Introduction to Plant Morphology - Morphological Study of Plant Roots and Stem

Objectives

After going through this lesson, the learners will be able to understand the following:

- Origins And History of Phytomorphology
- Importance / Significance of Study of Plant Morphology
- Contribution Of Phytomorphology To Current Studies On Plant Diversity
- Morphological Study of Plant Roots (Diversity In Form And Function)
- Morphological Study of Plant Stems

Content Outline

- Introduction
- Origin And History of Plant Morphology
- Morphological Study of Angiosperms
- Morphological Study of Roots
- Morphological Study of Stems
- Summary

Introduction

One of the basic themes that laid the foundations of plant sciences was made only by observation – through naked eyes or later through magnifying lenses and microscopes which helped in describing various forms of life on earth. This description is mainly of gross structural features, both external and internal. The study of morphology has been a silent partner for later studies in experimental biology or more specifically, physiology, evolution, taxonomy and various other applied biological fields. Initially the study of biology was dominated by the study of external and internal description of plant structures and therefore for a long time it remained as a part of natural history. The description, by itself, was amazing in terms of detail. While the initial reaction of a student could be boredom, one should keep in mind that the detailed description was utilized in the later day by reductionist biology where living processes drew more attention from scientists than the description of life forms and their structure. Hence, this description became meaningful and helpful in framing

research questions in physiology or evolutionary biology. In this module we will study origins and history of phytomorphology, morphological study of plant roots in angiosperms (diversity in form and function), morphological study of plant stems in angiosperms.

Origin and History of Plant Morphology

Plant morphology aims to study and explain the external form, structure and development of plants. Most of the initial studies of plant morphology started in Germany dates around 200 years back and were largely a part of natural history. However, later it had larger implications and significance in the study of plant systematics, taxonomy, evolution and genetics and later evolved into a branch of plant sciences.

The study of plant morphology is heavily dominated by the prominent figures in its history than some specific dates over the last two centuries. Few of the prominent figures include Johann Wolfgang von Goethe, Wilhelm Hofmeister, Karl von Goebel, and Wilhelm Troll.

The term 'morphology' was used by **Johann Wolfgang von Goethe** and these perspectives were originally published in 1790 in Goethe's book *Versuch die Metamorphose der Pflanzen zu erklären* ("An Attempt to Explain the Metamorphosis of Plants"; Goethe, 1790).

Friederich Wilhelm Benedikt Hofmeister was the discoverer of the alternation of generations and for his fundamental studies of plant embryology, he left a legacy of disciple who later became prominent plant morphologists. Hofmeister's major contribution to the field of plant morphology was his book *Allgemeine Morphologie der Gewächse* ("General Morphology of (Plant) Growth," Hofmeister, 1868).

Karl Ritter Eberhard von Goebel was a disciple of Hofmeister. His work published in form of a series of books in three volumes named '*Organographie der Pflanzen* (Organography of Plants).

Wielhelm Troll's contributions to the study of plant morphology were published in his major, multivolume book titled *Vergleichende Morphologie der höheren Pflanzen,* (Troll, 1937–1943) ("Comparative Morphology of Higher Plants").

The current botanists today utilize morphological descriptions in the study of genetics, structural evolution in plants,along with studying specific structures of plant fossils (Paleobotany) and plant systematics.

In this module our primary focus would be studying morphological diversity in terms of function and structure in angiosperm plants.

Morphological Study of Angiosperms

A typical angiospermic plant has vegetative parts and reproductive parts. Vegetative parts or includes roots, stems and leaves, whereas the reproductive part includes the characteristic feature of angiosperms that is the flower. The wide range in the structure of higher plants will never fail to fascinate us. Even though the angiosperms show such a large diversity in external structure or morphology, they are all characterised by presence of roots, stems, leaves which are the vegetative parts of a typical angiosperms, whereas the reproductive part includes the characteristic feature of angiosperms that is the flowers, the flower parts contain the reproductive gametes which fuse to form zygote that develops into seed however the ovary surrounding the ovule develop into fruits. In chapters 2 and 3, we talked about classification of plants based on morphological and other characteristics. For any successful attempt at classification and at understanding any higher plant (or for that matter any living organism) we need to know standard technical terms and standard definitions. We also need to know about the possible variations in different parts, found as adaptations of the plants to their environment, e.g., adaptations to various habitats, for protection, climbing, storage, etc. If you pull out any weed you will see that all of them have roots, stems and leaves. They may be bearing flowers and fruits. The underground part of the flowering plant is the root system while the portion above the ground forms the shoot system.

