B.Sc. Semester-II

Paper-II : PALAEOBOTANY & MORPHOLOGY OF ANGIOSPERMS

Topic: Root Morphology

By

Dr. Prashant Shahare

D. B. Science College, Gondia. India.

- *Tap root & adventitious roots*
- *Modifications for storage*
- *Respiration & reproduction.*

❖ *Tap root & adventitious roots*

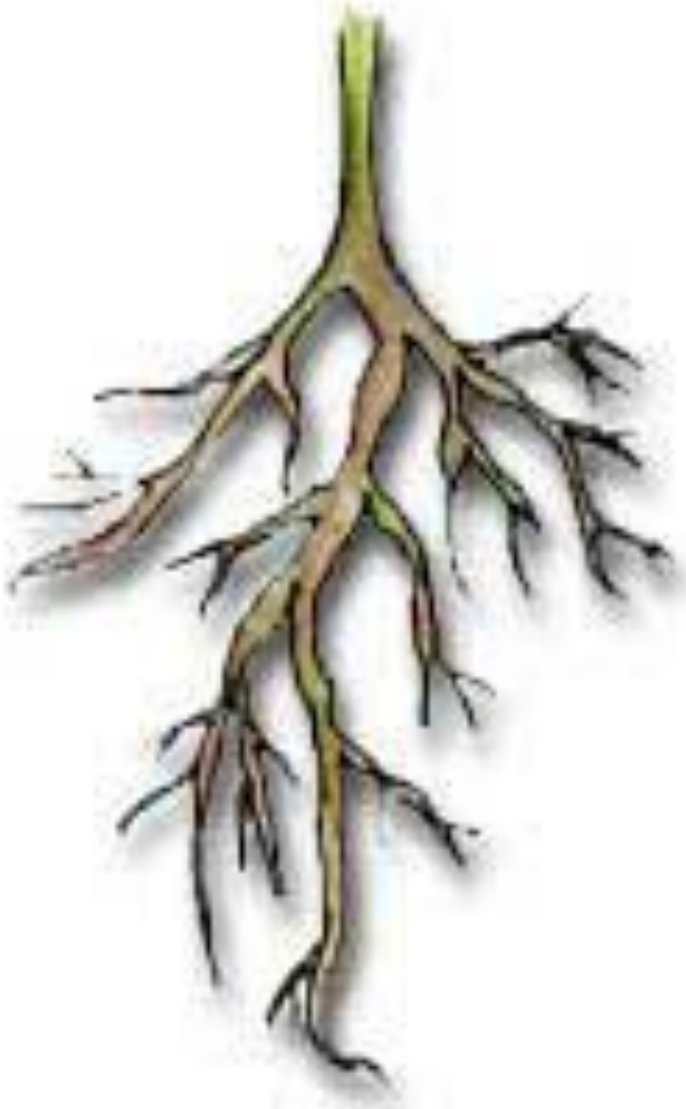
Tap root

1. It arises from the radicle of the embryo.
2. Primary root is persistent.
3. It is always underground.
4. There is a single main root.
5. It can be deep feeder or surface feeder.
6. Main root is very thick as compared to other roots.
7. Distinction of primary, secondary, tertiary and rootlets is quite conspicuous.

Adventitious root

1. It is formed either from places other than radicle or its branches i.e., stem, leaves.
2. Primary root is short-lived.
3. Adventitious root system can be both underground and above ground.
4. A number of larger roots arise in a cluster.
5. If underground, the adventitious root system is usually surface feeder.
6. All roots are generally fibrous.
7. There is no such distinction.

Taproot



Fibrous root

Root: Characteristics, Types, Structure and Functions:

1. Root is the descending or underground part of the plant axis.

2. Root is usually positively geotropic (i.e. grows downward into the soil) and positively hydrotropic (i.e. grows towards the source of water) but negatively phototropic (i.e. grows away from sunlight).

