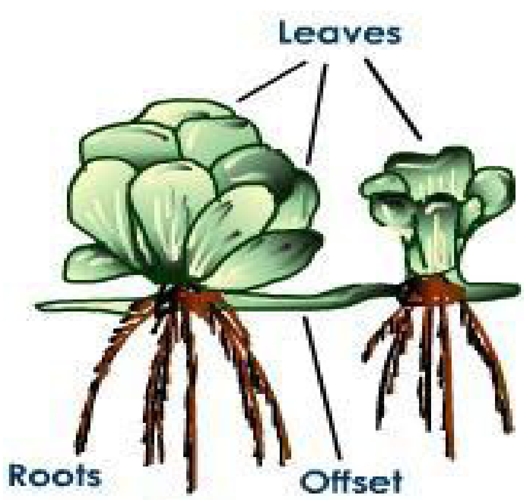


Fig.2.10. Offset of Pistia (Water Lettuce)
(Source: http://www.tutorvista.com)

(3) Offset – Like a runner it originates from the axil of a leaf as a horizontal branch, but shorter and thicker than runner. Having travelled a short distance the apex turns up and produces a tuft of leaves above and a cluster of roots below. Common examples are water lettuce (*Pistia)*, and water hyacinth.

(4) Sucker – Like stolon, a sucker is a horizontal branch originating from the underground part of the stem. However, it grows obliquely upwards and produces a leafy shoot or a new plant. Further, a sucker is much shorter than a stolon. The sucker strikes roots either before it severs itself from the mother plant or soon after. Common examples are *Chrysanthemum*, rose, mint (B. PUDINA), pine apple, banana etc.

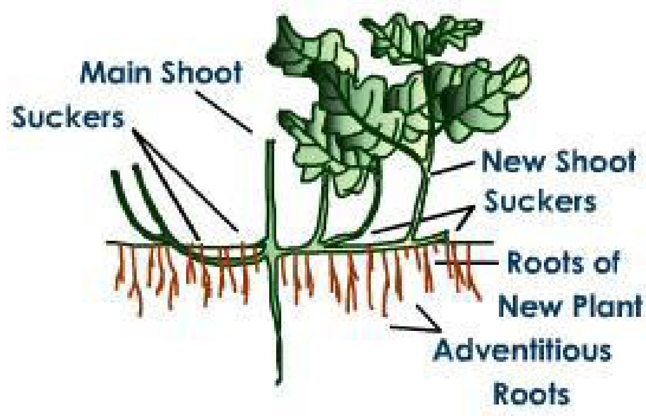


Fig. 2.11. Suckers of Chrysanthemum
(Source: http://www.tutorvista.com)

1.5.4 Aerial Modifications: Metamorphoses

Vegetative and floral buds normally develop into branches and flowers. However, in certain plants they undergo extreme modification or metamorphosis for definite purposes. Such aerial metamorphosed organs are of the following types

- Semi-tendril – for climbing, e.g. vine
- Thorn – for protection, e.g. Duranta
- Phylloclade and Cladode – for food manufacture (function of foliage leaves), e.g. cacti (phylloclade) and Asparagus (Cladode)
- Bulbil – for vegetative reproduction, e.g.Dioscorea, Agave.

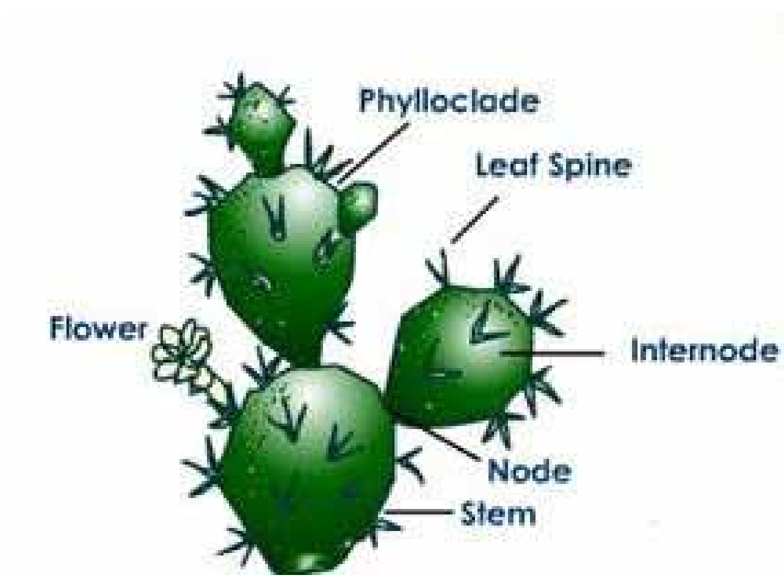


Fig. 2.12. Phylloclade of *Opuntia* (Prickly pear)
(Source: http://www.tutorvista.com)

Fig. 2.13. Bulbil of Agave
(Source: http://www.phgmag.com)

1.6 Branching

The manner in which branches are arranged on the stem is called **branching**. There are two principal types of branching – **(1) lateral** and **(2) dichotomous.**

1.6.1 Lateral Branching

When the branches are given off laterally from the lateral buds of the main axis, that is, from the sides of the stem, the branching is called **lateral**. Lateral branching is again of two types, namely **(1) racemose** or indefinite, and **(2) cymose** or definite.

- **Racemose branching** – This type of branching is seen in most of the angiosperms. Here the main stem continues to grow indefinitely by the terminal bud, and gives off branches laterally in acropetal succession (i.e lower branches are older and longer than the upper ones). Examples are *Casuarina* (B. JHAU), *Polyalthia* (B.DEBDARU). The plant takes a conical or pyramidal shape.
- **Cymose branching** – In this type, the growth of the main stem is definite, i.e. the terminal bud does not continue to grow, but lower down the main stem gives off one or more branches which grow more vigorously than the terminal one. This process may be repeated, and as a result the plant spreads out above and takes a dome shape. **Cymose** branching may again be of following types –
  - **Biparous Cyme** – two lateral axes develop at a time in this type, also called **true cyme.** Examples are mistletoe (*Viscum)*, Carissa (B.KARANJA), temple or pagoda tree (*Plumeria*, B.KATCHAMPA)
  - **Uniparous Cyme** – In this type only one branch is produced at a time. It has two distinct forms, namely,

(a) **helicoid**, or one sided cyme, where successive branches develop on the same side forming a helix structure. Examples are *Saraca indica (*B.Ashok)

(b) **scorpioid**, or alternate-sided cyme ,where successive lateral branches develop on alternative sides forming a zig zag structure. Examples are *Vitis* (Vine), *Cissus quadrangularis* (B. Harjora)

  - **Multiparous Cyme** –In this type more than two branches develop at a time. Examples are *Croton sparsiflorus* and *Euphorbia tirucalli*

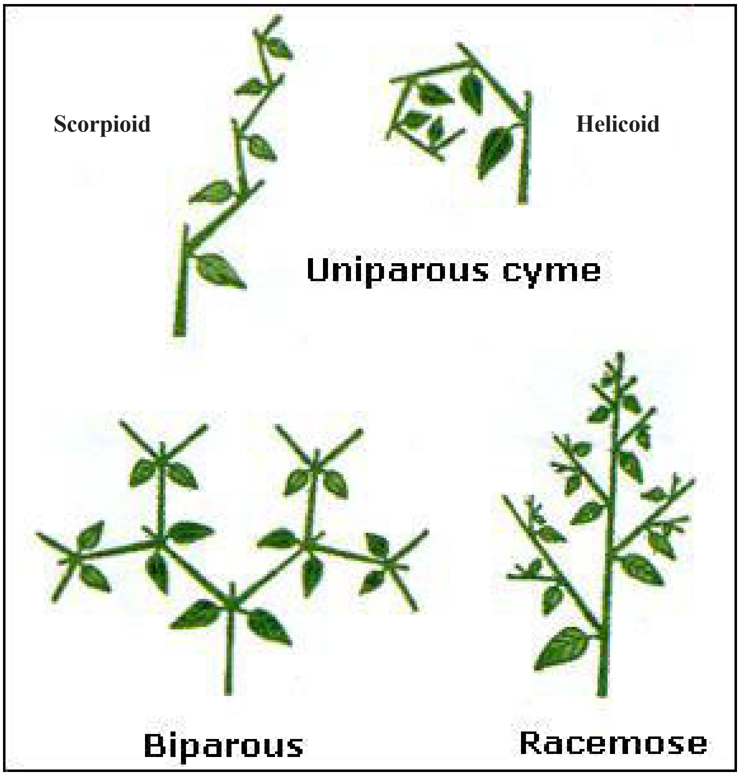


Fig. 2.14.Branching
(Source: http://www.tutorvista.com)

Source of Lesson Materials:-

1. A.C.Dutta ,1987, A class-book of Botany, Oxford University Press.

2. J.N.Mitra et.al.2014, studies in Botany, volume one, Moulik Library, Kolkata

3. http://www.uq.edu.au/_School_Science_Lessons/UNBiol1.html

4. http://www.botanicalgarden.ubc.ca/potd/2012/02/gloriosa-superba.php

5. http://www.tutorvista.com

6. www.bamboobotanicals.ca

7. http://www.forestryimages.org

8. http://www.phgmag.com

Time I hour

Lesson Plan Objective:

- To study the leaf as part of plant morphology
  - Parts of a leaf
  - Venation of a leaf
  - Compound leaf
  - Phyllotaxy
  - Functions of the leaf

Backward linkage

- Study of stem in lesson 2

Forward linkage

- Plant morphology in subsequent lessons

Training materials

- Copy of lesson 3 to be circulated beforehand
- Specimens of leaves

Allocation of time

- Parts of a leaf – 5 mts
- Duration of leaf – 3 mts
- Apex of the Leaf – 6 mts
- Margin of the Leaf – 5 mts
- Surface of the leaf – 5 mts
- Shape of the leaf – 8 mts
- Venation – 3 mts
- Simple leaf and Compound leaf – 10 mts
- Phyllotaxy – 5 mts
- Functions of Leaf – 5 mts
- Discussion/Miscellaneous – 5 mts

Plant Morphology (Continued)

1. The Leaf

The leaf is the flattened lateral outgrowth of the stem or the branch. Green in colour the leaf develops from the node and has a bud in its axil. The leaves develop in acropetal order and exogenous in origin.

1.1 Parts of a Leaf

A typical leaf has three parts – (1) Leaf base, (2) Petiole or the stalk of the leaf, and (3) Leaf lamina or leaf blade. Please see Fig.3.1.

1.1.1 Leaf base

It is the point of attachment of the leaf to the stem. In many plants the leaf-base expands into a **sheath** which clasps the stem partially or wholly. The sheathing leaf-base is frequently found among **monocotyledons**. Stem of a banana plant is made up of leaf sheaths. In **dicotyledons**, the leaf-base usually bears ***two lateral outgrowths known as the stipules***. In some plants, e.g. gram, pea, tamarind, rain tree, goldmohur etc. the leaf base is swollen and such swollen base is known as **pulvinus**.

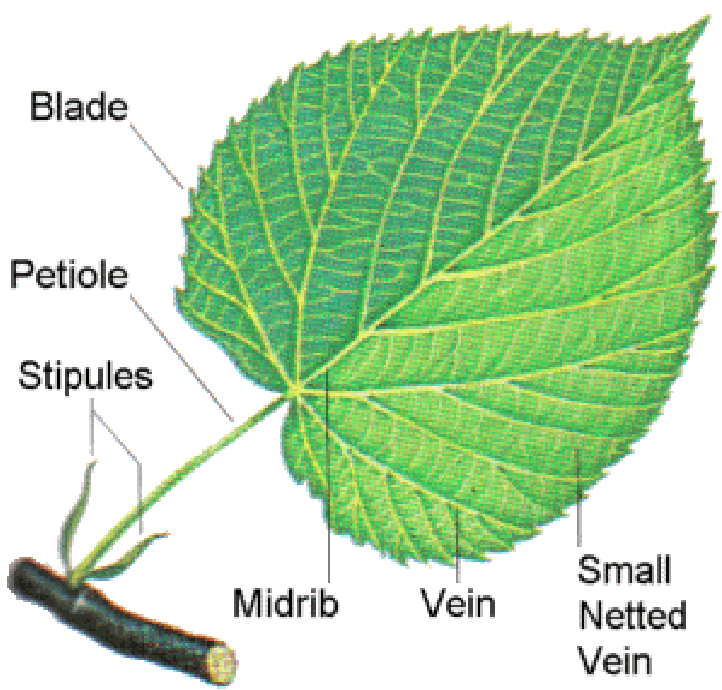


Fig. 3.1 parts of a leaf
(Source: http://www.robinsonlibrary.com/)

1.1.2 Petiole

Petiole is the stalk of leaf. When the petiole is absent the leaf is said to be **sessile**. If petiole is present the leaf is called **petiolate or stalked**.

1.1.3 Leaf blade or lamina

Lamina is the thin, membranous, green expanded portion of the leaf and comprises the greater part of the leaf. It is the most important part of leaf since food for the entire plant is manufactured in the lamina. The strong vein which runs centrally through the leaf blade from its base to the apex is known as **mid-rib**. The mid-rib produces thinner lateral veins which in turn give rise to even thinner veins or veinlets.

1.2 Duration of leaf

- **Caducous** – The leaf falls off soon after it appears;
- **Deciduous or annual** – The leaf lasts one season; normally falls off in winter;
- **Persistent or evergreen** – The leaf lasts more than one season, usually a number of years.

1.3 Apex of the Leaf

Apex of the lamina or leaf blade assumes various shapes.

- **Obtuse** – The leaf apex is rounded. Example: banyan (*Ficus bengalensis*)
- **Acute –** The leaf apex is pointed in the form of an acute angle. Examples: Mango, *Hibiscus rosa-sinensis*.
- **Acuminate or Caudate –** It is a longer acute apex. The apex is drawn into a long slender tail. Example: peepul (*Ficus religiosa*), lady's umbrella (*Holmskioldia*).
- **Cuspidate –** The leaf apex ends in a long rigid, sharp (spiny) point. Example: date palm, screw pine and pineapple.
- **Retuse –** The obtuse or truncate apex is provided with one shallow notch. Example: Water lettuce (pistia sp.)
- **Emarginate –** The apex is provided with deep notch. Example: *Bauhinia* (B. KANCHAN), wood sorrel (*Oxalis* sp.)
- **Mucronate –** The rounded apex abruptly ends in a short point. Example: *Ixora* (B.RANGAN), *Ruscus* sp., *Rhi zophora mucronata* (B.Garjan).
- **Cirrhose –** The leaf apex terminates into a slender coil or tendril – like structure. Example: Banana, Glory lily.

1.4 Margin of the Leaf

Various types of leaf margins are as follows

- **Entire** – The leaf margin is even and smooth. Example: Mango (*Mangifera*), Jack fruit (Artocarpus *sp.*), Banyan (*Ficus sp.*)
- **Sinuate** – The margin is undulating. Example: *Polyalthia* (B. Debdaru), *Mimusops elengii* (B.Bakul).
- **Serrate** – Margin is incised like the teeth of a saw. Example : *Hibiscus* (B.Jaba), *Margosa* (B.Neem)
- **Dentat-** Teeth of the leaf lamina are directed outwards at right angles to the margin. Example : *Nymphaea esculenta* (Water Lily)
- **Crenate-** The margin is toothed, but the teeth are rounded. Example : *Centella asiatica (*Indian Pennywort*) , Kalanchou pinnata* (B.Patharkuchi)
- **Spinous** – The margin is provided with spines. Example : Prickly poppy (*Argemone*)

1.5 Surface of the leaf

Various types of leaf surface are follows

- **Glabrous** – The leaf surface is smooth due to complete absence of any hair or outgrowth of any kind. Example : *Mangifera indica* (Mango), *Syzygium jambos* (Rose apple)
- **Scabrous or Rough** – The leaf surface is rough to touch due to the presence of short rigid points. Example : *Ficus cunia*
- **Glutinous** – The leaf surface is covered with a sticky exudation. Example : *Nicotiana tabacum* (Tobacco)
- **Glaucous-**The surface is green and shining. Example: *Calotropis sp., Nymphaea sp.*
- **Spiny** –The surface is covered by spine like prickles. Example : *Solanum ferox*
- **Pubescent or Hairy-** The leaf surface is covered, densely or sparsely, with hairs.

1.6 Shape of the leaf

Various shapes of the leaf blade are as follows

- **Acicular** –The leaf blade is very long, narrow and cylindrical that is needle shaped. Example: *Pinus sp.*
- **Linear** – The leaf blade is long, narrow and flat. Example: Many grasses, *Polyanthes tuberosa*, *Vallisneria sp.*
- **Lanceolate -** The shape of the leaf blade is like that of lance. Example: Bamboo, Oleander etc.
- **Elliptical or Oval-** The leaf has more or less the shape of an ellipse. Example : *Carissa, vinca* (Periwinkle), Guava, rose apple
- **Ovate-** The leaf blade is egg shaped. It is broader at the base than at the apex. *Hibiscus rosa synensis* (B.Jaba), *F.Bengalensis* (Banyan)
- **Oblong** –The leaf blade is wide and long with the two margins running straight up. Example : *Musa sp.*(Banana)

- **Rotund or Orbicular-** The leaf blade is more or less circular in outline. Example: Lotus.
- **Cordate-** The leaf blade is heart shaped. Example : Beetal, *Sida cordifolia* (Bala, Berela)
- **Reniform-** The leaf blade is kidney shaped, that is the apex of the leaf blade is rounded above with a deep notch at the base. Example: *Centella asiatica (*Indian Pennywort*).*
- **Oblique –** The two halves of the leaf are unequal. Example: Begonia, *Margosa* (B. Neem) , *Melia azadirach* (B.Ghoraneem)
- **Spathulate –** The leaf blade has a shape similar to that of a spatula, that is broad and somewhat rounded at the top and narrower at the base. Example: *Dorsera Burmannii* (Sun dew), *Calendula.*
- **Sagittate-** The leaf blade is arrow shaped. Example : *Sagittaria sagittifolia*
- **Hastate-** The two lobes of a sagittate leaf are directed outwards. Examples : *Ipomea* (B.Kalmi sakh),*Typhonium* (B. Ghet kochu)
- **Cuneate –** The leaf blade is wedge shaped. Example: *Pistia* (Water Lettus)
- **Lyrate-**The shape of the blade is like that of a lyre, that is with a large terminal lobe and some smaller lateral lobe. Example : Raddish, Mustard.
- **Pedate-** The leaf is divided into a number of lobes which spread out like the claw of a bird. Exa*mple : Vitis pedata* (B. Goale lota).