Morphological Study of Roots

The root is usually an underground part of the plant which helps in anchorage of plant in the soil and also helps in absorption of water and minerals from the soil. If we would ever tried to pull a weed from the garden we would know that roots anchor plants firmly in the soil. When we look at an uprooted plant we may see a ball of dirt at its lower end composed of a tough system of roots. This is a fibrous roots system which is typically seen in monocotyledonous plants, where the primary root is short lived and is replaced by a large number of roots. These roots originate from the base of the stem and constitute the fibrous root system, as seen in the wheat plant and grasses. In some plants, like grass, *Monstera* and the banyan tree, roots arise from parts of the plant other than the radicle and are called adventitious roots.

When we look at the roots of carrots and radish we find a single long tapering root such a root is called as tap roots as seen in majority of the dicotyledonous plants, where the direct elongation of the radicle leads to the formation of primary root which grows inside the soil. It

bears lateral roots of several orders that are referred to as secondary, tertiary, etc. roots. The primary roots and its branches constitute the tap root system, as seen in the mustard plant.
An interesting fact - A small rye plant (60 cm or 2 feet high) with its root system carefully removed from the soil was found to have about 14 million primary root branches with a total length of 600 kms.

Zones or Parts of a Root

- **Root Cap**: The root tip is covered with a layer of loosely attached, dead or dying cells that form a root cap. Root cap is present at the apex of the root. The root cap protects the underlying delicate cells of root apex from injury as it makes its way through the soil. In *Pandanus* (screw pine) multiple root caps are present while in aquatic plants, i.e. hydrophytes like Lemna, Eichornia, the apical portion is protected by root pocket in place of root cap that helps in providing buoyancy.
- **Meristematic zone**: This zone is present just above the root cap. These cells are part of the root meristems and divide to give rise to more cells. The cells of this region are very small, thin-walled and with dense protoplasm the cells of this region are isodiametric with vacuoles either absent or reduced in size. They divide repeatedly.
- **Zone of elongation**: This zone consists of elongated cells that increase the length of the root. The elongation is due vacuolation .
- **Maturation zone**: The cells of the elongation zone gradually differentiate and mature. Hence, this zone, proximal to the region of elongation, is called the region of maturation. From this region some of the epidermal cells form very fine and delicate, thread-like structures called root hairs are seen which are thin walled extensions of a single epidermal cell. These root hairs absorb water and minerals from the soil.

Modifications of Root

Roots in some plants change their shape and structure and become modified to perform functions other than absorption and conduction of water and minerals. They are modified for support, storage of food and respiration.

Modification of Tap Root

- **Storage roots or Fleshy Roots:** In some plants, the primary tap roots are modified for storing reserve food materials. The secondary roots remain thin and absorptive in function and are usually swollen and can be of various form:

- **Conical**: These roots have broad base tapering towards the apex giving it a shape as that of a cone. e.g., Daucus *carota* (carrot).
- **Fusiform**: In these roots the middle portion becomes thicker or swollen and tapers on both the ends, e.g., *Raphanus sativus* (radish).
- **Tuberous**: These roots have an irregular shape e.g., *Mirabilis jalapa*.
- **Napiform**: The upper portion of these fleshy roots is inflated or swollen which tapers towards the lower end e.g., *Brassica napus* (turnip), *Chenopodizan album, Beta vulgaris (beet root).*

- **Prop roots**: Roots arise from horizontal aerial branches. Initially, they are hygroscopic. They grow vertically downward, penetrate the soil, become thick and assume the shape of pillars. e.g., *Ficus bengalensis.*
- **Nodulated**: The plants of the Leguminosae family are characterised by the presence of nodules on branches of root in which nitrogen fixing bacteria are present, e.g., *Cicer arietinum.*
- **Pneumatophores or Respiratory roots**: This type of root arises from underground branches of tap root, in upward direction (—ve geotropic) bears numerous pores (pneumathodes). e.g., *Avicennia, Sonneratia etc.*

Modification of Adventitious Roots

- **Fleshy Roots:**
  - **Fasciculated roots**: From the base or lower nodes organ these tuberous roots arise in groups. e.g., *Dahlia.*
  - **Tuberous roots**: These roots become fleshy because of storing food, no definite shape. e.g., *Ipomoea batatas.*
  - **Nodulose roots**: The apex of these roots become swollen because of the accumulation of food, e.g., *Curcuma amada* .
  - **Moniliform roots**: These are also called beaded roots because of their bead-like appearance. *Momordica* (bitter gourd).
  - **Annulated roots**: These thickened roots look as if formed by a number of discs placed on one above another. e.g., *Ipecac (Cephaelis).*
- **Stilt roots:** In some plants roots are formed from the nodes of the lowermost portion of the stem and provide mechanical support to the plant by fixing it in soil firmly, *Pandanus tinctorius* (screw pine).