3. Root is usually cylindrical and non-green (i.e. lack chlorophylls), but sometimes green as in Trapa and Taeniophylum.

4. Root does not bear nodes, internodes, leaves or buds (exceptions are sweet potato, wood apple etc.)

5. The growing point of root tip is sub-terminal and protected by a root cap or calyptra.

6. Unicellular root hairs present just behind the root caps which increase the absorptive surface area of roots,

7. Lateral roots are endogenous in origin i.e. arise from pericycle of the main root..

Rootless Plants:
Many plants growing in aquatic habitats do not possess roots because there is little requirement for absorption of water and mineral salts, e.g., Wolffia, Utricularia, Myriophyllum, Ceratophyllum. In other aquatic plants, roots develop only for balancing (e.g., Lemna, Pistia) and fixation (e.g., Hydrilla).

Types of Roots:
On the basis of their origin, roots are of two types – tap root and adventitious root.

(a) Tap root:
On germination of a seed, the radicle elongates into primary root or true root or tap root. In dicot plants, the tap root is persistent and produces lateral roots such as secondary' roots, tertiary roots etc. All lateral roots arise in acropetal succession i.e. younger roots towards apex and older roots towards base. The tap root and its branches constitute the tap root system.

(b) Adventitious root:
These are the roots that grow from any part of the plant other than radicle. In monocot plants, the tap root is short lived and soon replaced by adventitious roots. A group of adventitious roots and their branches constitute adventitious root system.

Modification of Roots:
The structural and functional changes in the roots to perform a special function according to the need of the plant are called as modification of roots.

On the basis of their origin, the adventitious roots are of following three types:

i. Fibrous roots:

These are a cluster of equally prominent thread-like roots that develop either from the base of stem (e.g., rice, wheat, maize, onion etc.) or from the nodes of horizontal stem (e.g., grass, wood sorrel etc.)

ii. Foliar roots:

They arise from petiole (e.g., Pogostemon, rubber plant etc.) or veins of leaf due to some injury. These can also be induced by application of hormones. Some foliar buds can produce foliar roots, e.g., Bryophyllum, Begonia etc.

iii. True adventitious roots:

They arise from the nodes and internodes of the stem, e.g., Prop roots of banyan, stilt roots of sugarcane, clasping roots of money plant and roots from the stem cuttings.

Foot Structure:

A typical root can be differentiated into five regions. From apex to base they are:

(a) Root Cap (Calyptra):

It is a cap like protective structure of the growing root tip. In Pandanus (screwpine) multiple root caps present while in aquatic plants (Pistia, Eichhornia, Lemna) root pockets present instead of root cap.

Function:

(i) Protects root meristem,

(ii) Secrete mucilage that help tender root to penetrate the hard soil,

(iii) Helps in perception of gravity (Darwin, 1880),

(iv) Root packet s functions as balances.

(b) Growing point or Meristematic Zone:

It is about 0.25-1.0 mm long, lies just behind the root cap and thus sub-terminal in position. Its shape is like an inverted concave dome of cells. The central rarely dividing cells are called quiescent centre.

Function:

Root meristem adds cells to root cap and the basal region of the root.

(c) Zone of elongation:

It is about 1-10 mm long and lies just behind the meristematic zone. As the name implies, it is the site of rapid and extensive cell elongation. This zone increases length of the root. The external cells can absorb water and minerals from the soil.