Please see Fig. 3.2.

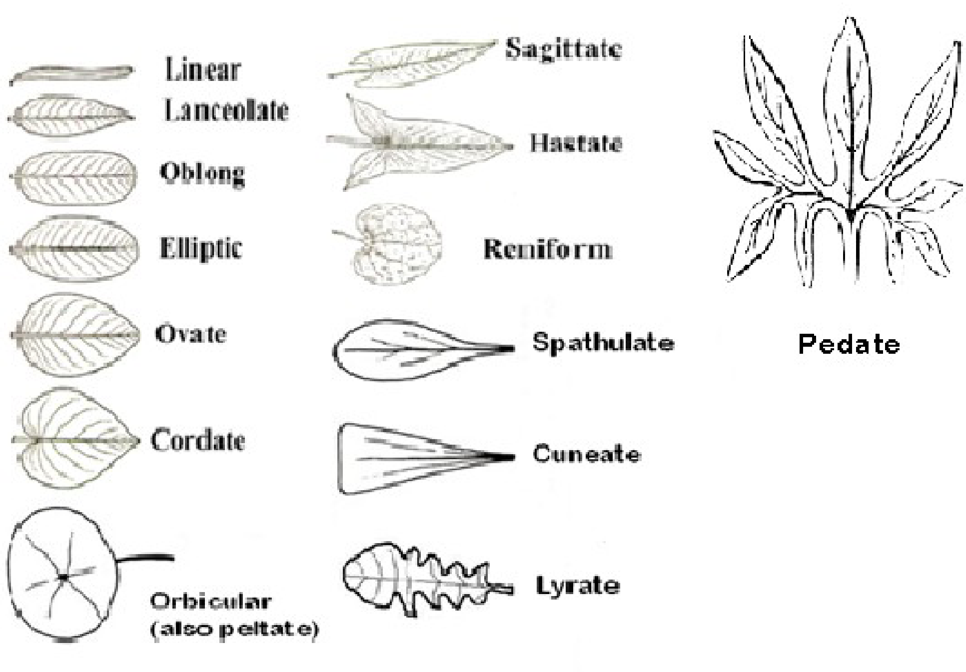


Fig. 3.2. Shape of leaf blade

(Source: http://botany.csdl.tamu.edu/FLORA/Wilson/tfp/veg/tfplec3f98.htm
http://eflora.library.usyd.edu.au/glossary/image/leaf_shape
http://science.kennesaw.edu/~jmcneal7/plantsys/vocabulary.html
http://etc.usf.edu/clipart/82900/82958/82958_pedate_leaf.htm)

1.7 Venation

The arrangement of the veins and the veinlets in the leaf blade or lamina is called **venation**. There are two principal types of venation – 1) **Reticulate Venation** and 2) **Parallel Venation.** Please see **Fig. 3.3.**

- **Reticulate Venation –** The veinlets are irregularly distributed, forming a network.
- **Parallel Venation –** The veins are in straight lines parallel to one another.

Reticulate venation is characteristic of dicotyledons and Parallel venation is characteristic of monocotyledons, though there are exceptions. Further subdivision of reticulate and parallel venation is not discussed here.

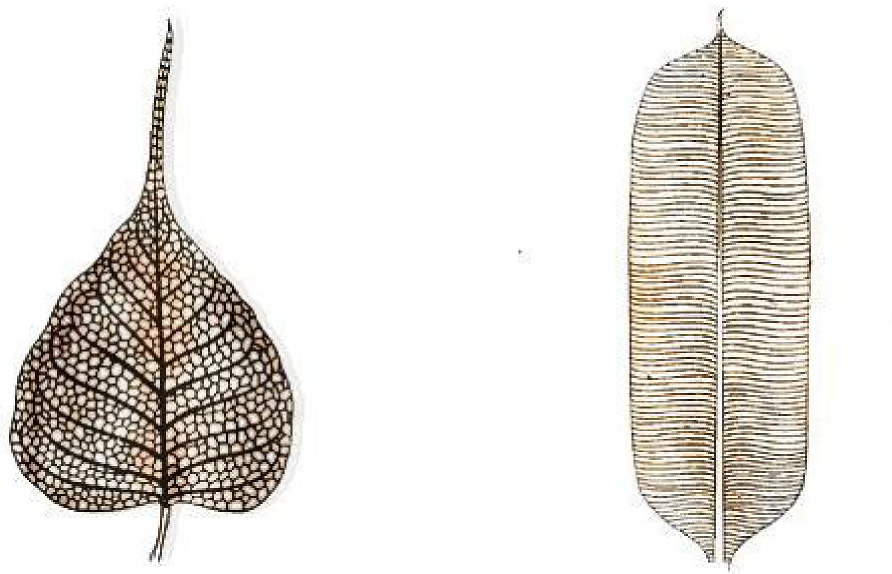


Fig.3.3. Venation of leaf (Source: http://www.tutorvista.com/)

1.8 Simple Leaf and Compound Leaf

Simple Leaf – A leaf is said to be simple if it consists of a single blade. The margin of the leaf may be entire or incised to any depth **but the incision is not down to the mid-rib or petiole**.

Compound Leaf – A leaf is said to be compound when **the incision of the leaf blade goes down to the mid-rib or to the petiole** so that the leaf is broken up into a number of segments, called **leaflets**. The leaflets are free from one another and arranged on the axis, i.e. mid-rib known as **rachis**. A bud (axillary bud) is present in the axil of a simple or compound leaf, but there is no such axillary bud at the axil of leaflet of a compound leave.

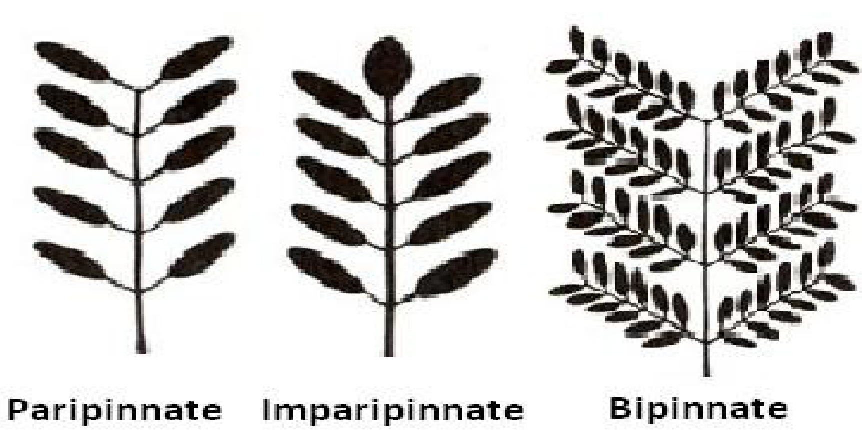
1.8.1 Types of Compound Leaf

There are two types of compound leaves **– (1) Pinnate and (2) Palmate.**

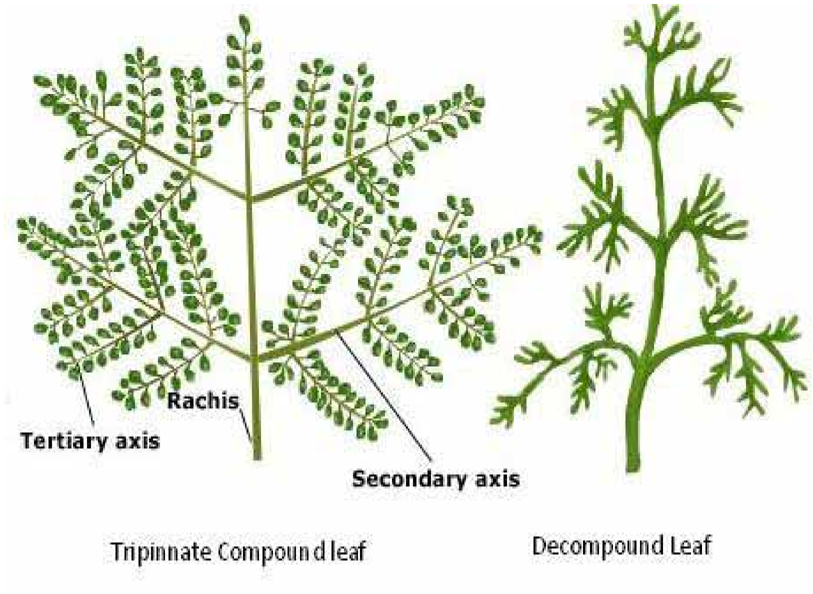
Pinnately Compound leaf – The leaflets are arranged either alternately or in an opposite manner on both sides of the rachis (mid-rib) directly or on the branches of the rachis. Pinnately compound leaves may be of the following types. Please see **Fig. 3.4.**

- **Unipinnate –** When the mid-rib (rachis) of the pinnately compound leaf **directly bears the leaflets**, it is said to be **unipinnate**. Unipinnate leaves may again be of two types –
  - **Paripinnate –** When the leaflets are even in number, that is, arranged in pairs, it is said to be paripinnate. Examples: Sesbania (B. BAKPHUL), *Saraca indica* (B. ASHOK), *Tamarindus indica* (B. TENTUL), etc.
  - **Imparipinnate –** When the leaflets are odd in number, that is, arranged on the rachis in such a manner that the apex of the rachis bears an unpaired odd leaflet, it is said to be imparpinnate. Examples: *Rosa centifolia*, *Azadirachta indica* (B. NEEM), etc.
- **Bipinnate –** When the compound leaf is twice pinnate, that is, the rachis produces secondary axes which bear the leaflets, it is said to be bipinnate. Example: *Acacia Arabica, Mimosa pudica* (B. LAJJABATI), *Caesalpinia pulcherrima* (dwarf Gulmohur B.KRISNACHURA)
- **Tripinnate –** When the leaf is thrice pinnate, that is, the secondary axes produce the tertiary axes and it is the tertiary axes that bear the leaflets, the leaf is said to be tripinnate. Example: *Moringa* (Drumstick, B. SAJINA), *Oroxylum indicum* (B.TOTOLA)
- **Decompound –** When the leaf is more than thrice pinnate, it is said to be decompounds. Example: *Daucus carota* var.sativa (Cultivated carrot), *Coriandrum sativum* (B. DHANIA) etc.

Palmately Compound Leaf – It is defined as one in which the petiole bears terminally, articulated to it, a number of leaflets which seem to be radiating from a common point like fingers from the palm. Leaflets are commonly five or more and such palmate leaf is called multifoliate or digitate. Example: *Bombax ceiba* (B. SIMUL), Gynandropsis gynandra. Sometimes the number of leaflets is three (trifoliate), as in *Vitex negundo* (B. NISHINDA) and *Aegle marmelos* (B.BEL). The number of leaflets is rarely one (Unifoliate) or two (Bifoliate) or four (Quadrifoliate). Please see **Fig. 3.5.**



(Source: http://eflora.library.usyd.edu.au/)



(Source: http://www.tutorvista.com/)
Fig. 3.4 Pinnately compound leaves

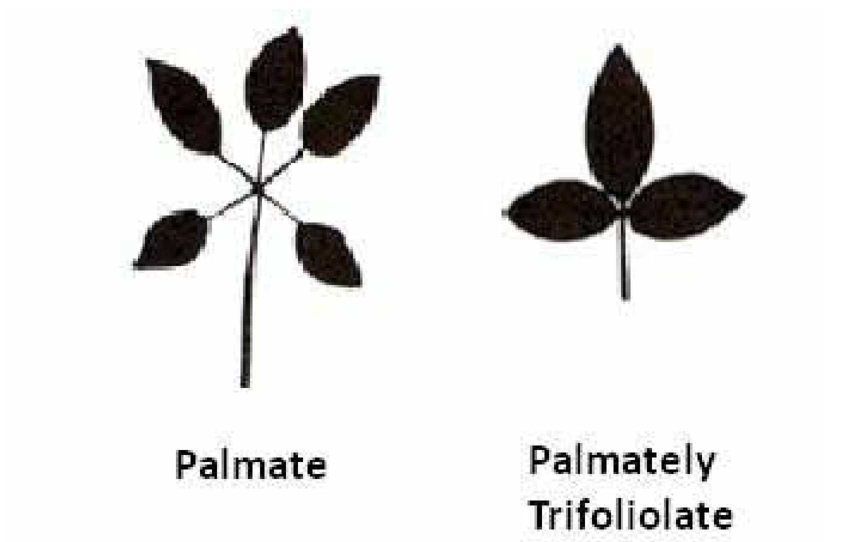


Fig. 3.5. Palmately compound leaf (Source: http://eflora.library.usyd.edu.au/)

1.9 Phyllotaxy

Phyllotaxy is the mode of arrangement of leaves on the stem or the branch. The principle of this arrangement is to avoid shading one another so that each leaf gets the maximum amount of sunlight to perform their normal function, particularly manufacture of food. Plants exhibit three principal types of phyllotaxy.

- **Alternate or Spiral** – A single leaf arises at each node. The leaves are seen to be spirally arranged round the stem. Example: Tobacco, China rose, Mustard, Sunflower etc. Please see **Fig. 3.6**
- **Opposite –** Two leaves arise at each node standing opposite to each other. This opposite phyllotaxy is again of two kinds –
    - **Opposite decussate –** One pair of leaves of one node stands at a right angle to the next upper and lower pair of leaves. Example: *Ocimum* (B. TULSI), *Ixora* (B. RANGAN), *Calotropis* (B.AKANDA) etc.
    - **Opposite Superposed –** A pair of leaves is seen to stand directly over the lower pair in the same plane. Example: Psidium guajava (B. PEYARA), Quisqualis indica (B.SANDHYAMALATI) etc. Please see **Fig. 3.7.**
- **Whorled –** Three or more leaves are arranged at each node in a circle or whorl**.** Example: *Alstonia scholaris* (B. Chatim or Chatian), *Nerium* (B. KARAVI). Please see **Fig. 3.8.**

Fig. 3.6 Alternate Phyllotaxy
(Source:http://www.tutorvista.com/)

Fig. 3.7 Opposite Phyllotaxy

Fig.3.8 Whorled phyllotaxy of Alstonia scholaris (Chatian)
(Source: http://toptropicals.com/cgi-bin/garden_catalog/cat.cgi?uid=Alstonia_scholaris)

1.10 Functions of the Leaf

Following are the normal functions of green foliage leaves.

- **Manufacture of food –** Primary function of leaf is to manufacture food, particularly sugar and starch. It produces food in presence of sunlight which is the original source of energy to the plant. Thus manufacture of food by leaves takes place only during daytime.
- **Interchange of gases –** Regular exchange of Oxygen and Carbon dioxide between the atmosphere and the plant body takes place through numerous minute openings called stomata located on the lower surface of the leaf. The exchange serves two purposes –

(1) respiration by all the living cells which absorb oxygen and give out carbon dioxide, and (2) food manufacture by green cells which absorb carbon dioxide and give out oxygen.

- **Evaporation of Water –** The excess water absorbed by root hairs evaporates mainly through the stomata during day time.
- **Storage of food –** Fleshy leaves of Aloe (B. GHRITAKUMARI), fleshy scales of onion store up water and food for future use.
- **Vegetative Propagation –** Leaves of certain plants like *Bryophyllum, Begonia* etc. develop buds on them for vegetative propagation.

Source of Lesson Materials:-

1. A. C. Dutta, 1987, A class-book of Botany, Oxford University Press.
2. J. N. Mitra et. al. 2014, studies in Botany, volume one, Moulik Library, Kolkata
3. Websites cited in the lesson

Time 1 hour

Lesson Plan Objective:

- To study the following of plant morphology
  - Inflorescence
    Types of Inflorescence
  - Bract, Bracteole
  - Flower
    Parts of a flower
  - Some terminologies

Backward linkage

- Study of plant morphology in lessons 2 and 3.

Forward linkage

- Study of plants in subsequent lessons
- Study of inflorescence during tour

Training materials

- Copy of lesson 4 to be circulated beforehand
- Specimens of flowers/inflorescence

Allocation of time

- Inflorescence – 2 mts
- Types of inflorescence and their descriptions Racemose Inflorescence – 20 mts Cymose Inflorescence - 10 mts
- Bract – Bracteole – 3 mts
- Flower – different parts – 15 mts
- Some Terminologies – 5 mts
- Discussion/Miscellaneous – 5 mts

1. Inflorescence

It is the branch system of the floral region bearing a group of flowers. The stalk or the main axis of the inflorescence is known as **peduncle**. The stalk of the individual flower of the inflorescence is called the pedicel. In certain plants the peduncle is short and dilated forming a kind of convex platform (example: Sunflower) or becoming hollow and pear- shaped (example: Ficus), and such structure is called **receptacle**.

1.1 Kinds of Inflorescence

Different types of inflorescence that are found may be classified into **two** distinct groups, namely, (1) **Racemose or Indefinite,** and (2) **Cymose or Definite.**

1.1.1 Racemose Inflorescence

In this type the main axis of inflorescence does not terminate in a flower, but continues to grow giving off flowers laterally. The flowers develop in acropetal order, that is, the oldest flower near the base and the youngest flower towards the apex, or flowers open in a centrepetal manner on the receptacle. Some of the **common types of racemose inflorescence** are decribed below.

(A) With the main axis elongated

1.1.1.1 Raceme

Raceme or simple raceme has long peduncle and bears on a number of pedicellate flowers in acropetal succession. The lower or older stalks have longer stalks than the upper or younger ones. Example: *Brassica juncea* (Mustard), *Caesalpinia pulcherrima* (dwarf gulmohur).

Panicle or Compound Raceme

Panicle is a branched raceme. The peduncle produces a number of branches in acropetal succession. On these branches pedicellate flowers are produced in acropetal succession.

Example: *Mangifera indica* (mango), *Delonix regia* (gold mohur) etc. Please see **Fig.4.1**.