- **Epiphytic roots:** Some epiphytes, e.g., *orchids* have aerial roots. These roots absorb moisture from the atmosphere with the help of velamen tissue.
- **Floating roots:** These roots have air present in them that makes them inflated and spongy. Due to buoyancy the plants project above the level of water to help them float. e.g., *Jussiaea.*
- **Assimilatory roots:** In some plants the roots develop chlorophyll, e.g., *Tinospora. Trapa.* etc.
- **Root thorns:** Roots of some plants arise from the stem and change into thorns, performing the protective function. e.g., *Pothos* (money plant).

Functions of Roots

- Roots support the plant by keeping it fixed firmly in the soil;
- Root absorbs water and minerals;
- Store food inside them;
- Roots hold the soil particles together.

Morphology of The Stem

The stem is the ascending part of the axis bearing branches, leaves, flowers and fruits. It develops from the plumule of the embryo of a germinating seed. The stem bears nodes and internodes. The region of the stem where leaves are born are called nodes while internodes are the portions between two nodes. The stem bears buds, which may be terminal or axillary. Stem is generally green when young and later often become woody and dark brown. The main function of the stem is spreading out branches bearing leaves, flowers and fruits. It conducts water, minerals and photosynthates. Some stems perform the function of storage of food, support, protection and of vegetative propagation.

Bud: A bud is a condensed young shoot with underdeveloped leaves.
There are three types of buds - (i) vegetative (ii) floral (iii) modified

Vegetative buds

These buds develop into a vegetative shoot. Vegetative buds are further classified into the following three sub-types.

1. **Apical buds:** Such buds are present at the tip of the branches and the main axis and are called terminal or apical buds. They also occur in the axil of leaves and are called axillary buds.
2. **Adventitious buds:** These are the buds which develop from any part of the plant body other than those of apical and accessory buds.
    (a) Cauline buds: These buds arise directly from the stem.
    (b) Radical buds: These buds develop on the roots: e.g., sweet potato, *Ipecac*, *Dalbergia*.
    (c) Foliar buds: These are the buds which develop on the leaves: e.g., *Bryophyllum*.

- **Strong stem**
    - **Excurrent:** The main axis shows continuous growth and the lateral branches develop regularly which gives a conical appearance to the trees; e.g., *Polyalthia longifolia*, *Casuarina*.
    - **Deliquescent:** The growth of the lateral branch is more vigorous than that of the main axis. The tree has a rounded or spreading appearance; e.g., *Mangifera.*
    - **Caudex:** It is an unbranched, stout, cylindrical stem, marked with scars of fallen leaves: e.g., *Cocos.*
    - **Culm:** Erect stems with distinct nodes and internodes. Stem shows jointed appearance. e.g. *Bambusa arundinacea.*
- **Weak stems**
    - **Trailing:** It is a weak stem that spreads over the surface of the ground without rooting at the nodes. These fall into three categories:
        - **Prostrate** (Procumbent): A stem that lies flat on the ground:. e.g., *Portulaca*
        - **Decumbent**: A stem that lies flat but its apex is raised: e.g., *Tridax*.
        - **Diffuse**: A trailing stein with spreading branches; e.g., *Boerhaavia.*
    - **Creeping:** The plant grows horizontally on the ground and gives off roots at each node; e.g., grasses. Runners, stolons, offset and suckers are creeping stems.
    - **Climbing:** This weak stem climbs a support by means of some special structure. These are divided into following types.
        - **Twiners**: It is a weak, long and slender stem that climbs by twining its body around the support; e.g., *Dalichose* (Dextrorse), *Convolvulus* (Sinistrorse).

- **Lianas**: It is a long woody perennial twiner; e.g., *Bauhinia vahlii.*
- **Tendril climbers**: It is a weak stem climbing by its slender, leafless, spirally coiled structures, known as tendrils. e.g., *Lathyrus aphaca, L. odorants* etc.
- **Root climbers**: Such climbers give out adventitious roots at each node which stick to the support: e.g., *Pathos scandens* (money plant), Piper betle (betel). etc.