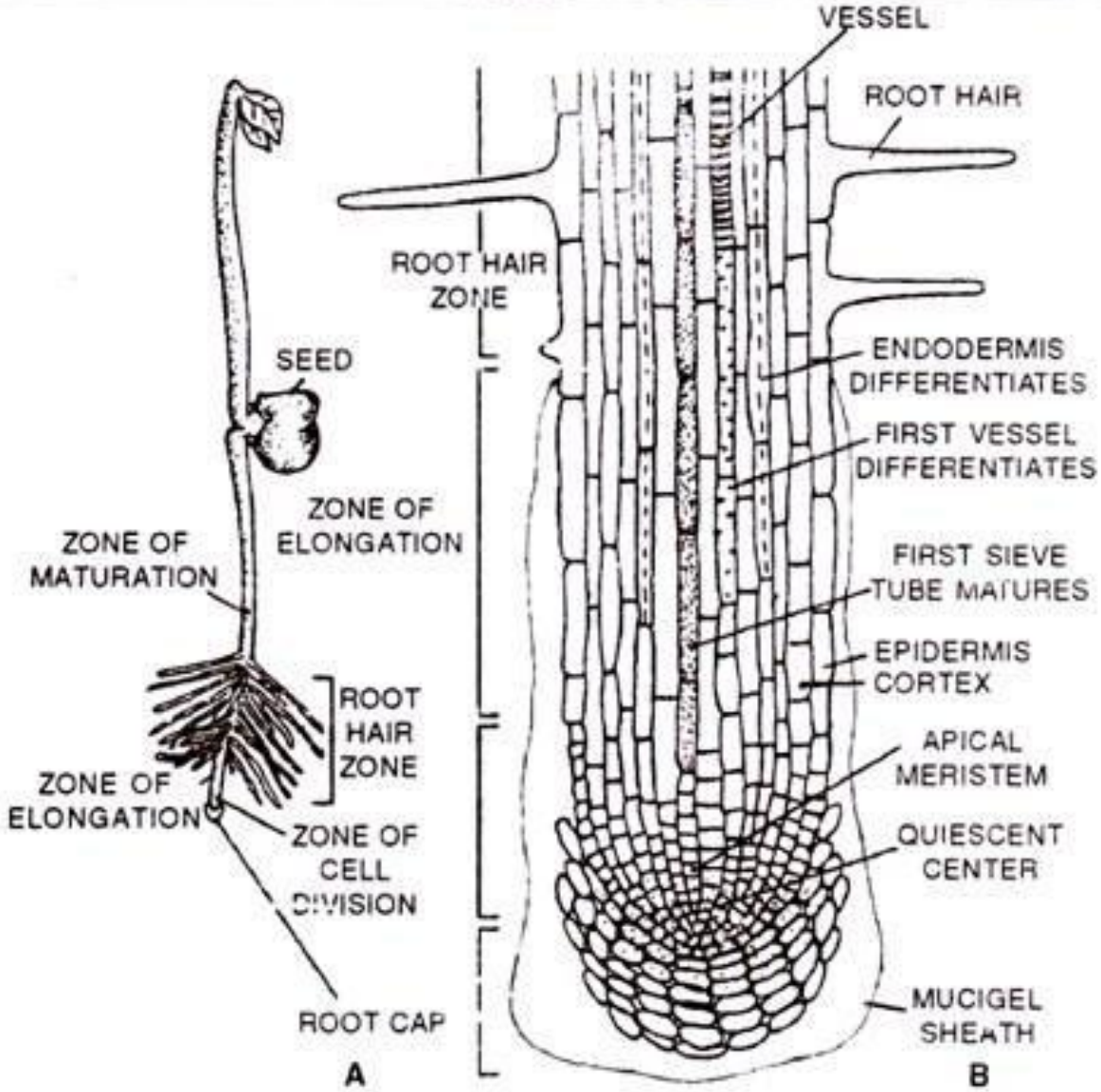


Figure 2.1 A, germinating seed showing a young root ; B, longitudinal section of young root showing different zones.

(d) Root hair Zone or Zone of differentiation:

It is about 1 -6 cm long. It is the zone where cell differentiate to form epiblema, cortex, endodermis, pericycle, xylem and phloem. Many cells of epiblema elongate to form unicellular root hairs. As the root grows, new root hairs develop and older one shrivel and sloughed off.

Function:

Root hairs increase the absorptive surface area of root.

(e) Zone of maturation:

In constitute the major portion of the root. The cells attain maturity when they reach this zone.

Function:

(i) Lateral roots may emerge from pericycle

(ii) Radial differentiation of tissues causes' secondary growth in dicots.