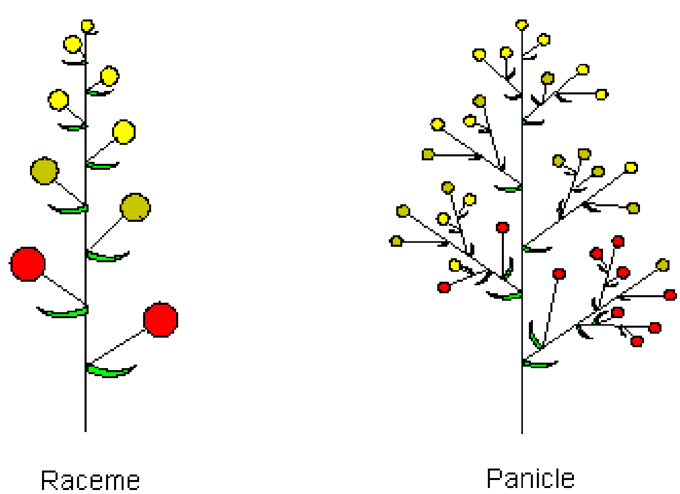


Fig.4.1 Simple Raceme and Compound Raceme (Panicle)
(Source: http://www.biotik.org/laos/defs/245_en.html)

1.1.1.2 Spike

Like raceme this type has also long peduncle or main axis and the flowers are produced in acropetal succession (lower flowers are older, opening earlier than the upper ones), but the flowers are sessile, that is, without any stalk. Example: *Adhatoda vasi*ca (B. Basak), Amaranth (B. NATE-SAK), *Achyranthes aspera* (B. APANG) etc. Please see **Fig. 4.2.**

Fig.4.2 Spike of Achyranthes aspera
(Source: http://en.wikipedia.org/wiki/Achyranthes_aspera)

1.1.1.3 Catkin

Catkin is a type of spike inflorescence with a pendulous peduncle. The flowers in this type of inflorescene are unisexual. Please see **Fig. 4.3**. Example: *Acalypha hispida* (foxtail), *Morus alba* (Mulberry), *Betula* (Birch), *Quercus* (Oak).

Fig. 4.3 Catkin of Acalypha hispida (foxtail) (Source:http://en.wikipedia.org/wiki/Acalypha_hispida)

1.1.1.4 Spadix

This is also a type of spike with a fleshy peduncle which is enclosed by one or more large, often brightly coloured bracts, called **spathe**. Spadix is found only in monocotyledons. Example: Aroids (members of *Araceae*) , Banana, Palm etc.

Fig. 4.4 Spathe of *Typhonium trilobatum* (Araceae)(Source: http://www.amjbot.org/content/99/10.cover-expansion)

B. With the main axis shortened

1.1.1.5. Corymb

Corymb is a racemose inflorescence with a slightly shortened axis. The older flowers have the longer and the younger flowers have the shorter pedicels. As a result, all the flowers of the corymb inflorescence are found more or less at the same level (**Fig.4.5**) *Example: Cassia sp.(Caesalpinaceae).*

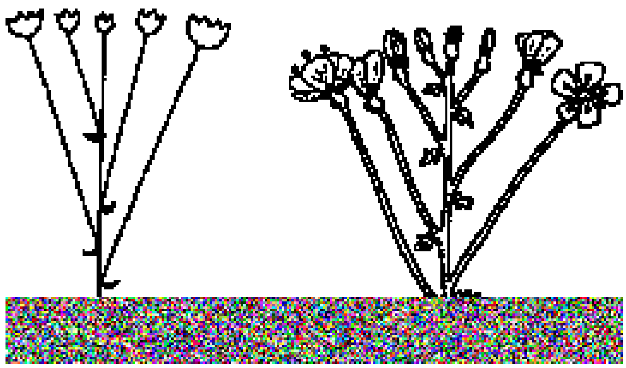


Fig. 4.5 Corymb Inflorescence
(Source: http://botany.csdl.tamu.edu/FLORA/201Manhart/repro/inflor/inflor.html)

1.1.1.6 Umbel

This inflorescence has a short floral axis at the tip of which pedicellate flowers are arranged in a radiating manner. The order of development of flowers is centripetal. In the umbel there is always a whorl of bracts forming an involucre and each flower develops from the axil of a bract. Commonly the umbel is branched and is known as **compound umbel**. Example: Species of *Foeniculum* (Anise or fenel, B. PANMOURI), *Coriandrum* (B. Dhania). In certain plants, however, the umbel is simple or unbranched and is called **simple umbel**. Example: *Centella asiatica* (B. BRAHMI). *Eryngium* (Wild coriander).

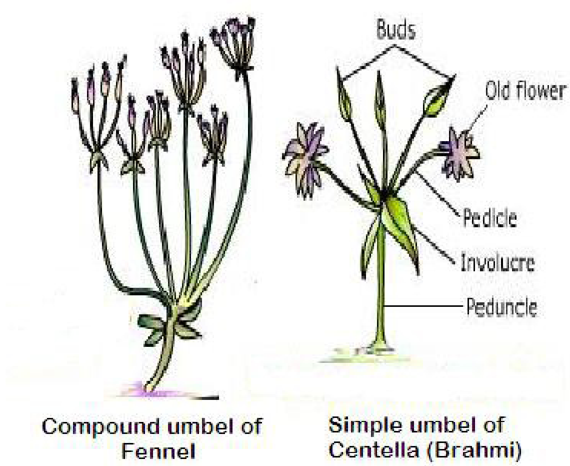


Fig. 4.6 Umbel
(Source: http://biology.tutorvista.com/plant-kingdom/inflorescence.html)

C. With the main axis flattened

1.1.1.7 Head or Capitulum

In this type of inflorescence, characteristic of sunflower family, the main axis or receptacle is suppressed and almost flat. The flat receptacle bears a mass of small sessile flowers (florets) on its surface. The base carries one or more bracts forming an involucre. In the head the outer flowers are older and open earlier than the inner ones. Usually, the florets are of two kinds – ray florets (marginal strap shaped) and disc florets (central tubular). Example: sunflower, margold, zinnia, Acacia (gum tree), Mimosa (sensitive plant), Anthocephalus (B.KADAM), Adina (B. KELIKADAM)

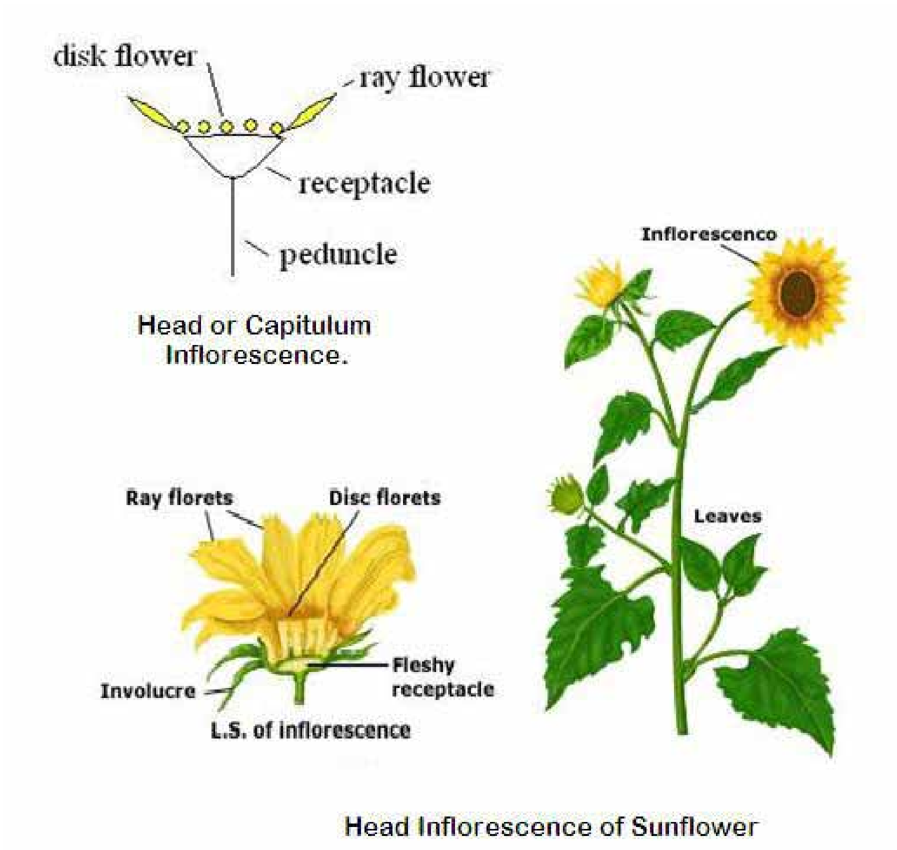


Fig. 4.7 Head or Capitulum Inflorescence.

(Source: http://www.smccd.edu/accounts/leddy/inflorescence.htm) http://www.tutorvista.com/content/biology/biology-iii/angiosperm-families/family- asteraceae.php)

1.1.2 Cymose Inflorescence

In Cymose Inflorescence the main axis ends in a flower; the lateral axis also terminates in a flower. The terminal flower is older and opens earlier than the lateral ones. Thus the order of opening of flowers is **centrifugal**. Cymose Inflorescence is of the following types.

(1) Uniparous or Monochasial Cyme – In this type, as the main axis ends in a flower, it produces only one lateral branch at a time ending in a flower. The process is repeated. There are two kinds of Uniparous Cyme , namely-

- o **Helicoid Cyme-** The lateral axis develops successively on the same side, forming a sort of helix. Example : *Drosera* (Sundew)
- o **Scorpioid Cyme-** Here the lateral branches develop on alternate sides, forming a zig zag structure. Example: *Heliotropium* (B.HATISUR)

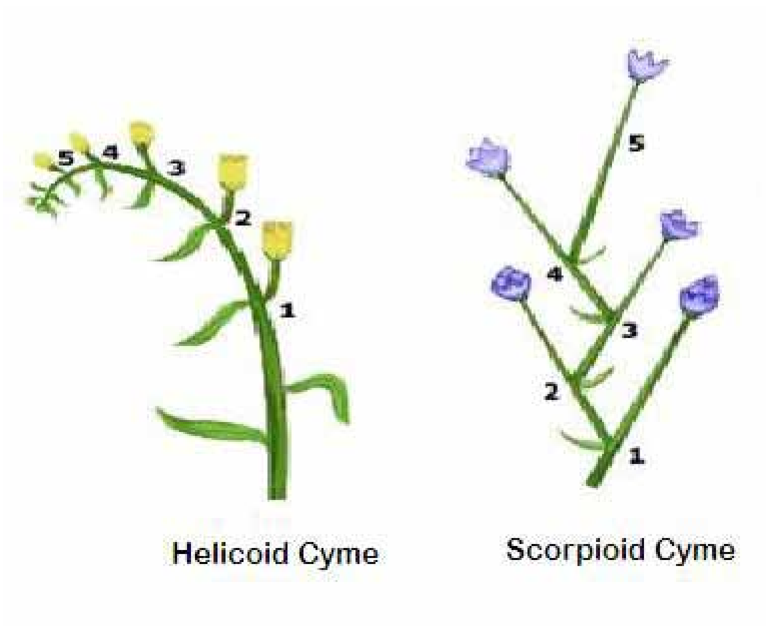


Fig 4.8 Helicoid and Scorpioid Cyme

(Source: http://biology.tutorvista.com/plant-kingdom/inflorescence.html)

(2) Biparous or Dichasial Cyme- Here the primary axis ends in a central flower which opens first , and at the same time at the base of the primary axis two lateral branches bearing flowers arise. The lateral flowers are younger. Each lateral branch may again give rise to succeeding flowers in the same manner. This is called **True Cyme**. Example : *Jasminum* (Jasmine), *Techtona grandis* (Teak) *Ixora* (B. RANGAN)

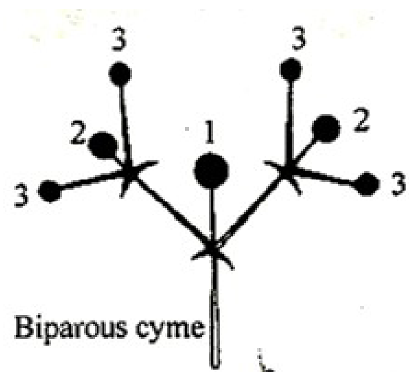


Fig. 4.9 Biparous Cyme
(Source:http://www.askiitians.com/biology/morphology-of-flowering-plants/flower.html)

(3) Multiparous or Polychasial Cyme – Here the main axis ends in a flower and at the same time it again produces a number of lateral flowers around. It is distinguished from umbel by the opening of the middle flower first. Example : *Calotropis* (B. AKANDA), *Asclepias.*

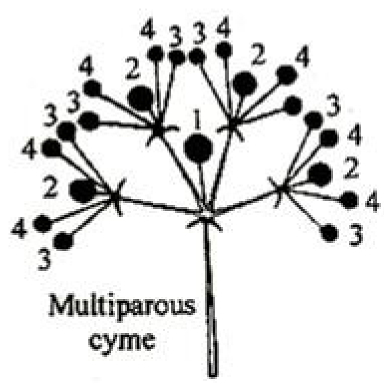


Fig. 4.10 Multiparous cyme
(Source:http://www.askiitians.com/biology/morphology-of-flowering plants/flower.html)

2. Bracts

Bracts are special leaves from the axil of which flowers, solitary or in clusters, are developed. There are many kinds of Bracts like leafy bracts, spathe, Petaloid bracts, involucres, scaly bracts etc.

2.1. Bracteoles

Bracteoles are smaller than bracts, either thin leafy or scaly structures developing on flower stalks between bracts and calyx.

The Flower

The flower is a modified shoot meant for reproduction of the plant.

3.1. Parts of a flower

The flower is borne on an axis which has two regions – (1) **Pedicel** – Stalk of the flower, and

(2) **Thalamus** –Swollen end of the axis on which floral leaves (whorls) are inserted. A flower has the following four whorls arranged in a definite order one above the other.

(a) The outer most or the first whorl, called **Calyx** consists of a number of green leafy **Sepals**

(b) The second whorl above the calyx is called **Corolla** which consists of a number of usually bright and coloured **Petals.**

(c) The third whorl is the male whorl called **Androecium** which consists of stamens.

(d) The fourth or the female whorl is called **Gynoecium** or **Pistil** which consists of **Carpels**

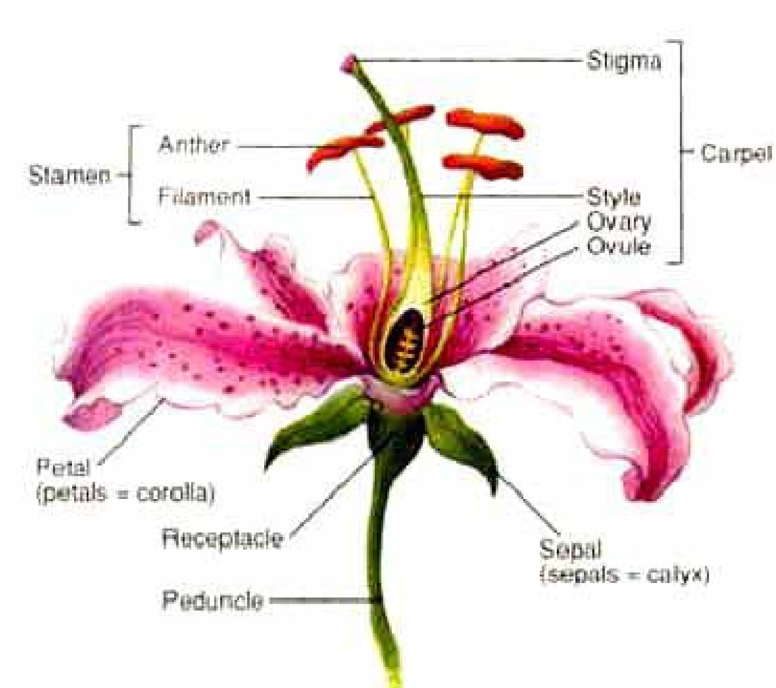


Fig. 4.11 Parts of a flower
(Source: http://andromeda.cavehill.uwi.edu/flower_structure_and_function.htm)
Description of the various parts of a flower and their functions are given below.

3.1.1. Calyx

It is the first or the lower most whorl of the flower and consists of a number of sepals. It is usually green, but in certain flowers it is coloured, as in Gold mohur. The calyx may be **regular** (divisible into two exactly equal halves by any vertical section passing through the centre), **zygomorphic** (divisible into two similar halves by one such vertical section only), or **irregular** (not divisible into two similar halves by any vertical plane) The sepals may be united together (**Gamosepalous**) or free from each other (**Polysepalous**). Examples of Gamosepalous Calyx: Brinjal, Chili, Potato. Example of Polysepalous Calyx: Mustard , Radish etc. The calyx may be modified into scales, as in sunflower, merry gold etc. In Mussaenda one of the sepals becomes large, leafy and sometimes coloured.

Fig. 4.12 Mussaenda Flower with a sepal modified into leaf
(Source: http://www.botany.hawaii.edu/faculty/carr/rubi.htm)

Functions-

- **Protection-** Protects the flower in bud condition.
- **Assimilation-** When green in colour it manufactures food.
- **Attraction –** When coloured , it attracts insects.

Duration-

Duration of Calyx varies

- **Caducous-** When calyx falls off before complete opening of flowers
- **Deciduous-** When Calyx falls off at the same time with corolla after fertilization
- **Persistant-**When Calyx is attached with the fruit and become permanent.

3.1.2 Corolla

The corolla is the second whorl of the flower and consists of a number of petals. Often brightly coloured and sometimes scented the petals attract insects for **pollination**. Like calyx, the corolla may be regular, zygomprphic or irregular. The corolla may be **gamopetalous** (petals are united) or **polypetalous** (petals are free). The corolla may sometimes be narrowed below forming a stalk, known as **claw,** and expanded above; the extended portion being known as **limb**.

Functions –

- Attract insects and help pollination
- In the bud stage protect the essential organs like stamens and carpels from heat, rain and insect attack.

3.1.3 Androecium

It is the third or male reproductive whorl of the flower. It consists of individual members known as **stamens**. The number of stamens may be one to many. The stamens may remain free or variously united or attached with other whorls.

Each stamen consists of-

- **Filament** – It is the slender stalk of stamen

  Anther – It is the expanded head borne on the tip of filament. Each anther consists usually of two lobes. Each anther lobe has within it two chambers called **pollen-sacs** or **microsporangia**. Each pollen sac contains fine, powdery or granular mass of cells, called the **pollen grains or microspores**. **Pollen grains** are the male reproductive bodies of a flower.
- **Connective –** It is the midrib connecting the two lobes that comprise the anther.