Modifications of Stem I

Underground modifications of stem

- **Rhizome:** It is a thick, prostrate and branched stem growing horizontally beneath the soil surface. It has distinct nodes and internodes. The nodes bear small scale leaves. Axillary bud is present in the axil of the scale leaf. The lower surface of the nodes gives out small slender adventitious roots, e.g. *Zingiher offkinale* (ginger); *Curcuma domestica* (turmeric) etc.
- **Tuber:** It is the swollen tip of the underground branch. The growth of these branches is retarded, hence the tips become swollen due to accumulation of food material. The tubers are round or oval in shape. Each tuber has many eyes which represents nodes. e.g., *Solanum tuberosum*.
- **Corm:** Corm is a condensed form of rhizome growing vertically down into the soil. Internodes are usually reduced and one or more axillary buds are present in the nil of the scale leaves. Some of these buds grow into daughter corms. Corms bear adventitious roots either at the base or throughout the surface; e.g., *Crocus sativus* (saffron), *Gladiolus*, etc.
- **Bulb:** It is a highly condensed stem, represented by a short convex or slightly conical disc. On its upper surface are present large numbers of fleshy scale leaves surrounding a terminal bud at the centre of the disc. Few scale leaves near buds in their axil. The fleshy leaves of the bulb store food in the form of carbohydrates. A few outer leaves which become dry and scaly, are protective in function. Large number of adventitious roots arise from the lower surface. The common examples are *Allium cepa* (onion), *Allium sativum* (garlic), etc.

Sub-aerial modifications of stem

- **Runner:** It is a slender, prostrate aerial stem creeping horizontally on the surface of the soil. At the nodes axillary buds form new aerial shoots and roots are given off on

the lower surface. Thus, several daughter plants are linked by runners e.g., *Cynodon* (doob grass). *Oxalis* sp. (wood sorrel), etc.

- **Sucker:** Arising from the basal underground portion of the main stem. Initially it grows horizontally below the surface of the earth but soon grows obliquely upward forming a leafy shoot. e.g., *Chrysanthemum*, *Mentha arvensis* (mentha), etc.
- **Offset:** It is the runner of aquatic plants. It is also similar to runner and originates from the axil of a leaf but has shorter and thicker internodes. e.g., *Eichhornia* (water hyacinth), *Pistia* etc. .

Aerial modifications of stem

- **Stem tendril:** In plants with weak aerial stems some axillary buds, instead of developing into branches, form tendrils. e.g., *Vitis (vine), Passiflora*.
- **Thorn:** A thorn represents an axillary branch of limited growth. It is hard, often straight pointed and may be branched. Thorns serve as defensive organs, e.g., *Duranta, Citrus*.
- **Phylloclade:** Stem or its branches become modified into flat, fleshy and green leaf-like structure with distinct nodes and internodes. These are known as Phylloclades or cladophylls. Some phylloclades also bear modified leaves in the form of scale or spines. Thus, it is an adaptation of plants to xerophytic conditions. Phylloclades serve as photosynthetic and storage organs; *Opuntia, Cocoloba, Euphorbia*.
- **Cladode:** These are phylloclades made of only one or two internodes of a branch. In *Asparagus* each cladode consists of a single internode and in *Ruscus* it is made of two internodes. Cladodes are flat and leaf-like and perform the function of foliage leaves.
- **Bulbils:** Bulbils are modified vegetative or floral buds arising in the axil of scale or foliage leaves. They grow into a new plant either while still attached to the parent plant or after their separation. Thus, bulbils are organs of vegetative propagation; e.g., *Agave, Lillian bulbiferum. Dioscorea (wild yam), Oxalis etc.*

Summary

Flowering plants exhibit enormous variation in shape, size, structure, mode of nutrition, life span, habit and habitat. They have well developed root and shoot systems. Root system is either tap root or fibrous. Generally, dicotyledonous plants have tap roots while monocotyledonous plants have fibrous roots. The roots in some plants get modified for

storage of food, mechanical support and respiration. The shoot system is differentiated into stem, leaves, flowers and fruits. The morphological features of stems like the presence of nodes and internodes, multicellular hair and positively phototropic nature help to differentiate the stems from roots. Stems also get modified to perform diverse functions such as storage of food, vegetative propagation and protection under different conditions.