Functions of Roots:

Roots perform two kinds of functions — Primary and Secondary. The primary functions are performed by all kinds of roots, and they are structurally adapted to per-form these functions. The secondary functions are specialized one and are performed only by those roots which are modified accordingly.

The primary functions of roots are:

1. Anchorage or fixing the plant firmly to the soil so that they are not easily uprooted.
2. Absorption and translocation of water and minerals from the soil to the aerial parts of the plant.
3. Prevent soil erosion by holding the soil particles.

In many plants, roots are modified to serve many secondary functions like food storage, mechanical support and various physiological activities other than absorption.

Tap Root System: Definition and Types

1. Definition of Tap Root System
2. Types of Tap Root System
3. Modification
4. Modification of Tap Root Branches.

Definition of Tap Root System:
It is a mass of roots which develops from the radicle of the embryo. It consists of a tap root, secondary roots, tertiary roots and rootlets (Fig. 5.5).

The radicle itself grows up directly into the main or primary root. The persistent primary root is known as tap root. It is usually the most prominent, thickest and largest of all. Tap root becomes gradually narrow towards the tip. Secondary and tertiary roots are respectively the branches of first and second order.

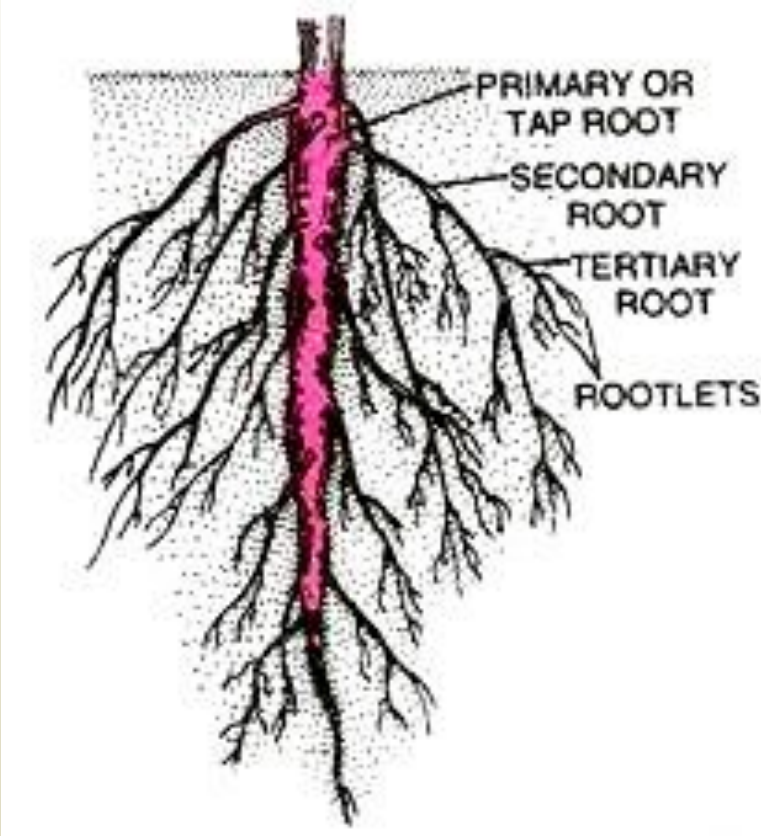


Fig. 5.5. Typical or racemose tap root.

They are formed in acropetal succession (youngest towards growing point and oldest towards the base of the parent root). In orientation the tap root is vertical, secondary roots are horizontal or oblique while the tertiary roots run in different directions. Rootlets are the ultimate root branches. They bear root hairs for absorption.

Types of Tap Root System:

Tap root system is of two types— deep feeder and surface feeder. Deep feeder tap root system has an elongated tap root which penetrates the deeper layers of the soil. It is mostly met in trees. Deep feeder tap root system is also called racemose tap root system.