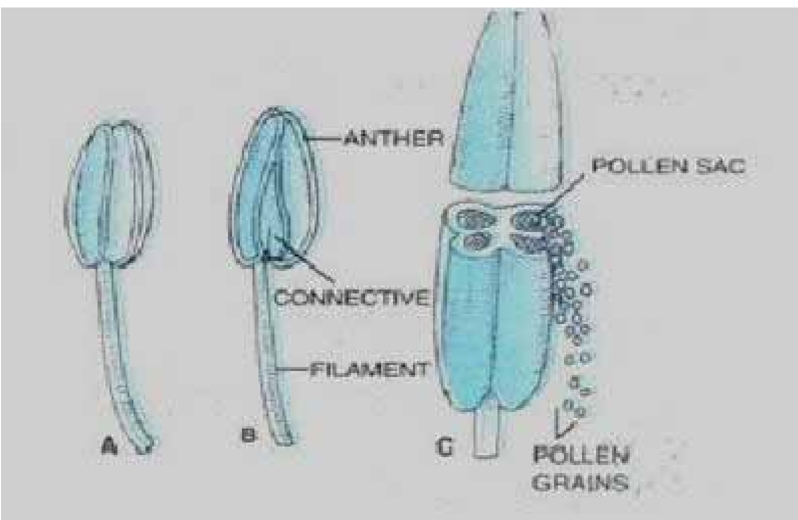


Fig.4.13. Stamen A. Ventral view B. Dorsal view C. Three dimensional cut section of Anther (Enlarged)

(Source : http://www.yourarticlelibrary.com/reproduction-in-plants/structure-of- stamen-anther-pollen-sac-and-pollen-grain-in-plants-biology/26771/)

3.1.4. Gynoecium or Pistil

It is the topmost fourth whorl or the female reproductive whorl of the flower. It consists of one or more **carpels**. The carpels are modified leaves meant to bear ovules and an embryo sac within each ovule.

A **carpel** consists of three parts –

- **Ovary** – the basal swollen portion containing one or more little egg-like bodies which are the rudiments of seeds, and are known as ovules.
- **Style** – short or long stalk-like protrusion of the ovary. Usually the style is apical, i.e. it arises from the top of the overy.
- **Stigma** – the receptive end (for the pollen grains) of the style which is knob-like in appearance.

3.1.4.1. Simple and Compound Gynoecium

A gynoecium is said to be **simple** when it consists of one carpel only, i.e. **monocarpellary**. This is seen in the members of the family Leguminosae, examples being pea, bean, gold mohur etc. But when the gynoecium is made of two or more carpels, the pistil is said to be **compound, or polycarpellary. Compound gynoecium** may be -

- **Apocarpous** – carpels are completely free from one another, with as many ovaries as the number of carpels, as seen in lotus, *Michelia* (B. CHAMPA), rose, *Magnolia* etc.
- **Syncarpous** – carpels are united together into one overy, which is more common.

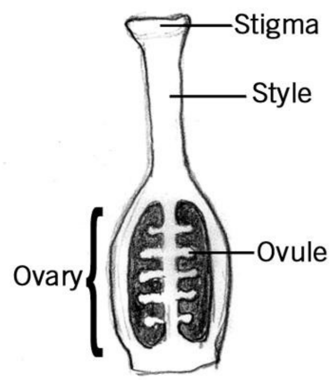


Fig. 4.14 A typical carpel and its parts.
(Source:http://cwf-fcf.org/en/discover-wildlife/resources/glossary/)

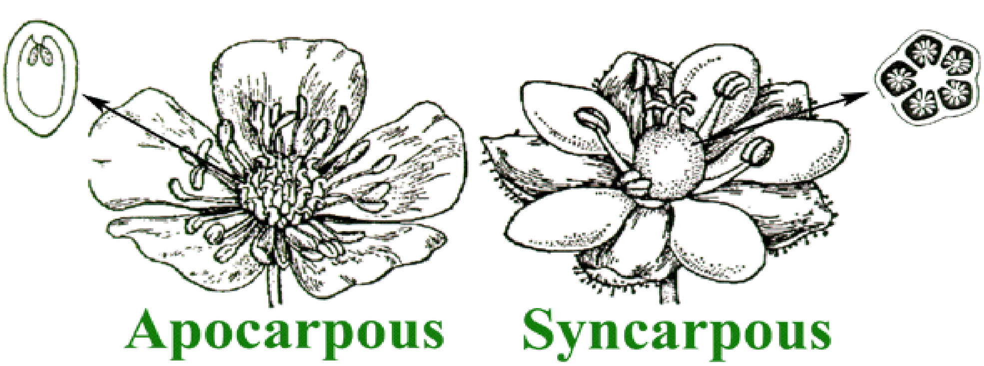


Fig. 4.15 Apocarpous and Syncarpous gynoecium
http://www.bio.tamu.edu/courses/biol301/tfplec4s01.htm

3.2 Some Terminologies

- **Complete and Incomplete Flowers –** A flower is said to be **complete** when all the four floral whorls are present. Absence of any of the floral whorls makes the flower **incomplete**.
- **Bisexual and Unisexual Flowers –** A flower is called **bisexual or hermaphrodite** when both androecium and gynoecium are present in the same individual flower. When a flower contains either androecium or gynoecium, that is, one of the male and female whorl is absent, it is called **unisexual or diclinous**.
- **Pistillate and Staminate Flowers –** Pistillate stands for unisexual female flowers and staminate stands for unisexual male flowers.
- **Dioecious, Monoecious and Polygamous plants –** Plants bearing **flowers of one sex** only, either female or male, are called **dioecious**. Plants bearing **unisexual flowers of both sexes** (on the same plant) are called **monoecious**. **Polygamous** are those plants which bear **unisexual flowers of both sexes, i.e. male and female flowers, in addition to bisexual flowers.**

Source of Lesson Materials:

1. A.C.Dutta ,1987, A class-book of Botany, Oxford University Press.
2. J.N.Mitra et.al.2014, studies in Botany, volume one, Moulik Library, Kolkata
3. Websites cited in the lesson

Time 1 hour

Lesson Plan

Objective:

- To study the following of plant morphology
  - Pollination
  - Types and agents of pollination
  - Fertilization
  - The fruit
  - Parts of fruit
  - Functions
  - Classification
  - Dispersal of seeds and fruits

Backward linkage

- Study of plant morphology in lessons 2, 3 and 4.

Forward linkage

- Study of plants in subsequent lessons
- Study of fruits / seeds during tour

Training materials

- Copy of lesson 5 to be circulated beforehand
- Specimens of fruits / seeds

Allocation of time

- Pollination– 8 mts
- Fertilization - 4 mts
- The Fruit
  - Parts of fruit-4 mts
  - Functions/ True and False fruit- 5 mts.
  - Classification-20 mts.
- Dispersal of Fruits / Seeds– 14 mts
- Miscellaneous /Discussion -5 mts.

1. Pollination

Pollination is the transference of pollen grains from the anther of a flower to the stigma of the same flower or of another flower of the same or sometimes allied species.

2. Types of Pollination

Pollination is of two kinds -

- **Self Pollination or Autogamy –** Pollination takes place within a single flower (bisexual) or between two flowers (bisexual or unisexual) of the same plant. In self pollination the offspring are produced by one parent plant.
- **Cross pollination or Allogamy –** Pollination takes place between two flowers (bisexual or unisexual) borne by two separate parent plants of the same or allied species.

Cross pollination is believed to be advantageous for the plant because the seeds produced by the flower will contain another source of genetic material which may contain genes which are advantageous to the survival of the seedlings. Plants that self pollinate are said to be **inbreeding** whereas plants which only cross pollinate are said to be **outcrossing**. However, most plant species are not strictly inbreeding or outcrsossing but a combination of the two.

3. Agents of Pollination

The agents that bring about pollination are –

- Wind
- Water
- Animals that include insects, snails, birds and bats.

Based on pollinating agents, pollination is classified into the following types –

- **Anemophily** – Pollination brought about **by wind** is called anemophily. **Anemophilous** plants bear small and inconspicuous flowers. The anthers produce immense quantity of pollen grains which are minute, light and dry and sometimes, as in pines, provided with wings. The stigma is large, often feathery, sometimes branched, and projects beyond the floral envelopes, so that pollen grains floating in air are easily captured by such stigma. Examples are maize, rice, grasses, bamboo etc.
- **Hydrophily** – In this case, pollination is brought about by water. Typical hydrophilous flowers are found in many submerged monocotyledons, like species of *Vallisneria*, *Hydrilla*, *Najas*, *Zostera* etc.
- **Zoophily** – In this case pollination is brought about by animals. The pollination agents here include insects, birds, snails and slug and bats. One subdivision of zoophily is entomophily where pollination is brought about by insects like bees (the most common insect pollinators), butterflies, moths, beetles and wasps. Entomophilous flowers have various adaptations by which they attract insects and use them as carriers of pollen grains. Principal adaptations are colour, nectar and scent. In other subdivisions of zoophily, that is, where agents of pollination are animals other than insects, we have, as agents, birds which bring about pollination in Erythrina (B. MANDAR), Bombax (B. SIMUL) etc, bats bringing about pollination in Anthocephalus (B. KADAM), and snails in large varieties of aroids.

4. Fertlization

It is the union of two **dissimilar sexual cells, that is, the male and female gametes,** resulting in the formation of a **zygote.**

When pollen grains land on the stigma of a flower of the correct species they germinate. A pollen tube grows through the tissues of the flower until it reaches an ovule inside the ovary. The nucleus of the pollen grain (the male gamete) then passes along the pollen tube and joins with the nucleus of the ovule (the female gamete). This process is called **fertilisation**. After fertilisation the female parts of the flower develop into a fruit. The ovules become seeds and the ovary wall becomes the rest of the fruit.

5. The Fruit

A fruit may be defined as a seed bearing structure produced usually after fertilization from the ovary of a flower or from an entire inflorescence. Thus **the fruit may be regarded as a mature or ripened ovary**.

5.1 Parts of the Fruit

A fruit consists of **two** parts, namely **-**

- **The Pericarp –** the part developing from the wall of the ovary.
- **The seed or seeds –** developing from the ovule or ovules**.**

The **pericarp** may be thick or thin. When thick, it exhibits **three** layers or parts. These parts are –

- **Epicarp** – the outer thin layer which forms the skin of the fruit.
- **Mesocarp** – the middle layer which forms the pulp;
- **Endocarp** – the inner layer which is often very thin and membranous as in orange, or it may be hard and stony as in many palms, mango etc.

5.2 Functions of the Fruit

- Protects the seed and therefore the embryo.
- Stores food material
- Helps in the dispersal of seed.

5.3 True and False Fruit

Normally the ovary grows into fruit, and the fruit which develops from the ovary is known as **true fruit**. However, in certain plants other floral parts, particularly the thalamus or even the calyx may grow and form a part of the fruit, and such a fruit is called **false fruit**. Some common examples of false fruit are apple, cashew nut, Dillenia (B. CHALTA) etc.

5.4 Classification of the Fruit

Fruits may be broadly classified into three groups. They are –

(1) Simple Fruits – When the ovary of a single flower with or without accessory parts matures into a single fruit, it is called **simple fruit**. Simple fruit may be dry or fleshy. The dry fruit again may be **(a) dehiscent, (b) indehiscent and (c) schizocarpic**.

(a) Dehiscent fruits - When these fruits mature the pericarp bursts to liberate the seeds. There are **different types of dehiscent fruits** –

- **Legume or Pod –** It is a dry, one chambered, many-seeded fruit developing from a simple pistil and dehiscing by both the margins. Example : pulses (pea, gram, lentil etc.),
- **Follicle –** It is also a dry, one chambered, many seeded fruit, but it dehisces by one suture only. Example: Calotropis (Madar), Alstonia scholatris (B. Chatian) etc.
- **Siliqua –** This is a dry, long, narrow two-chambered fruit developing from a bicarpellary pistil. It dehisces from below upwards by both the margins. The ovary, which is originally one-chambered, becomes two-chambered by the formation of a false partition wall called **replum** to which the seeds remain attached. Example: mustard, radish etc.
- **Capsule –** This is a dry, one-to-many chambered, many-seeded fruit developing from a syncarpous pistil and dehiscing in various ways. Example: Cotton, lady's finger, *Datura*, cock's comb, poppy etc.

(b) Indehiscent fruits – Indehiscent fruits do not burst or split open on maturity. The seeds are liberated by decaying or accidental destruction of the pericarp. There are many types of indehiscent fruits.

- **Achene** – A small, dry, one-seeded fruit developing from a single carpel. The pericarp is very thin and free from the seed coat. Example: *Mirabilis* (four o'clock plant), *Boerhaavbia* (hogweed)
- **Caryopsis** – it is also a small, dry, one-seeded fruit developing from a simple (or syncarpous) pistil. The pericarp is fused with the seed coat and is inseparable. Example: maize, rice, wheat, bamboo, grass etc.
- **Cypsela** – It is a dry, one-seeded fruit developing from an inferior bicarpellary ovary. The pericarp is free from the seed coat. Example: Sunflower, marigold, cosmos etc.
- **Samara** – It is a dry, one-or-two-seeded, winged fruit developing from a superior bi-or-tri-carpellary ovary. One or more wing always develop from the pericarp of the fruit. Example: Hiptage (B.MADHABILATA), Dioscorea (yam) etc. Fruits of Shorea (B. SAL), Dipterocarpus (B. GARJAN) also bear wings which are dry persistent sepals and belong to the type **samaroid**.
- **Nut** – It is a dry, one-celled, one-seeded fruit which develops from superior bi-or- poly-carpellary ovary having a hard or woody pericarp. Example: cashew nut, marking nut, oak etc.

(c) Schizocarpic or Splitting Fruits – Schizocarpic fruits break up into a number of indehiscent bits, called maricarps, generally equal to the number of component carpels. The pericarp does not burst or break down; the seeds are liberated only by the decomposition of the pericarp or by its splitting. There are following types of schizocarpic fruits.

- **Lomentum** – The pod is constricted or partitioned into a number of one-seeded compartments. Example: *Acacia* (B.Babla), *Mimosa* (B.Lajjabatilata), *Cassia fistula* (B.Bandarlathi), *Desmodium* (Indian telegraph plant) etc.
- **Cremocarp** – Dry two-chambered inferior fruit splitting into two indehiscent one-seeded pieces called mericarp. Each mericarp remains attached to the forked end of the axis. Example: coriander, anise or fennel, cumin, carrot etc.
- **Double Samara** – When mature, the fruit splits into two samaras each with a wing and a seed Example: *Acer* (maple)
- **Regma** – This is a dry, three-to-many chambered fruit developing from a syncarpous pistil. The fruit splits up in as many parts, called **cocci**, as there are carpels. Example: *Ricinus communis* (castor), *Geranium* sp. *Jatropha* (B.Bharenda) etc.

(d) Fleshy Fruits – There are following types of fleshy fruits.

- **Drupe –** It is a fleshy, one or more chambered, one or more seeded fruit developing from superior mono-or-poly-carpellary ovary. Here the pericarp is differentiated into epicarp (outer skin), mesocarp (fleshy middle layer) and endocarp (hard stony inner layer). Example: mango, plum, coconut-palm, zizyphus maritiana (B. KUL)
- **Berry or Bacca –** It is usually many-seeded fleshy fruit developing from poly- carpellary (rarely from monocarpellary) superior (sometimes inferior) ovary. The seeds after separation from the placenta lie freely in the pulp formed from mesocarp and endocarp. The epicarp remains as the skin. Example: tomato, gooseberry, grapes, banana, guava, brinjal etc.
- **Pepo –** It is also a fleshy many-seeded fruit like berry but it develops from an inferior, one celled or falsely three-celled, syncarpous pistil with parietal placentation (ridge of tissue bearing the ovules on the inner wall of the ovary). Example: gourd, cucumber, melon, water melon, squash etc.
- **Pome -** This is a two-to-many celled, inferior, fleshy syncarpous fruit surrounded by the thalamus. The fleshy succulent thalamus forms the edible part. The actual fruit (ovary) lies within. This type of false fruit is called pome. Example: apple, pear etc.
- **Hespiridium –** This is a superior, many celled fleshy fruit with axile placentation. Here the epicarp and the mesocarp are fused together forming the skin (rind) of the fruit, the endocarp remains thin papery forming the outer covering of the compartments. The edible part is the inner juicy succulent hairs of the endocarp. Example: orange, pummelo, lemon etc.

(2). Aggregate Fruits

An aggregate fruit is a collection of simple fruits (or fruitlets) developing from an apocarpous pistil (free carpels) of a flower. There are as many fruits as there are free carpels. An aggregate of simple fruits borne on a single flower is known as **etaerio**.

Common forms of etaerios are –

1) An etaerio of follicles; example: *Magnolia grandiflora*, *Michelia champaca* (B. CHAMP)etc.

2) An eaterio of achenes; example: rose, lotus, *Naravelia* etc.

3) An eaterio of drupes; example: raspberry

4) An eaterio of berries; example: custard apple, *Polyalthia longifolia* (B. DEBDARU)

(3). Multiple or Composite Fruits

A multiple or composite fruit develops from an inflorescence where the flowers are crowded and often fused with one another. There are two types of multiple fruits.

1) Sorosis – develops from a spike or a spadix. Example: jackfruit, mulberry.
2) Syconus – develops from a hollow pear shaped fleshy receptacle which encloses a number of minute male and female flowers. As it grows, the receptacle becomes the so-called fruit which in fact contains the true fruits originating from the female flowers. Example: banyan, peepul etc.

6. Dispersal of Seeds and Fruits

Seeds contained within fruits need to be dispersed far from the mother plant so that they may find favorable and less-competitive conditions in which to germinate and grow. We discuss here dispersal of seeds and fruits by various external agents.

6.1 Dispersal by wind

Wind is one of the best carriers of seeds. Fruits and seeds need to have certain properties or adaptations to be carried away easily by wind. We see many adaptations of fruits and seeds that facilitate their dispersal. Some of the adaptations are discussed here.

- **Wings** –Seeds and fruits of certain plants develop membranous wings. Examples of seeds developing wings are: *Oroxylum indicum* (B. SONA, TOTOLA), *Lagerstroemia* (B.JARUL), Moringa (B. SAJINA). Likewise fruits of certain plants develop one or more wings. Example: *Shorea robusta* (B.SAL), *Dipterocarpus* (B.GARJON) *Dioscorea* etc.

A. *Dipterocarpus turbinatus* (B.GARJAN) B. ***Shorea robusta* (B.SAL)**

(Source: http://www.arkive.org) (Source:http://www.dreamstime.com/)

Fig.5.1 Winged fruit

- **Parachute Mechanism-** Calyx of mini plants of the sunflower family or compositae is modified into hair like structure known as **pappus.** Persistant in the fruit the papus opens out like an umbrella and gets carried away to a long distance.
- **Censer Mechanism-** In certain plants, the fruit dehisces and liberates the seeds, and when it is shaken by wind, the seeds are dispersed to a distance. Example : *Aristolochiya gigas* (Pelicun flower, B.HANGSHALATA), *Orgemone mexicona* etc.