In surface feeders the tap root does not elongate very much. The secondary roots spread to a greater extent, mostly horizontal near the soil surface. Such a system is also named as cymose tap root system. The cymose or surface feeder tap root system of some annual plants consists of thin fibrous roots. It may be called fibrous tap root system.

Modification of Tap Root System:

The tap root becomes swollen and fleshy with the stored food. The secondary roots remain thin. Hypocotyl (embryonic region between cotyledons and radicle) may also join the tap root in storing food. Stem is reduced and discoid in the beginning and bears radical leaves.

Depending upon the shape, the fleshy tap roots are of the following types:

(i) Conical:

Here the fleshy tap root resembles a cone, that is, the thickest towards base and gradually tapering towards the apex (Fig. 5.6 A). Many thread-like secondary roots are found throughout the length of conical fleshy root, e.g., Carrot (Daucus carota).

(ii) Fusiform:

The fusiform fleshy root is like a spindle, that is, thickest roughly in the middle and narrow towards both its base and apex, e.g., Radish (Raphanus sativus, vern. Mooli). The fusiform root of Indian Radish consists of swollen hypocotyl near the base only and swollen tap root in the remaining region (Fig. 5.6 B).

The latter possesses thin and thread-like secondary roots. In European Radish (Fig. 5.6 C) the tap root forms only the terminal tapering fleshy part of the root. The middle and the basal fleshy parts are formed by the hypocotyl.

(iii) Napiform:

The fleshy root is very thick at the base and is almost spherical. It suddenly thins out towards the apex (top-like), e.g., Turnip (Brassica rapa, vern. Shalgam) and Beet (Beta vulgaris, vern. Chakander). In Turnip most of the swollen part is hypocotyl. The tap root occurs only towards the narrow pointed apical region which also bears threadlike secondary roots (Fig. 5.6. D). In Beet both the tap root and hypocotyl are swollen.

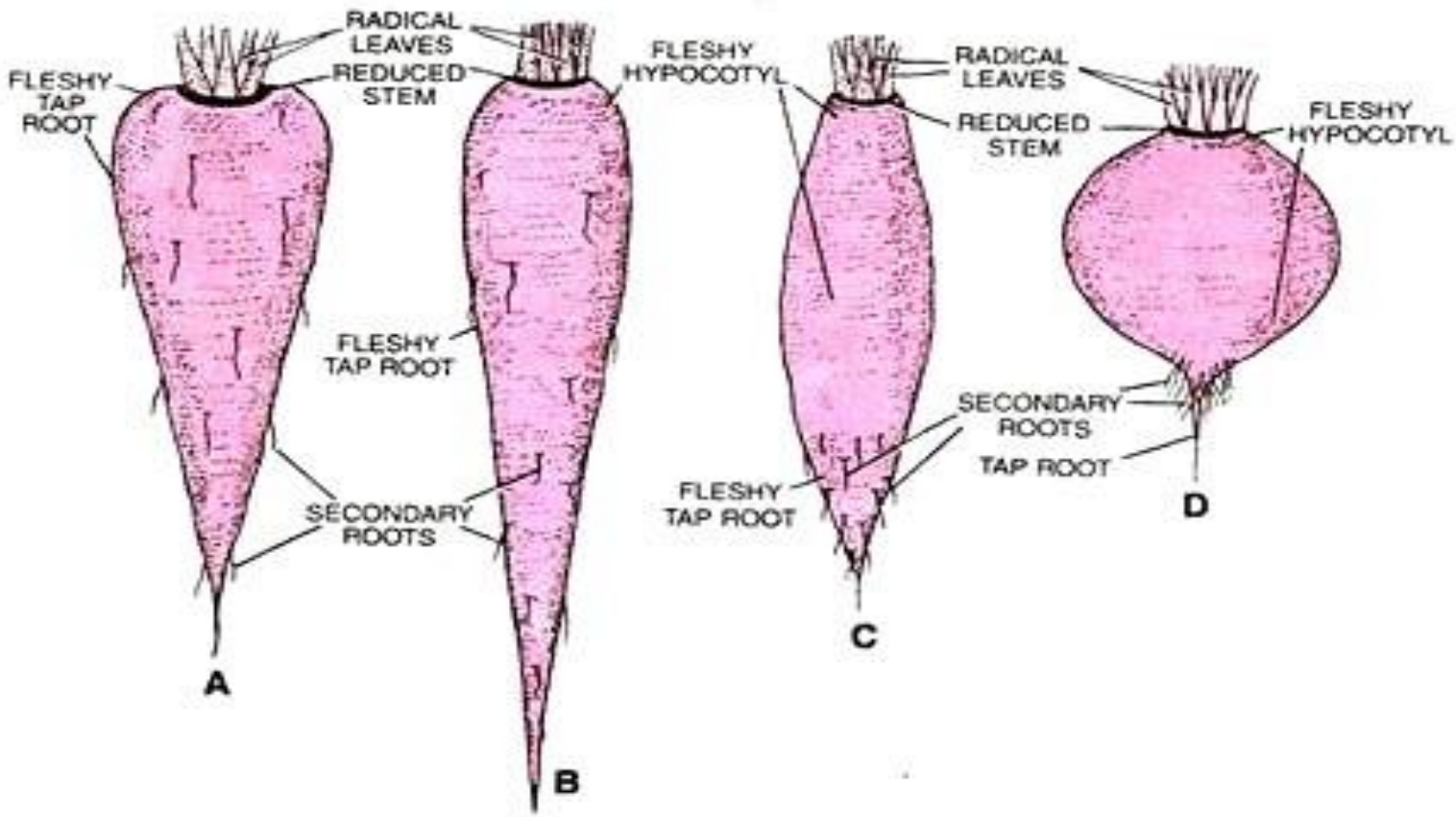


Fig. 5.6. Fleshy tap roots. A, conical fleshy tap root of Carrot (**Gaajar**). B, fusiform root of Indian Radish (**Mooli**). C, fusiform root of European Radish. D, napiform fleshy tap root of Turnip (**Shalgam**).

(iv) Tuberous Roots:

They are those thickened tap roots which do not assume any definite form, e.g., Mirabilis jalapa (Four O' Clock) (Fig. 5.7), Trichosanthes (vem. Parwal), Echinocystis lobata. In Echinocystis lobata the tuberous root is lobed and weighs as much as 22 kg.

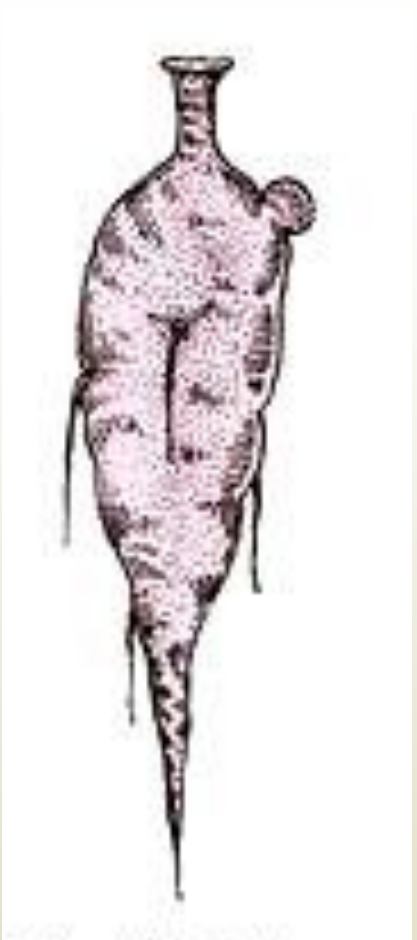


Fig. 5.7. Tuberous root of *Mirabilis*.

Modification of Tap Root Branches:

i. Nodulated (Tuberculate) Roots:

They occur in papilionaceous (leguminous) plants like Pea (Pisum sativum), Gram (Cicer arietinum), Groundnut (= Peanut, Arachis hypogea), Methi (Medicago falcata), Soy Bean (Glycine max), Alfalfa, etc.