- **Hairs-**In certain plants seeds develop a tuft of hairs or a dense coating of hairs to facilitate dispersal by wind. Example: *Calotropis* (MADAR), *Alstonia* (Devil tree), *Gossypium* (Cotton) etc.
- **Persistent styles -** In certain plants like *Clematis, Naravelia,* the Styles are persistent and very feathery. This structure thus helps the fruits to float in air.

Fig.5.2 Persistant style of Naravelia
(Source: http://www.phytoimages.siu.edu/)

- **Light Weight -** If the fruits or seeds are small and light in weight (example, orchids and grains) they are easily carried by wind.

6.2. Dispersal by water

In aquatic plants and the plants growing by water side, seeds and fruits usually develop floating devices in the form of spongy or fibrous outer coats so that they are carried by water current to a long distance. For example the fibrous Mesocarp in *cocos nucifera* (Coconut) is a floating device. Such device is also seen in *Areca catechu* (B.SUPARI) and *Nipa fruticans*.

6.3. Dispersal by Explosive mechanism

Explosive and dehiscence mechanism of capsules of many plants help the seeds to disperse through certain distance. The fruits of *Impatines balsamina* and *Oxalis species*, when touched, burst with sudden jerk and a little sound resulting in scattering of the seeds. Mature fruits of Andrographis paniculata (B. KALMEGH), *Barleria* (B.JHANTI) etc. burst suddenly in dry air. The long pods of *Bauhimia vahlii* (B.LATAKANCHAN) explode suddenly with a loud noise and scatter the seeds.

6.4. Dispersal by animals

Dispersal by Human beings and animals such as grazing cattle, birds etc. is also a common phenomenon. Dry indehiscent fruits develop various devices to facilitate dispersion.

Common examples of such devices are –

- o **Hooked fruits-** Certain fruits are provided with hooks, barbs, spines, bristles by means of which they get attached to animal bodies or clothing of mankind and thus get carried to other places. Examples: Fruits of *Xanthium* (B. OKRA) and *Urena* (B. BONOKRA) develop curved hooks; seeds (fruits of *Aristida* (Spear grass) have a cluster of steep hairs.
- o **Sticky fruits-** Fruits of *Boerhaavia* (B. PUNARNAVA) are provided with sticky glands so that they stick to the bodies of grazing animals.
- o **Edible fruits-** Many fruits are regularly and widely distributed by animals over a long distance. Human beings and birds are the more active agents in this respect. The edible or pulpy portion of the fruits are eaten away, and the seeds are rejected which therefore get a chance to germinate and grow into new plants. Common examples are Guava, Papaya, mango, custard apple etc.

Source of Lesson Materials:

1. A.C.Dutta ,1987, A class-book of Botany, Oxford University Press.
2. J.N.Mitra et.al.2014, studies in Botany, volume one, Moulik Library, Kolkata
3. Websites cited in the lesson

Time 1 hour

Lesson Plan

Objective:

To study the following of plant Anatomy

- The Cell

  Definition Cell wall

  The Protoplast Protoplasmic components

Non protoplasmic components

- The Tissue

  Definition

Meristematic tissue-Classification of Meristems Permanent Tissue-Classification of Permanent tissues

- Secondary Growth
- Annual Rings
- Heartwood and Sapwood

Backward linkage

- Study of plant morphology in previous lessons.

Forward linkage

- Study of plants in subsequent lessons
- Study of Annual Rings during tour

Training materials

- Copy of lesson 6 to be circulated beforehand

Allocation of time

- Definition of Cell-Cell wall -3 mts
- The Protoplast- 3 mts
- Protoplasmic components-12 mts
- Non protoplasmic components-7 mts
- Definition of Tissue-3 mts
- Meristematic tissue-Classification of Meristems- 7 mts
- Permanent Tissue-Classification of Permanent tissues- 7 mts
- Secondary Growth- 5 mts
- Annual Rings -4 mts
- Heartwood and Sapwood- 4 mts
- Discussion / Miscellaneous – 5 mts

Plant Anatomy –

1. **The Cell-**The plant body is composed of cells which are its fundamental structural and functional units. A typical plant cell consists of a centrally situated mass or unit –The **protoplast** and a surrounding membrane or wall known as the cell wall.

1.1. Cell wall – It is the non living boundary wall of a cell. It is mainly composed of cellulose. It is formed by the protoplast to maintain its form and to protect it from external injury. The cell wall is a laminated structure and comprises of (i) a **middle lamella**, (ii) a primary wall on each side of the middle lamella, and in many cells (iii) a secondary wall on each side of the primary wall. The middle lamella is the common middle layer of the cell wall connecting to adjoining cells, and holds the adjoining cells together.

1.2 The protoplast – It is the organized mass that lies within the wall and has, as its constituents, **(i) protoplasmic components**, i.e, **Protoplasm,** and **(ii) Non- Protoplasmic components.** The protoplasmic components or protoplasm include bodies, namely, **Cytoplasm, Endoplasmic Reticulum, Nucleus, Plastids** etc. It is noteworthy that these living bodies are never formed afresh in the cells but they develop from pre-existing ones by divisions, and thus one kind of living body cannot give rise to another kind. To the non protoplasmic component belongs (i) Ergastic substance i.e. Non- living cells like reserve food material, excretory material and (ii) The Vacuole.

1.3 Protoplasmic components or protoplasm –

(i) Cytoplasm- It comprises the living, hyaline, jelly-like and viscous transparent semi-fluid portion of the protoplast, in which nucleus, plastids and other cell inclusions; both living and nonliving are embedded. At the young stage of the cell the cytoplasm occupies the whole cavity, i.e, the space between the cell wall and the nucleus. As the cell increases rapidly, the cytoplasm cannot keep pace with the growth of cell wall. As a result, a number of small (Non –Protoplasmic) cavities, called **vacuoles** appear in the cytoplasm. With further increase in cell size, these small vacuoles combine to form a large one, occupying the greater space of the cell. In the process the cytoplasm is pushed outward as a thin lining layer against the cell wall. The cavities or vacuoles formed within the cytoplasm are filled up with a fluid, called the cell-sap. The cell-sap is a watery and non- protoplasmic liquid containing various substances in solution or in colloidal condition or in crystals viz. in organic salts, carbohydrates, proteins, colouring matters etc.

Cytoplasm is a very complex structure and it contains various organic and inorganic substances.

It has three distinct parts-

- **Ectoplasm or plasma membrane –** The thin, non granular, outermost membrane like layer. The ectoplasm controls passage of water and many chemical substances into and out of the cell.
- **Endoplasm –** The granular middle part which forms the general mass of cytoplasm. The endoplasm performs general functions of the cytoplasm.
- **Tonoplasm or vacuole membrane-** The inner most layer of cytoplasm surrounding or bounding the vacuole as a thin membrane. It controls the permeability of water and substances into and out of the vacuole.

(i) Endoplasmic Reticulum – It is a network of tube like structures distributed throughout the cytoplasm, and is revealed by the Electron microscope. They appear to have functions in enzyme formation, protein synthesis, storage and transport of metabolic products.

(ii) Nucleus- The nucleus is a specialized protoplasmic body, much denser than the cytoplasm, and is commonly spherical or oval in shape. The nucleus is universally present in all living cells. Normally the nucleus lies in the central position and occupies a considerable portion of the cell wall. However, as described earlier, with development of the cell size, the nucleus along with the cytoplasm moves to the periphery.

Structure of a nucleus- Following are the components that form a nuclear structure.

- **Nuclear Membrane –** Each nucleus is surrounded by a thin, transparent, protoplasmic membrane called **nuclear membrane**. It separates the nucleus from the surrounding cytoplasm.
- **Nuclear sap or Nucleoplasm or karyolymph –** The cavity of the nucleus is filled up with a colourless jelly-like dense but clear mass of protoplasm, known as nuclear sap or nucleoplasm or karyolymph.
- **Nuclear reticulum or Chromatin network –** Numerous fine crooked threads, connected loosely, forming a network or reticulate structure, called **nuclear reticulum**, is present in the nucleoplasm in a dispersed state. The threads are made of a substance known as chromatin or nuclein which is strongly stainable. The threads of the nuclear reticulum are the constituents of **chromosomes**.
- **Nucleoli (sing. Nucleolus)** – One or more spherical, thick, prominent and highly refractory bodies, called **nucleoli**, are also found in dispersed condition within the nucleoplasm.

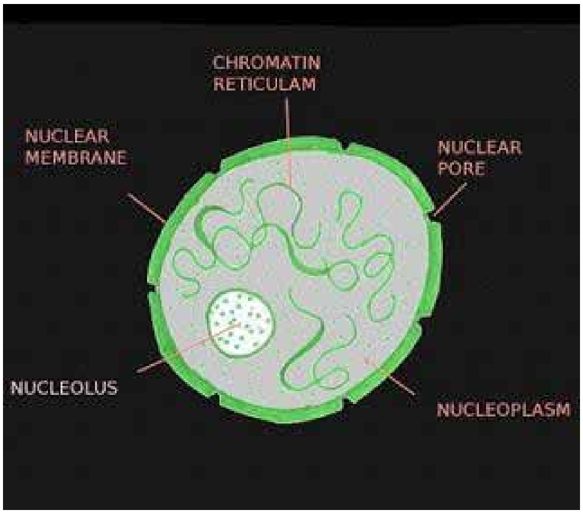


Fig. 6.1 Structure of Nucleus of plant cell
(Source : http://xrislynn13.blogspot.in)

DNA and RNA – DNA (deoxyribonucleic acid) and RNA (ribonucleic acid), particularly, the former are known to be the most important constituents of living cells. RNA occurs in the nucleoli, chromosomes and cytoplasm. Of these, cytoplasm has the largest share, about 90% of cell's RNA. DNA, however, occurs in chromosomes (nuclear reticulum). DNA is the controlling centre of all vital cell activities. DNA is the sole genetic (hereditary) material moving in tact down the generations through the reproductive units or gametes. Specific characters of a plant are attributable to this DNA. RNA is a chemical messenger and plays a vital role in the protein synthesis.

Functions – The specific functions of the nucleus are –

- The nucleus has a direct role in reproduction. Two reproductive nuclei called gametes (egg- cell and male gamete) fuse together to produce an oospore which grows into an embryo.
- The nucleus has an initiative role in cell division. The nucleus divides first followed by the cell. This is the mode by which cells multiply and the plant body grows.
- The nucleus is the carrier of hereditary characters.

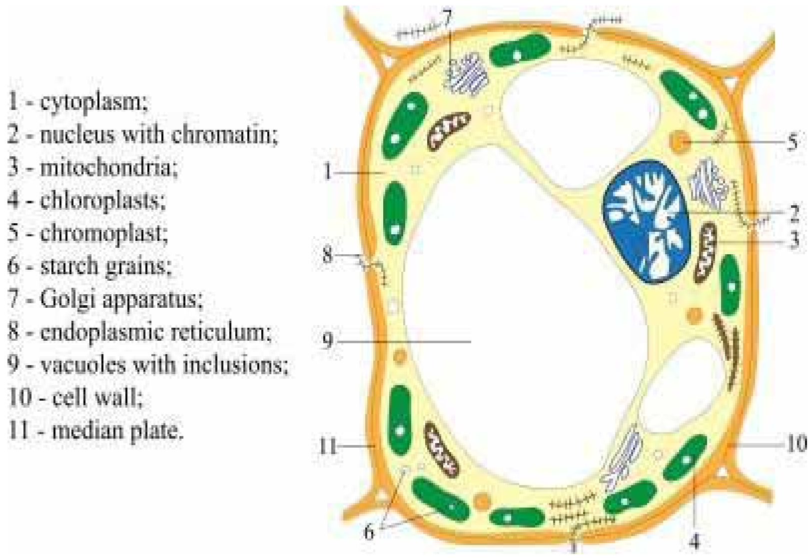


Fig 6.2 Typical plant cell
(Source: http://biology.tutorvista.com/animal-and-plant-cells/plant-cell.html)

(iv) Plastids - Plastids are cell organelles that store specific things found only in plant cell but absent in animal cells. In plant cell they are found in the cytoplasm. Plastids are spherical or ovoid in shape. They are involved in manufacture and storage of certain important chemical compounds.. According to their colour the plastids are of three types –

- **Leucoplasts -** These are colorless plastids and occur in parts of plants that are not exposed to light like roots and seeds. The absence of color is due to the lack of pigments. Their Starch grain formations are seen in leucoplast. Oils and proteins are synthesized here.
- **Chloroplasts -** The word *chloros* means green and *plast* means form or entity. Chloroplast is an elongated or disc-shaped organelle containing chlorophyll. They have two membranes and have structures that look like stack of coins. It is the most important plastid as they are involved in photosynthesis. The chloroplasts are situated near the surface of the cell and in parts where there is sufficient reception of sunlight. The shape of the cholorplast varies, it may be spheroid or ovoid or discoid.
- **Chromoplast -** Chromo means color; plast means living. Chromoplasts are colored plastids and they contain various pigments like yellow, orange and red. They are found commonly in flowers and fruits. The color is due to pigment, carotenes and xanthophylls. In flowers the main function is to attract agents for pollination. In fruits it is to attract agents for dispersal.

(v) Mitochondria- They are minute bodies occurring often in large numbers in the cytoplasm of all plant and animal cells. They have the form of short rods or long filaments and sometimes of spherical or oval bodies. Mitochondria are surrounded by two membranes. They are described as the 'power plants' of the cell as they convert glucose to energy molecules. They possess their own hereditary material which helps in self duplication and multiplication.

(vi) Golgi Bodies – They are minute net like structure, and more common in animal cells than plants. The Golgi bodies look like the endoplasmic reticulum and are situated near the nucleus. Their main function is to process and package macromolecules synthesized from other parts of the cell. The Golgi apparatus is referred to as the cell's packaging center.

(vii) Centrosomes – They are found to occur in cells of some lower plants like algae and fungi. A minute body the centrosome occurs close to the nucleus and has usually two central bodies called centrioles. During nuclear division they move on to the opposite ends of the cell and organize the nuclear spindle.

(viii) Ribosomes – The small, sub spherical particulate components of the cytoplasm. They are composed of RNA and Protein. Ribosomes are sites for protein synthesis. They are found in all cells because protein is necessary for the survival of the cell.

(ix) Lysosomes - They occur as tiny particles in the cytoplasm. They are spherical in shape with an outer membrane and dense contents. Lysosome contains digestive enzymes. They digest excess or worn out organelles, food particles and any foreign bodies.

1.4. Non protoplasmic components

The non protoplasmic components of a plant cell include the following

(i) Vacuoles – This has already been described in sub para (i) in para 1.3.

(ii) Ergastic matters that is non living cell contents - Ergastic matters are divided into three groups

- **Reserved materials** – These are substances manufactured by the protoplasm and stored up in particular cells for utilization as food. Many of them occur in solution in the cell sap, others are deposited in solid forms in the cytoplasm. These are materials consists of three main groups namely, **(a) Carbohydrates, (b) Nitrogenous materials and (c) Fats and oils.**
- **Secretory materials**–These includes various products secreted by the protoplasm within a living cell or outside it to perform some special functions. Secretory materials are (a) Plant pigments , (b) Enzymes and (c) Nectar
- **Excretory materials –** These are substances that are formed during metabolism. There are not of any vital use to the plant body and are formed as mere by-products. These waste products are deposited in the bark, old leaves, dead wood and other special cells away from protoplasmic activity. These excretory materials are (a) Alkaloids (b) Organic acids (c) Resins (d) Gums (e) Tannins (f) Etherial or Essential Oils (g) Latex and (h) Mineral crystals.

2. The Tissue

Cells grow and assume specific shapes. Cells of the same shape combine into a group to perform a common function. Each group of mature cells forms a tissue. A tissue is thus defined as a continuous mass of cells of common origin and performing an identical function. Tissues are primarily classified into **two groups – meristematic and permanent**.

2.1 Meristematic tissue

Meristematic tissue, also called meristem, is defined as the embryonic tissue in the mature plant body, the cells of which continue to divide indefinitely, and as a result new cells are added continuously to the plant body. Some cells produced by meristematic tissue stop dividing and acquire certain changes to become permanent tissues of the plant. This change from meristematic to permanent tissue is called **differentiation**. The remaining cells in the meristem retain their meristematic activity. Meristematic cells are self -perpetuating.

2.1.1 According to their position in the plant body, there are three types of **meristems**: **Apical Meristems, Lateral Meristems** and **Intercalary Meristems.**

- **Apical meristem** is found at the tips of roots, stem and branches. It is responsible for increase in length of plant. It is divided into three zones – **protoderm**, **procambium** and **ground meristem**. Protoderm gives rise to epidermal tissue; procambium gives rise to primary vascular tissues and ground meristem gives rise to cortex and pith.
- **Lateral Meristem** - The meristem that is present along the longitudinal axis of stem and root is called **lateral meristem**. Vascular cambium and cork cambium (phellogen) are examples for lateral meristem. It produces secondary permanent tissues, which result in the thickening of stem and root.
- **Intercalary meristem -** It is present in the nodal region and is prominently found in monocotyledons, eg. grasses. As the name indicates, it is present in between the permanent tissues. It is derived from the apical meristem and is responsible for the elongation of internodes.

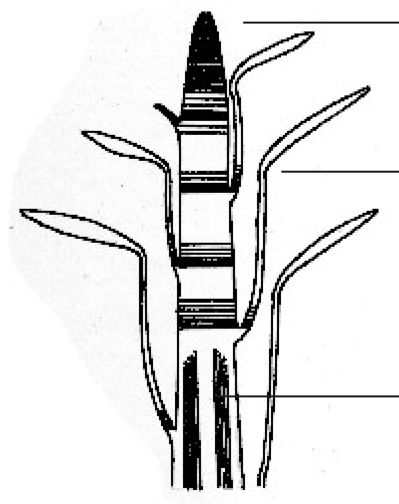


Fig.6.3 *L.S of shoot - showing the positions of meristems*
(Source: Biology, Botany, HS Second Year, Tamilnadu Textbook Corporation)

2.2 Permanent Tissues – These are composed of cells that have lost the power of dividing, having attained their definite form and size. They may be living or dead, thick walled or thin walled. Permanent tissues are formed by differentiation of the cells of the meristems.

2.2.1 Classification of permanent tissue - Based on the constituent cells, the permanent tissue is classified into two types – simple tissue and complex tissue.

- **Simple tissue -** A tissue with the cells of similar structure and function is called simple tissue. It is of three types **- parenchyma, collenchyma** and **sclerenchyma.**
  - **Parenchyma -** It is generally present in all organs of the plant. It constitutes the ground tissue in a plant. Parenchyma is a living tissue and made up of thin walled cells. The cell wall is made up of cellulose. Its function is mainly storage of food material.
  - **Collenchyma** generally occurs in the dicot stems in two or more layers below the epidermis. It is absent in the roots of land plants. It also occurs in petiole and pedicel. It gives strength to young organs. Collenchyma is a living tissue. It consists of more or less elongated cells, which are polygonal in cross section. The cell wall is unevenly thickened. Besides cellulose, the cell wall contains high amounts of hemicellulose and pectin. Collenchyma may contain chloroplasts and carry out photosynthesis.
  - **Sclerenchyma** is a dead tissue. The cells have lignified secondary walls. They lack protoplasts. They are fibre like in appearance. They provide strength and rigidity to the plant body.

- **Complex Tissue -** A tissue that consists of several kinds of cells but all of them function together as a single unit is called complex tissue. It is of two types – **xylem** and **phloem.**
  - **Xylem** (Greek word 'xylos'= wood) is a complex tissue that is mainly responsible for the conduction of water and mineral salts from roots to other parts of the plant. **Xylem** is made up of four kinds of cells - **tracheids, vessels or tracheae**, **xylem fibres** and **xylem parenchyma.**

- **Tracheids -** Tracheids are elongated with blunt ends. Its lumen is broader than that of fibres. Their secondary wall is lignified. In cross section, the tracheids appear polygonal and thick walled. The pits are simple or bordered. Tracheids (and not vessels) occur alone in the wood of ferns and gymnosperms, whereas in the wood of angiosperms they occur associated with the vessels. Being lignified and hard, tracheids give strength to the plant body. But their main function is conduction of water and mineral salts from the root to the leaf.
- **Vessels –** They are rows of elongated tube-like dead cells with their transverse or end-walls dissolved. A vessel is thus very much like a series of water pipes forming a pipe line. They occur parallel to the long axis of the plant body. Vessels are chief water conducting elements in angiosperms and they are absent in pteridophytes and gymnosperms.
- **Xylem (wood) Fibres -** The fibres of sclerenchyma associated with the xylem are known as xylem fibres. They give additional mechanical support to the plant body.
- **Xylem (Wood) Parenchyma** - The parenchyma cells associated with the xylem are known as xylem parenchyma. Xylem parenchyma is the only living tissue amongst the constituents of xylem. The cell wall is thin and made up of cellulose. The xylem parenchyma cells store food reserves in the form of starch and fat. They also assist in conduction of water.

■ **Phloem -** Like xylem, phloem is also a complex tissue. It conducts food materials to various parts of the plant. Phloem is composed of four kinds of cells: **sieve tubes**, **companion cells**, **phloem parenchyma** and **bast fibres**.

- **Sieve Tubes –** Sieve tubes are slender tube-like structure composed of elongated cells placed end to end. Each transverse wall is perforated by a number of pores, which give it a sieve like appearance. Sieve elements are the conducting elements of the phloem. In matured sieve tube, nucleus is absent. It contains a lining layer of cytoplasm.
- **Companion cells** - The thin-walled, elongated, specialised parenchyma cells, which are associated with the sieve tubes, are called companion cells. In contrast to sieve tubes, the companion cells have cytoplasm and a prominent nucleus. They are connected to the sieve tubes through pits found in the lateral walls. The companion cells are present only in angiosperms and absent in gymnosperms and pteridophytes. They assist the sieve tubes in the conduction of food materials.
- **Phloem parenchyma -** The parenchyma cells associated with the phloem are called phloem parenchyma. These are living cells. They store starch and fats. They also contain resins and tannins in some plants. They are present in all, pteridophytes, gymnosperms and dicots. In monocots, usually phloem parenchyma is absent.
- **Bast Fibres -** The fibres of sclerenchyma associated with phloem are called phloem fibres or bast fibres. They are narrow, vertically elongated cells with very thick walls and a small lumen (the cell cavity). Among the four kinds of phloem elements, phloem fibres are the only dead tissue. These are the strengthening and supporting cells.

1. Secondary Growth

Increase in the circumference/girth of the plant organs due to the formation of secondary tissues in stelar and extra stelar regions, is called secondary growth. The secondary growth takes place in sturdy herbs and in all shrubs and trees. Secondary tissues are formed by two meristems – cambium in the stelar region and cork-cambium in the extra stellar region. Normally secondary growth takes place in roots and stem of dicotyledons and gymnosperms.

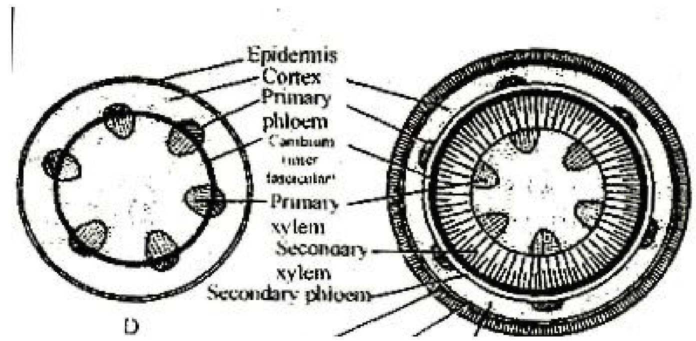


Fig.6.4 Activity of cambium ring

(Source:http://www.askiitians.com/biology/anatomy-of-flowering-plants/secondary- growth.html)

3.1 Secondary Growth in Dicotyledonous stem

The Vascular bundles which comprise xylem, phloem and the cambium are arranged in a circle and are open. The cambium lies between the xylem and phloem and is called **fascicular cambium.** With the start of secondary thickening, a portion of each medullary ray becomes meristematic, and forms a strip of cambium called **interfascicular cambium**. This joins on either side with fascicular cambium and forms a complete ring known as **cambium ring (Fig.6.4)**. The cambium ring begins to cut off new cells both externally and internally. Those cut off on the outer side constitute **secondary phloem** and those cut off by the cambium on its inner side constitute the secondary xylem. As the cambium cuts off more secondary tissues on the inner side, secondary xylem increases more rapidly than secondary phloem and soon forms a compact mass occupying the major portion of the stem. Primary xylem, though pushed inward, however, remains in tact.

4. Annual Rings

Activity of the cambium in producing secondary tissues is influenced by the climatic conditions. In spring, under favourable conditions, the activity of the cambium increases. It then produces a greater number of vessels with wider cavities (large pitted vessels). However, in winter the cambium's activity slows down and it produces narrower elements (narrow pitted vessels). The wood formed in spring, called **spring wood**, and that formed in winter, called **autumn wood**, appear together as a concentric ring, which is known as **annual ring** or **growth ring**. Each annual ring reflects one year's growth. The annual rings are visible in the naked eye in the logs of tree trunks of pines and many other timber trees. A count of the number of the annual rings gives an estimation of age of the tree.

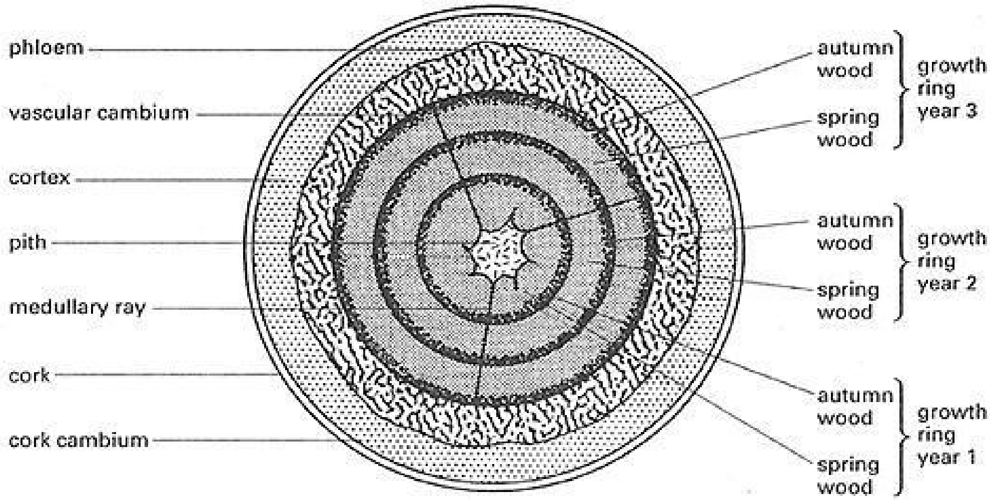


Fig 6.5 Annual Rings
(Source: http://montagepages.fuselabs.com)

5. Heartwood and Sapwood

In a stem, two types of wood zone appear following the formation of considerable amount of secondary Xylem. The recently formed outer zone of such secondary Xylem (i.e, wood) which is of lighter colour is known as the Sapwood. Sapwood contains living cells and is functional in conduction of water and salt solutions from the root to the leaf. However, the centrally situated Xylem, which has been formed earlier gets filled up with tannins, resins, gums, and essential oils etc. which make it hard and durable. This region of secondary wood is known as heartwood whose cells become non functional in conduction and storage. The heartwood is generally darker in colour. Composed of dead Xylem elements, heartwood simply gives mechanical support to the stem. The quantitative relation between the amount of heartwood and sapwood varies in different plants and is generally influenced by the conditions under which the plants are grown. Heart wood is more durable and forms commercial timber.

Source of Lesson Materials:-

1. A.C.Dutta ,1987, A class-book of Botany, Oxford University Press.
2. J.N.Mitra et.al.2014, studies in Botany, volume one, Moulik Library, Kolkata
3. Websites cited in the lesson

Time 1 hour

Lesson Plan Objective:

To study the following of Plant Physiology

- Photosynthesis

  Significance Site Mechanism

  Two main reactions

  Factors affecting photosynthesis
- Transpiration

  Types Significance

  Factors affecting Transpiration
- Translocation

  Mode
- Respiration

  End products

  Steps of respiration

Backward linkage

- Study of plant anatomy dealt with in Lesson 6.

Forward linkage

- Study of plants in subsequent lessons

Training materials

- Copy of lesson 7 to be circulated beforehand

Allocation of time

- Photosynthesis - 20 mts.
- Transpiration - 12 mts
- Translocation - 8 mts
- Respiration - 10 mts
- Discussion / Miscellaneous - 10 mts

1. Plant Physiology

Plant physiology is the branch of biological science, which deals with the functioning, and interrelationships of cells, tissues and organs of plants.

2. Photosynthesis

It is the process in which carbohydrates are synthesized in green cells in presence of light from carbon dioxide and water absorbed from air and soil respectively.

2.1 Significance of photosynthesis

Photosynthesis is a source of all our food and fuel. It is the only biological process that acts as the driving vital force for the whole animal kingdom and for the non-photosynthetic organism. It provides organic substances, which are used in the production of fats, proteins, nucleoproteins, pigments, enzymes, vitamins, cellulose, organic acids, etc. Some of them become structural parts of the organisms. It makes use of simple raw materials such as CO2, H2O and inexhaustible light energy for the synthesis of energetic organic compounds.

2.2 Site of photosynthesis

Chloroplasts are the actual sites for photosynthesis. All green parts of a plant are involved in photosynthesis. Leaves are the most important organs of photosynthesis. In xerophytes like Opuntia, the stem is green and it performs photosynthesis. Over half a million chloroplasts are present in one square millimetre of a leaf. It measures about 4 to 6 micron. A typical chloroplast of higher plants is discoid shaped. It is a double membrane bound organelle. The space enclosed by the envelope is filled with matrix called **stroma**. In the stroma, many **grana** are embedded. In each granum, several **disc shaped lamellae** are found. These disc shaped structures are called **thylakoids**. They resemble a stack of coins. This structure is known granum. Generally a chloroplast contains 40 to 60 grana. The photosynthetic pigments are found in grana. The stroma contains circular DNA, RNA and enzymes for starch synthesis.

2.3 Mechanism of Photosynthesis

The mechanism of photosynthesis can be described by the following equation

$$6CO_2 + 12\ H_2O \rightarrow C_6\,H_{12}O_6 + 6O_2$$

Thus the process of photosynthesis liberates Oxygen from water and causes reduction of carbon dioxide into Glucose. The above equation however indicates merely the beginning and the end of the process, but does not tell us anything about the complicated intermediate steps that take place.

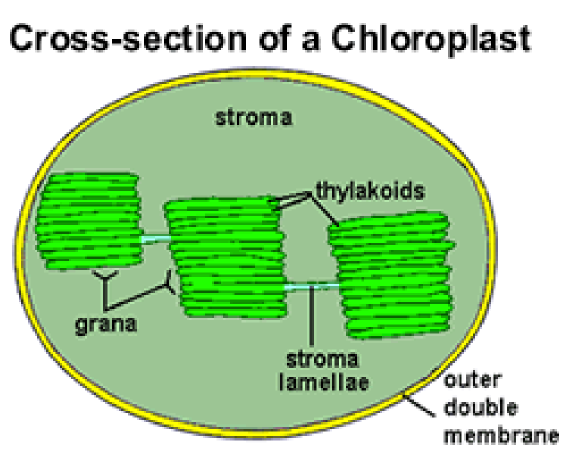


Fig.7.1 Chloroplast
(Source: http://crescentok.com/staff/jaskew/ISR/botzo/class7.htm)

2.3.1 Two main reactions

Photosynthesis has two main reactions. **Light-dependent reactions** or **Light Reactions** - which need light to work - and **light-independent reactions or Dark Reactions** - which do not need light to work.

- **The Light Reactions: $H_2O \rightarrow O_2 + ATP + NADPH$**
  - Light energy from the sun is used to split water (**photolysis**). Inside the thylakoid membranes of the granum, **water is split** to produce oxygen, electrons (e^-), and hydrogen ions (H^+).
  - This system depends on sunlight for activation energy.
  - Light is absorbed by *chlorophyll a* which "excites" the electrons in the chlorophyll molecule.
  - Electrons are passed through a series of carriers to produce adenosine triphosphate, **ATP** (that transports chemical energy within cells for metabolism) and **NADPH** (a coenzyme that carries electrical energy used in cellular processes and is used in the dark reactions).
  - Oxygen diffuses out of the plant as a waste product of photosynthesis.

- **Light-independent or Dark reactions: $ATP + NADPH + CO_2 \rightarrow C_6H_{12}O_6$**
  - The reactions that catalyze the reduction of CO_2 to carbohydrates with the help of ATP and NADPH generated by the light reactions are called the dark reactions. The enzymatic reduction of CO_2 by these reactions is also known as carbon fixation. These reactions that result in CO_2 fixation take place in a cyclic way and was discovered by Melvin Calvin. Hence the cycle is called Calvin Cycle.
  - During the dark reactions, sugars are built up using carbon dioxide and the products of the light-dependent reactions (ATP and NADPH) and various other chemicals found in the plant in the Calvin Cycle. Carbon dioxide diffuses into the plant and glucose is made.
  - The dark reactions continue as long as the light reactions supply energy in the form of ATP and NADPH
  - The ultimate product is glucose ($C_6H_{12}O_6$) - a stable, transportable, and storable form of chemical energy.

2.4 Main factors affecting Photosynthesis

There are three main factors affecting photosynthesis:

- Light intensity
- Carbon dioxide concentration
- Temperature

1) **Light intensity:** If there is little light shining on a plant, the light-dependent reactions will not work efficiently. This means that photolysis will not happen quickly, and therefore little NADPH and ATP will be made. This shortage of NADPH and ATP will lead to the light-independent reactions not working as NADPH and ATP are needed for the light- independent reactions to work.
2) **Carbon dioxide levels:** Carbon dioxide is used in the light-independent reactions. It combines with NADPH and ATP and various other chemicals (such as Ribulose Biphosphate) to form glucose. Therefore, if there is not enough carbon dioxide, then there will be a build up of NADPH and ATP and not enough glucose will be formed.
3) **Temperature:** There are many enzymes working in photosynthetic reactions - such as the enzyme in photolysis. These enzymes will stop working properly at high or low temperatures and therefore, so will do the light-dependent and light-independent reactions.

3. Transpiration

Plants absorb a large quantity of water from the soil with the help of root hairs. Only a small part (1-2%) of water absorbed is retained by the plants for growth. A major part (98-99%) of water intake is lost in the form of water vapour. **Transpiration** is the loss of water from the aerial parts of the plant in the form of water vapour.

3.1 Types of transpiration

Transpiration may be of the following types.

- **Stomatal -** transpiration taking place through the stomata (minute openings on the under surface of the leaves) is called stomatal transpiration.
- **Cuticular -** The surface of the plant is covered by a thin layer of cuticle through which water vapour is lost during transpiration. This is called cuticular transpiration.
- **Lenticular -** The process of loss of water vapour through the lenticels of stems and fruits is called lenticular transpiration.

Of the three types, **maximum transpiration (80-90%) is accounted through the stomata**. At night when the stomata are closed, transpiration is checked.

3.2 Significance of transpiration

- Excess water is got rid of.
- Movement of water through xylem vessels is favoured by active transpiration.
- Helps the intake of inorganic salts from the soil.
- Reduces the temperature of the leaves and helps the latter function normally.

3.3 Factors affecting transpiration

- **Light –** Rate of transpiration greatly increases with light and decreases in darkness.
- **Humidity –** There is an increase or decrease in the rate of transpiration according to whether the air is dry or moist.
- **Temperature –** The higher the temperature, the greater is the transpiration.
- **Wind velocity –** increase in the wind velocity usually increases the rate of transpiration.

4. Translocation

(Source: http://www.biologyreference.com/Ta-Va/Translocation.html#ixzz3CLHLbFQj) Translocation is the movement of organic food-stuff from leaves to other tissues throughout the plant. Plants produce carbohydrates (sugars) in their leaves by photosynthesis, but non- photosynthetic parts of the plant also require carbohydrates and other materials. For this reason, nutrients are **translocated** from sources (regions of excess carbohydrates, primarily mature leaves) to sinks (regions where the carbohydrate is needed). Some important sinks are roots, flowers, fruits, stems, and developing leaves. Leaves are particularly interesting in this regard because they are sinks when they are young and become sources later, when they are about half grown.

4.1 Mode of Translocation

The tissue in which nutrients move is the **phloem.** Please refer to Lesson 6. The phloem is arranged in long, continuous strands called vascular bundles that extend through the roots and stem and reach into the leaves as veins. Vascular bundles also contain the **xylem,** the tissue that carries water and dissolved minerals from the roots to the shoots.

4.1.1 In order to accommodate the flow of sap, the internal structure of the conducting cells of the phloem, the sieve elements, is drastically altered. As the sieve elements mature, they lose many of the **organelles** commonly found in living cells and they modify others. The **nucleus** disappears, as do the vacuoles, and some other cell components. Therefore, the inside (lumen) of the cell is left essentially open. The sieve elements are greatly elongated in the direction of transport and are connected to one another to form long sieve tubes. Large pores perforate the end walls of the sieve elements to facilitate flow through the tube. The connecting walls thus look like a sieve, giving the cell type its name.

4.1.2 The rate of translocation in angiosperms (flowering plants) is approximately 1 meter per hour. In conifers it is generally much slower. It is the pressure, generated in the sieve elements and companion cells in source tissues, which drives the flow of material in the phloem. In leaves, sugar is synthesized and is then actively pumped into the phloem, using metabolic energy. By using energy, the sugar is not only transferred to the phloem but is also concentrated. When a **solute** such as sugar is concentrated inside cells, water enters the cells by **osmosis.** Since the plant cells have a rigid cell wall, this influx of water creates a great deal of internal pressure. The pressure causes sap to move out through the pores of the sieve element, down the tube.

4.1.3 At the other end of the transport stream, in the sinks, sugar is constantly leaving the phloem and being used by surrounding cells. Some is consumed as an energy source, some is stored as sugar or starch, and some is used to make new cells if the sink tissue is growing. Since sugar leaves the phloem in the sink, water also exits (again by osmosis) and the pressure goes down. Therefore, there is a difference in pressure between source and sink phloem. This causes the solution to flow, just as water flows along a pressure **gradient** in a pipe. This process is known as the **pressure-flow mechanism**.

5. Respiration

(Source: http://kea.kar.nic.in/vikasana/bridge/biology/chap_07.pdf; http://www.excellup.com/InterBiology/plantrespiration.aspx)

Living cells require a continuous supply of energy for maintaining various life activities. This energy is obtained by oxidizing the organic compounds (carbohydrates, proteins, and lipids) in the cells. This process of harvesting chemical energy for metabolic activities in the form of ATP by oxidising the food molecules is called ‘respiration’. The most common substrate used in respiration for oxidation is glucose.

5.1 End Products

The complete combustion of glucose yields energy during respiration. Most of the energy produced during respiration is given out as heat. CO2 and H2O are the end products of respiration.

$$C_6H_{12}O_6 + 6CO_2 \rightarrow 6CO_2 + 6H_2O + \text{Heat}$$

The energy produced during respiration is also used for synthesizing other molecules. To ensure adequate supply of energy for synthesis of different molecules, plants catabolize the glucose molecule in such a way that all the liberated energy does not go out as heat. Glucose is oxidized in several small steps. Some steps are large enough to ensure that the released energy can be coupled with ATP synthesis.

5.2 Steps of Respiration

Respiration happens in two main steps in all living beings, viz. **glycolysis** and processing of **pyruvate**. Glycolysis involves breaking down glucose into pyruvate. This is common in all living beings. Further processing of pyruvate depends on the aerobic or anaerobic nature of an organism. In anaerobic respiration, pyruvate is further processed to produce either lactic acid or ethyl alcohol. There is incomplete oxidation of glucose in anaerobic respiration. In aerobic respiration, pyruvate is further processed to produce carbon dioxide and water; along with energy. There is complete oxidation of glucose in case of aerobic respiration.

Source of lesson materials:

1. A Class-book of Botany by A C Dutta, Oxford University Press, 1987
2. Studies in Botany, Vol 2, by D Mitra et.al, Moulik Library, Kolkata, 2014
3. http://crescentok.com/staff/jaskew/ISR/botzo/class7.htm
4. http://www.biologyreference.com/Ta-Va/Translocation.html#ixzz3CLHLbFQj
5. http://kea.kar.nic.in/vikasana/bridge/biology/chap_07.pdf;
6. http://www.excellup.com/InterBiology/plantrespiration.aspx
7. Botany, Higher Secondary, Second Year, Tamilnadu Textbook Corporation

Time 1 hour

Practical class on Plant Morphology

Lesson Plan Objective:

- To help the trainees familiarize themselves with following of plant morphology
  - Root, Stem , Leaf and modification thereof
  - Phyllotaxy
- To have better understanding of these topics dealt with in theoretical classes.

Backward Linkage:

- Topics of plant morphology dealt with in Lesson 1, 2 and 3.

Forward Linkage:

- During tour the trainees will have opportunities to see and refresh what they have learnt about plant morphology in theoretical and practical classes.

Methodology:

- Practical classes should be with examples/specimens of forestry species.
- Venue of class may be field or a combination of laboratory and field
- Trainees may be asked to identify phyllotaxy in the field.

Allocation of Time:

- Plant morphology - Leaf, stem, root, and modifications thereof – 25 mts
- Phyllotaxy - 15 mts
- Recording of observations - 20 mts

Practical Class: Subject:

- Familiarisation with plant morphology - Leaf, stem, root, and modifications thereof.
- Phyllotaxy

To demonstrate and elucidate the above aspects of plant morphology with specimens of forestry species

Observations: Trainees may record noteworthy characteristics on data sheet

Name____ Date _____________

____

Class Period ____

Familiarization with Root, Stem, Leaf and Phyllotaxy

Data Sheet

Part A. Root

1. Describe the characteristics

Specimen #1

a) Species _______________________

b) Description ____________________

Diagram Specimen #1

Diagram Specimen #2

Specimen #2

a) Species _______________________

b) Description ____________________

____

____

Part B. Stem

1. Describe the characteristics

Specimen #1

a) Species ______________________

b) Description ___________________

____

____

Diagram Specimen #1

Diagram Specimen #2

Specimen #2

a) Species ______________________

b) Description ___________________

____

____

Part C. Leaf

1. Describe the characteristics

Specimen #1

a) Species ______________________

b) Description ___________________

____

____

Diagram Specimen #1

Diagram Specimen #2

Specimen #2

a) Species ______________________

b) Description ___________________

____

____

Part D. Phyllotaxy

1. Describe the characteristics

Specimen #1

a) Species ____________________

b) Description ____________________

____

____

Specimen #2

a) Species ____________________

b) Description ____________________

____

____

Diagram Specimen #1

Diagram Specimen #2

Specimen #3

a) Species ____________________

b) Description ____________________

____

____

Specimen #4

a) Species ____________________

b) Description ____________________

____

____

Diagram Specimen #3

Diagram Specimen #4

Time 1 hour

Practical class on Plant Morphology (Inflorescence and Flowers)

Lesson Plan Objective:

- To help the trainees familiarize themselves with inflorescence and flowers
- To have better understanding of topics dealt with in theoretical classes.

Backward Linkage:

- Topics (Inflorescence and flowers) of plant morphology dealt with in Lesson 4.

Forward Linkage:

- During tour the trainees will have opportunities to see and refresh what they have learnt about inflorescence and flowers in theoretical and practical classes.

Methodology:

- Practical classes should be with examples/specimens of forestry species.
- Venue of class may be field or a combination of laboratory and field
- Trainees may be asked to identify various kinds of inflorescence in the field.

Allocation of Time:

- Observation/demonstration – 40 mts
- Recoding on data sheet - 20 mts

Practical Class: Subject:

- Familiarisation with plant morphology – Inflorescence
- Familiarisation with plant morphology - Parts of a Flower

To demonstrate and elucidate the above aspects of plant morphology with specimens of forestry species

Observations: Trainees may record their observations on data sheet.

Name____ Date ________________

Class Period _______________________________________

Familiarization with Inflorescence and flowers

Data Sheet

Part A. Inflorescence

1. Describe the inflorescence

Specimen #1

a) Type ____________________

b) Description ______________

____

____

c) Species___________________

Diagram Specimen #1

Diagram Specimen #2

Specimen #2

a) Type ____________________

b) Description ______________

____

____

c) Species___________________

Specimen #3

Specimen #4

Diagram Specimen #3

Diagram Specimen #4

Part B. Flower

1. Describe the parts of flower

Specimen #1

a) Description ____

____

____

____

b) Species____

Diagram Specimen #1

Specimen #2

a) Description ____

____

____

____

b) Species____

Diagram Specimen #2

Time 1 hour

Lesson Plan Objective:

Practical class on Plant Morphology (Flower Dissection)

Time 1 hour

- To help the trainees familiarize themselves with the parts of a flower and their function

Backward Linkage:

- Topics (Inflorescence and flowers) of plant morphology dealt with in Lesson 4.

Forward Linkage:

- During tour the trainees will have opportunities to see and refresh what they have learnt about inflorescence and flowers in theoretical and practical classes.

Methodology:

- Practical classes should be with examples/specimens of forestry species.
- Venue of class may be a laboratory.
- Trainees may be asked to identify record their observations on data sheet.

Allocation of Time:

- Dissection – 30 mts
- Recording on data sheet - 30 mts

Practical Class:

Subject: **Flower Dissection**

(Source: www.biologyjunction.com/**10sFlowerDissectionLab**.doc)

In this investigation, you will learn the structures of a flower and how they serve the reproductive function. Answer the questions and draw the diagrams on the data sheet.

<u>MATERIALS</u>: slide and cover slip razor blade dissecting needle (one per table) microscope or a magnifying glass (one per pair) one fresh flower

PROCEDURE:

Part A. Sepals and Petals

Examine the outside parts of the flower. The outermost whorl of floral parts may be green or brown and leaf-like. These sepals protected the flower bud when it was young. In some flowers the sepals look like an outer whorl of petals. Petals are usually large and coloured and lie inside the sepals. Both sepals and petals are attached to the enlarged end of a branch. These parts of the flower are not directly involved in sexual reproduction.

B. Stamen and Pollen

Carefully strip away the sepals and petals with the probe or blade to examine the reproductive structures. Around a central stalk-like body are 5 to 10 delicate stalks, each ending in a small sac, or anther. These are the male reproductive organs, or stamens. Thousands of pollen grains are produced in the anther. The number of stamens varies according to the type of flower. Shake some of the pollen into a drop of water on a clean slide, add a cover slip and examine with a microscope/magnifying lens.

C. Pistil and Ovary

The central stalk surrounded by the stamens is the female reproductive organ, known as a carpel or pistil. It is composed of an enlarged basal (bottom) part, the ovary, above which is an elongated part, the style, ending in a stigma. Use a probe or blade to cut into the ovary lengthwise. Gently open the ovary. Inside are one or more ovules. The union of egg and sperm causes extensive changes in the female reproductive parts. Fertilization of the egg stimulates the growth of the ovary and enclosed ovules.

D. Observations

Record your observations in the data sheet.

Name____ Date _________________

Class Period ____

Flower Dissection

Data Sheet

Part A. Sepals and Petals

1. Whether the flower is regular, Zygomorphic or irreguar?
   Ans:

2. Whether the sepals are Polysepalous or gamosepalous?
   Ans:

3. Whrther the petals are Polypetalous or gamopetalous?
   Ans:

4. Describe the sepals and petals – Number, shape, size and colour.

Diagram sepal

Diagram petal

Part B. Stamen and Pollen

2. How many stamens are present in your flower?

____

Diagram Stamen

Diagram Pollen

Part C. Pistil and Ovary

5. Describe the pistil and Ovary

____

6. Approximately how many ovules do you see?

____

Diagram Pistil	Ovary & Ovule

Directions: Arrange the parts of your flower in concentric circles. Glue them down in the appropriate circle.

- Outermost circle: sepal
- 2nd circle: petals
- 3rd circle: stamen
- 4th circle: carpel/pistil

Time 1 hour

Practical class on Plant Morphology (Fruits)

Lesson Plan Objective:

- To help the trainees familiarize themselves with fruits
- To have better understanding of topics dealt with in theoretical classes.

Backward Linkage:

- Topics (fruits) of plant morphology dealt with in Lesson 5.

Forward Linkage:

- During tour the trainees will have opportunities to see and refresh what they have learnt about fruits in theoretical and practical classes.

Methodology:

- Practical classes should be with examples/specimens of forestry species.
- Venue of class may be field or a combination of laboratory and field
- Trainees may be asked to identify various kinds of fruits in the field.

Allocation of Time:

- Observation/demonstration – 40 mts
- Recoding on data sheet - 20 mts

Practical Class: Subject:

- Familiarisation with plant morphology – fruits

To demonstrate and elucidate fruits of different types (Simple dry, Simple fleshy, Aggregate, and Multiple) with specimens of forestry species

Observations: Trainees may record their observations on data sheet.

Name____ Date _________________

Class Period ____

Familiarization with Fruits

Data Sheet

1. Describe the Fruits

Specimen #1

a) Type ______________________

b) Description _________________

____

____

c) Species_____________________

Diagram Specimen #1

Specimen #2

a) Type ______________________

b) Description _________________

____

____

c) Species_____________________

Diagram Specimen #2

1. Describe the Fruits

Specimen #3

a) Type ___________________________

b) Description ____________________

____

____

c) Species_________________________

Diagram Specimen #3

Specimen #4

a) Type ___________________________

b) Description ____________________

____

____

c) Species_________________________

Diagram Specimen #4

1. Describe the Fruits

Specimen #3

a) Type ________________________

b) Description __________________

____

____

c) Species______________________

Diagram Specimen #5

Specimen #4

a) Type ________________________

b) Description __________________

____

____

c) Species______________________

Diagram Specimen #6

Time 1 hour

Lesson Plan Objective:

- To study the following of Taxonomy
  - Definition – what is taxonomy
  - Binomial Nomenclature
  - Classification
- To study the following of vegetative propagation
  - Definition
  - Artificial methods
    - Stem cutting
    - Grafting

Backward linkage

- Study of plant morphology in lessons 2, 3 and 4.

Forward linkage

- Study of plants in subsequent lessons
- Study of artificial vegetative propagation during tour

Training materials

- Copy of lesson 12 to be circulated beforehand

Allocation of time

- Taxonomy

Definition, concept – 5 mts Binomial Nomenclature, classification – 10 mts

- Vegetative Propagation

  Definition - 5 mts

  Artificial methods - 30 mts

    - Stem cutting
    - Grafting
- Miscellaneous /Discussion -10 mts.

1. Taxonomy

Taxonomy is the science of naming, describing and classifying organisms and includes all plants, animals and microorganisms of the world. Using morphological, behavioural, genetic and biochemical observations, taxonomists identify, describe and arrange species into classifications, including those that are new to science.

When the taxonomy is concerned with plants, it is often referred to as **systematic botany**.

1.1 Carl Linnaeus (1707-1778), a Swedish physician and botanist, was the founder of modern taxonomy. He originated a system called binomial nomenclature which is used for naming living things and grouping similar organisms into categories.

1.2 Units of Classification

Species – A species is a group of individuals (plants or animals) of one and the same kind. They resemble one another in almost all important morphological characteristics – **both vegetative and reproductive** – so closely that they may be regarded as having been derived from the same parents. Thus all mango plants constitute a species. Similarly all Amlaki plants, all Sal plants constitute different and distinct species. Occasionally owing to variation in climatic or soil factors, **individuals of a species** may show **some amount of variation** in form, size, colour and other **minor characteristics. Such variants are said to form varieties**. A species **may or may not have** variety (ies).

Genus – A genus is a collection of species which have close similarity in the morphological characters of the floral or reproductive parts. For example, consider the three species, namely, banyan, peepul and fig. They are **different species** because they **differ in their vegetative characters**, like habit of the plant, the shape, size and surface of the leaf etc. But these species have close resemblance in their reproductive characters, namely, inflorescence, flower, fruit and seed. Therefore they belong to the same genus *Ficus.*

1.3 Binomial Nomenclature

Binomial Nomenclature, also called binary nomenclature, is the formal system of naming organisms, and it consists of **two Latinized names**, the **genus** and the **species**. All living things, and even some viruses, have a scientific name.

1.3.1 The binomial aspect of this system means that each plant (in case of botanical nomenclature) is given **two names**, a **'generic name**,' which is called the genus (pl. genera) and a **'specific name,' the species**. Together the generic and specific name of a plant is its scientific name. Having a universal system of binomial nomenclature allows scientists to speak the same language when referring to living things, and avoids the confusion of multiple common names that may differ based on region, culture or native language.

1.3.2 When written, a scientific name is always either **italicized**, or, if hand-written, underlined. The genus is capitalized and the species name is lower case. For example, the scientific or the botanical name of the mango plant is *Mangifera indica. Mangifera* is the generic, i.e. genus name, while the *indica* is the specific or species name.

1.3.3 To complete the name of a plant, the name of the author who has given the name of the particular plant, is appended. For example, in case of *Mangifera indica* L., the L. at the end indicates the name of the author Linnaeus in abbreviation.

1.4 Classification

Classification is the arrangement i.e placement of a plant or a group of plants in a series of groups or categories according to a particular system and in accordance with the rules of nomenclature. Species is the basic unit, e.g in case of Mango plant *Mangifera indica* L., *Mangifera* is the generic name and *indica* is the specific name. As explained, species which are similar to each other are placed in a genus e.g. *Terminalia alata* (Pacasaj or Asan), *Terminalia belerica* (Bahera) and *Terminalia chebula* (Haritaki) all belong to the genus *Terminalia.* Similar genera are again grouped into families, families into orders, orders into classes and classes into divisions.

1.4.1 Systems of Classification

There are two systems of classification – **artificial** and **natural**. In the **artificial system**, only one or at most few characters, selected arbitrarily, form the basis of classification into groups. In the natural system, all the important characteristics are taken into consideration to classify the plants.

1.4.1.1 Bentham and Hooker's System – This natural system of classification is in practice in India. According to these authors,

- **Plant kingdom** divided into two divisions – **cryptogams** (flowerless plants) and **phanerogams** (flowering plants);
- **phanerogams** divided into two subdivisions – **gymnosperms** (naked seeded plants) and **angiosperms** (closed seeded plants);
- **angiosperms** divided into two classes – **dicotyledons** and **monocotyledons**;
- **dicotyledons** have been divided into following three subclasses -
  - **Polypetalae** – both calyx and corolla present, petals free, stamens and carpels usually present. Stamens often indefinite; carpels are apocarpous or syncarpous.
  - **Gamopetalae** – both calyx and corolla present; the petals are united. Stamens almost always definite; carpels usually two but sometimes more, free or united; ovary inferior or superior.
  - **Monochlamydeae** – Flowers incomplete; either calyx or corolla or both absent. Flowers are generally unisexual.
- According to Bentham and Hooker, the monocotyledons are divided into seven series. A simpler classification by Vines divides monocotyledons into three subclasses. These details are not discussed here.

2. Plant Propagation by vegetative methods

Vegetative reproduction is a form of asexual reproduction in plants. It does not involve flowers, pollination and seed production. Instead, a new plant grows from a vegetative part, usually a stem, of the parent plant. However, plants which reproduce asexually almost always reproduce sexually as well, bearing flowers, fruits and seeds. Since no gametes are involved, the plants produced asexually have identical genomes and the offspring form what is known as a **clone.** The principal types of vegetative reproduction structures by natural methods are bulbs, corms, rhizomes and runners.

2.1 Artificial Methods of Vegetative Reproduction

There are various artificial methods of vegetative propagation, namely, propagation by **cutting**, **budding**, **grafting** etc. Although many of the techniques can be used for a range of different types of plants, it is important to know that some plants root better at a particular stage of growth, at a specific time of year or using a particular technique. We restrict our discussion to only **stem cutting,** and **grafting** as they are often employed in forestry practices. It may be noted that plants propagated using vegetative methods have the same characteristics as the parent or source plant since vegetative material is used and no genetic recombination is involved.

2.2 Objectives: Following are the main objectives for vegetative propagation.

- One basic objective is simply to make multiple plants from a single plant.
- To make a young plant from an old plant.
- To propagate a particular plant because of its unique features.
- To be reasonably sure to have healthy young plants and reduce the chance of false breeding which often happens with plants of seed origin.

2.3 Prerequisites: Regardless of the reason for propagating plants, there are some basic factors that are useful to ensure success:

- use only healthy, vigorous source plants;
- use the most appropriate method, growth stage, and timing for the plant;
- protect propagation material from heat and from drying; use the material as quickly as possible after it is prepared;
- give newly propagated plants extra attention and care during their establishment phase

2.4 Stem cutting

Any portion of a plant, a piece of stem, leaf or root, which has been removed from a plant with the object of inducing it to strike roots and thus begins an independent existence, is called cutting**.** In this method stem cuttings are used. Stem cutting is the most versatile of all methods used for vegetative propagation. Stem cuttings can be taken at different stages of development and are categorized as softwood, semi- hardwood, and hardwood cuttings. **Softwood stem cuttings** are taken in late spring or early summer and consist of tender shoots of current season growth. **Semi-hardwood stem cuttings** are taken from mid- to late-summer and consist of current season growth that is firm and has begun to form woody tissues. **Hardwood stem cuttings** are taken in late fall or winter and consist of woody stems that have just completed their first season of growth. For deciduous plants, these are taken after the plants have dropped their leaves.

2.4.1 Procedure

- Cuttings are to be taken at the time appropriate for the particular plant to be propagated;
- Gather polythene tube or hykopots of the appropriate size for the number of cuttings that you will be rooting; the pots are open at both ends.
- prepare the rooting medium (either a soil-less potting mix or peat moss and coarse sand, for Eucalyptus the common rooting medium is vermiculite); this should be moist but not wet; fill the pots with the medium;
- select and cut terminal shoots (preferably not in flower) from the source plant using a sharp, clean knife or pruning shear; the length of the cutting is determined by the source plant (cuttings usually vary from 2-8 inches in length.)
- remove the leaves near the cut end making certain that some leaves (3-8) remain on the cutting;
- use a clean, razor blade or scalpel to remove a thin slice of tissue about ½ - 1 inch long on two opposite sides of the cut end or base of the cutting; this provides a surface for root development;
- lightly dust the cut sides of the cutting with rooting hormone, as necessary;
- stick the cuttings into the pots' prepared rooting medium about one-third to one-half of the total length of the cutting; carefully firm the medium around each cutting with your fingers but avoid injury to the stem;

- the hykopot (ramet) trays or polypots are normally placed on a raised metal wire frame while ensuring bottom end of the pots are not blocked so that adventitious roots that will eventually grow find space through the bottom end and are self pruned;
- the frames containing the pots are kept in a mist chamber having provision of sprinklers for watering. If the scale of production is low, smaller poly chambers or hygropits (poly tunnels) without sprinkler system but having some means of watering arrangement can be used. The purpose of using mist chamber or low cost rooting chamber is to cut off a portion (pre-envisaged) of direct sunlight, and create a micro climate of very high humidity and moderately high temperature. (The chambers at Arabari nursery, while producing Eucalyptus ramets, operate at a temperature ranging between 30 and 35 degree and at a humidity level around 90%.);
- inspect the pots regularly and water as necessary to keep the potting medium moist but not wet;
- after 5-8 weeks (depending upon the plant being propagated), roots should have started to form (In south West Bengal the rooting time for Eucalyptus clone is about 45 days.);
- when the cuttings have developed a sufficient root system, they are taken out of rooting chamber and placed in hardening chamber and thereby exposing the cuttings (new plants) to increasing light levels (in south west Bengal the Eucalyptus clones are normally kept in hardening chamber for about 15 days before they are considered ready for transplanting in the field);

2.4.2 Clonal Multiplication Area

It is obvious that if vegetative propagation by stem cutting, that is, clonal plantation of a species is taken up on a large scale in successive years, a sustainable source of stem cuttings has to be available. Stem cuttings in large number are provided by clonal hedge or clonal multiplication area. Protocol for creation and management of Eucalyptus clonal multiplication area adopted in Arabari may be seen in the **Appendix** (a note prepared by A Basu Ray Chaudhuri, former Addl PCCF Finance, WB)

2.5. Grafting:

It is an operation in which two cut surfaces of the same or different plants are so placed as to unite and grow together. The plant on which grafting is done is called **stock** and the plant part that is inserted on a stock, is called a **scion** or the **graft**. Grafting is done to transfer certain characters such as vigour, disease resistance etc. from stock to scion. These characters are sometimes difficult to transfer to the offspring's through the seeds. Grafting gives rapid results. For instance, the sapota plant take 8 – 10 years to fruit when developed from the seed and only 2-3years when developed from the graft. The best season for grafting is from Feb. – Jun as it is the growing season for the tree.

2.5.1 There are different methods of grafting depending upon the shape of the cut given to stock and scion, but the principle involved is the same i,e bringing together the cambia of stock & scion for union.

- **Splice Grafting:** In splice grafting, both scion & stock are cut across obliquely at the same angle and then tied firmly with plastic tape.
- **Whip Grafting:** This is a kind of grafting in which both scion & stock are cut diagonally. A vertical incision is made in the stock. One end of the scion is trimmed wedge shaped structure. The wedge shaped scion is then inserted into the vertical incision of the stock. It is then covered with grafting clay and wrapped with rags. After about a month, a new plant develops from this graft.

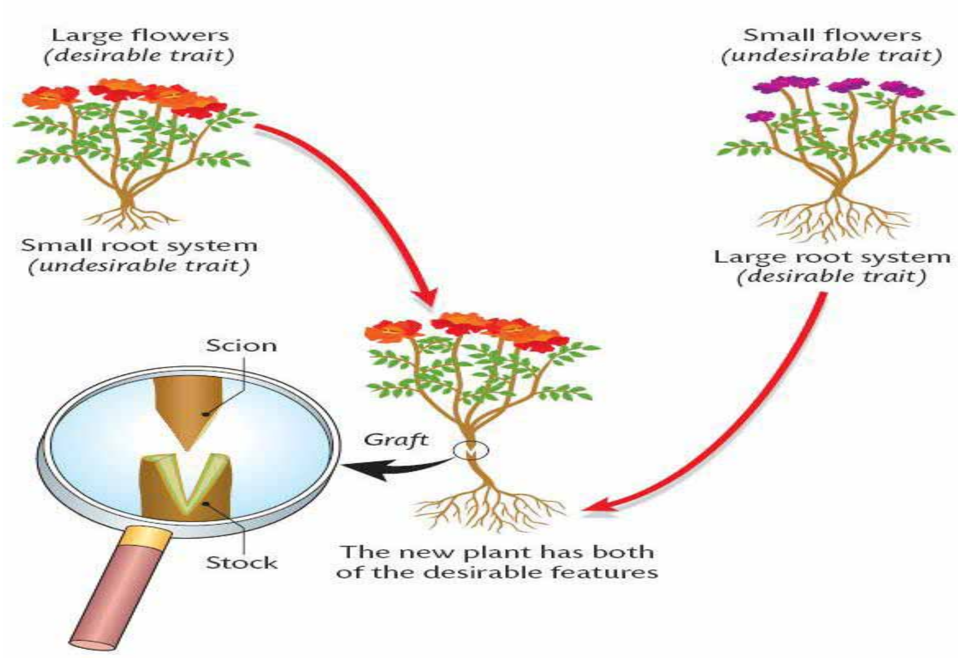


Fig.12.1 Grafting (Source: Vishwendu Vidya Prasarak Mandal's Abhinav Vidyalay & Junior College at www.abhinav.ac.in/DoV/Labs/B/B12Ph8_**Vegetative**_Propogation.pdf)

Source of Lesson materials:

1. *Basic Techniques for Propagating Plants S. M. Douglas The Connecticut Agricultural Experiment Station (www.ct.gov/caes)*
2. *Vishwendu Vidya Prasarak Mandal's Abhinav Vidyalay & Junior College at www.abhinav.ac.in/DoV/Labs/B/B12Ph8_**Vegetative**_Propogation.pdf*
3. http://www.itis.gov/servlet/SingleRpt/SingleRpt?)
4. *J.N Mitra et.al 2014, Studies in Botany, Volume one, Moulik Library, Kolkata 5*: http://www.scienceprofonline.com/biology-general)
6. (Source: http://www.cbd.int/gti/taxonomy.shtml)
7. *A C Dutta, 1984, A Class Book of Botany, Oxford University press*.

CLONAL MULTIPLICATION AREA (CMA) OF EUCALYPTUS **Appendix – Forest Botany**

– CREATION & MANAGEMENT

INTRODUCTION

A Clonal Multiplication Area (CMA) is a living collection of asexually propagated plants belonging to a selected clone (same genetic origin), which is managed to ensure regular production of juvenile materials for mass multiplication. The standard cloning technology for production of eucalyptus ramets involves a few steps that include (a) preparation of cuttings from juvenile materials obtained from CMA, (b) rooting the cuttings in root trainers placed in mist propagation unit and (c) hardening the rooted cuttings in shaded and open nurseries. The CMA thus serves as a steady source of juvenile materials for mass production of Eucalyptus ramets.

LOCATION

Ideally, the CMA should be located close to the mist propagation facilities and nurseries. It not only reduces the carrying cost of cuttings from the CMA to the nursery site, but also increases the rooting percentage by containing evapotranspiration from the cuttings during the carriage.

READY FOR PRODUCTION

CMA of Eucalyptus is ready for exploitation at the end of third year, that is, after three years of growth in the field.

FIRST YEAR - CREATION:

1. **The site** to be chosen should be of superior quality having favourable soil depth and properties, and should not be prone to water logging.
2. **Spacing** of pits is 1mt x 1mt, permitting a stock of 10000 plants per hectare. If at subsequent stage, mechanized weeding – cleaning is considered preferable or unavoidable, a spacing of 1.5m x1.5m may be adopted.
3. **Size** of the pits is **(1/2(60+45) 45x45)**.
4. **The CMA sites for each clone should be separate and clearly demarcated.**
5. The planting pits are **filled up** with application of **50 grams of neem oil cake** per plant.
6. Planting of ramets is done in the normal planting season. The ramets/rooted cuttings, chosen for planting in the CMA, should have bushy or well-ramified roots for better survivability and health of the crop.
7. In order to prevent the attack of termites, which is very common in Eucalyptus in South West Bengal, **termiticides** like Chloropyrophos 25% EC (Dursban etc.), may be applied at the time of planting itself.
8. During the year **weeding, cleaning, hoeing, mulching** etc., are done **twice** like any other plantation. At the time of mulching, hoeing etc., **20 grams of DAP** per plant is applied, and this is done twice in the first year.
9. At every mulching, hoeing etc., about 5 grams (per plant) **systemic insecticides** like Phorate, Thymate etc., may be applied, as an added preventive measure.
10. It is very important to maintain **hygienic and healthy** conditions in the area of plantation for better growth and hence **regular weeding** must be done.
11. In case of **causalities**, the infilling of the clonal seedlings should be done in the **same year** with the **same batch** of (ramets) clonal seedlings maintained in the nursery to ensure homogeneity in the crop.

12. **Regular irrigation or watering** is done up to next rainy season. However, care must be taken to avoid water logging in the planted site. Therefore effective drainage system should be laid out before the area is prepared for planting and pits are laid.
13. **Fire line** should preferably be laid for the newly created CMA and in case the CMA is in fire prone area, it is important that fire line is laid out carefully and continuously managed.

SECOND YEAR OPERATIONS:

1. **Weeding, cleaning and other related maintenance** works are done regularly for the plantation.
2. **Mulching, hoeing, fertilization** etc., is done twice with **20 gram of DAP** per plant. The insecticides (5 gram per plant) and termiticides (5 gram per plant) are also applied twice simultaneously.
3. Some **fungicides** may also be applied, if required. During the rainy season, sometimes black spots start appearing on both the leaf surfaces from the leaf base and then spread towards the leaf tip. During severe attack the plant becomes leafless.
4. **Watering** is done regularly as per the requirement, while keeping the plantation site properly drained and free from water logging.
5. **Pruning and throwing away of unwanted side branches** from each plant, as per the requirement, is done very carefully avoiding any damage to the plants. This facilitates growth of apical bud and prevents any bend in the main stem.

THIRD YEAR OPERATIONS:

1. The regular activities and operations as done in the second year are **repeated in the third year** till the CMA reaches harvestable stage and becomes established at the end of third year.
2. **Felling (coppicng) of CMA** is done in the months from **November to January**.

MAINTENANCE OF CMA (POST ESTABLISHMENT STAGE)

Good maintenance and management increase the CMA productivity and the latter's life span. The main steps to be followed during the maintenance and management of the CMA are as follows:

- **Felling of trees**

1. **It is suggested that the CMA should be allowed to grow upto 3 years and then harvested towards the end of third year.**. The **stem girth** is ideal for cutting if it is **20cm or more** for its use as coppicer.

2. The stems in CMA are **cut** at the base **at a height of 6-8 inches** above ground in a **slanted and single cut** by using a sharp edged cutter. Care should be taken so that the stumps thus obtained are not damaged in the slashing process and that the top surface of the resulting stumps is even and slightly slanted.
3. The slightly slanting even surface is preferred, as it would help in draining of excess water immediately and thus remove the possibility of infection by microbes on the surface. The height is preferred at 6-8 inches, as beyond this height the stem would produce epicormic sprouts that are not useful for production of ramets subsequently. The epicornic branches do not form good cutting material for rooting, as their polarity is not well defined
4. Proper **systemic fungicide** is essentially applied at the cut portion of the stump to prevent any future fungal attack.
5. Further **irrigation** for watering and **application of DAP, insecticides, termiticides**, etc. are required regularly along with maintenance of proper drainage to prevent water logging near the stumps.

- **Typical Harvest Schedule**

THIRD YEAR –

November (early) – First Coppice Felling

November – December: First Harvest

45 days allowed for flush of coppice shoots to come up; Next 15 days - the shoots are harvested with sharp cutter.

While harvesting the shoots, both the leading shoots and the unwanted side branches are cut off the stools. The leading shoots are transported to the nursery, and the branches (unwanted side branches) are removed from the site.

January – February: Second Harvest

45 days allowed for second flush of coppice shoots;

Next 15 days - the shoots are harvested with sharp cutter

March : Third flush of coppice shoots grows; FOURTH YEAR

April : Third Harvest

Coppice shoots grow till mid-April

During the last 15 days, shoots are harvested;

May – June : Fourth harvest

45 days allowed for the fourth flush of coppice shoots;

Next 15 days - the shoots are harvested with sharp cutter;

During the fourth harvest, a couple of leading shoots per stool is left to grow. These shoots grow till October and render the CMA ready for second coppice felling.

November (early) – Second Coppice Felling

The same cycle of four harvests continues till June of the FIFTH YEAR; and the Third Coppice Felling follows in November.

In this manner one CMA can undergo four coppice felling in successive years and it is possible to harvest four times after each felling. After the fourth felling, the stumps are uprooted and the site is tractor- ploughed for creation of fresh CMA.

- **Production Capacity**

A 3 -year old well-managed CMA can produce about **40 to 50 cuttings** of optimum size (out of about 10 shoots) per stump/stool during each harvest after the 1^{st} coppice felling. Subsequently during the 2^{nd} felling to the 4th felling, an average of **20 numbers of cuttings** (out of 5 -7 shoots) are obtained per stool at each harvest, if the CMA is managed properly.

- **Watering / Irrigation**

Continuous production of clones in modern nurseries requires supply of abundant and superior shoots on a regular basis. As in normal plantation, coppicing is vigorous and better if watering is done regularly as and when the need arises. It is more crucial in the dry parts of South West Bengal than in other areas. Watering can be done by various means viz., by flooding of ground in the CMA site along with proper drainage or by use of sprinklers. **Ridge and furrow method** applied in these parts is considered as the most economical method. By this method watering is done during **November to May**, annually during the harvesting season to facilitate coppicing of shoots.

- **Cleaning, Mulching and Hoeing**

1. The CMA area is regularly cleaned off the invading weeds especially grasses, and the debris is removed from the site immediately.
2. Hoeing, mulching etc. is done at the base of the stumps at least **2 to 3 times a year**. During the process, **50 grams of DAP and 10 grams of Phorate** per plant are applied simultaneously

each time. However, application of very high quantity of nitrogenous fertilizer is not advised, as it affects the rooting of eucalyptus ramets adversely and also invites rampant fungal attack in the nursery.

- **<u>Weeding, Cleaning, General Maintenance</u>**

As tiny ramets grow quickly to trees during the period (first three years) of establishment of the CMA, they do not permit much sunlight to reach the forest floor and thus contain the invasion of undergrowth. However, as soon as the CMA is slashed to the ground, the site receives sunlight in abundance. This on the one hand promotes vigorous coppice growth, on the other it leads to invasion by weeds and grasses. The slashed Eucalyptus stumps often get covered by the weeds. The CMA in the harvest stage thus needs **thorough and frequent weeding and cleaning**. In case the weeding-cleaning operation becomes too labour-intensive or uneconomic, power tiller can be utilized for hoeing and weeding the area between the stumps during the maintenance of CMA.

In short, maintenance of Eucalyptus CMA in south West Bengal should include (i) watering on a regular basis, (ii) regular removal of weeds and grasses, (iii) taking preventive steps against termite attack and (iv) giving regular inputs of fertilizers.

A write-up on CMA received from the Silviculture South Division and information provided by Shri Abhijit Kar, FR, Range Officer, Arabari Research Rrange form the basis of this note.

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