The secondary, tertiary roots and sometimes the primary root develop numerous small or large irregular swellings called root nodules or tubercles (Fig. 5.8). The root nodules enclose millions of minute nitrogen fixing bacteria of the genus Rhizobium (e.g., R. leguminosarum).

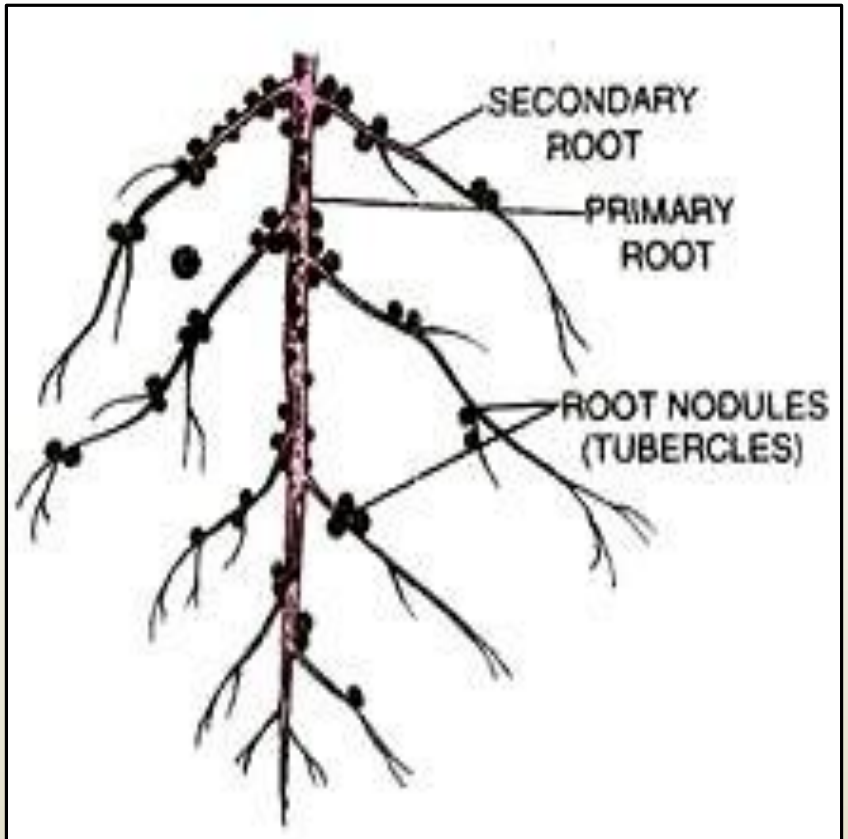


Fig. 5.8. Nodulated root of a legume.

These bacteria pick up the free nitrogen present in the soil atmosphere and convert it into organic compounds of nitrogen. The property of converting free nitrogen into nitrogenous compounds is called nitrogen fixation.

Some of the nitrogenous compounds are taken up by the legume in return for food and shelter. Therefore, both the bacteria and the leguminous plant are benefitted by their association. Such a mutually beneficial relationship is called reciprocal symbiosis or mutualism.

ii. Pneumatophores (= Aerophores = Respiratory Roots, Fig. 5.9): They are breathing or respiratory roots which are found in plants growing in mangroves or saline swamps near the sea shore, e.g., Avicennia, Sonneratia, Heritiera (vern. Sundri). The plants possess spreading horizontal cable roots. The horizontal roots develop upright aerial roots or pneumatophores at short intervals. Short downwardly growing absorbing roots are formed from the bases of pneumatophores.

Pneumatophores or respiratory roots come out of water and pick up oxygen for perspiration of roots. Excess CO_2 is also given out. For this they bear small pores called lenticels (= pneumathodes) near their tips. The remaining surface of pneumatophores is covered by cork.

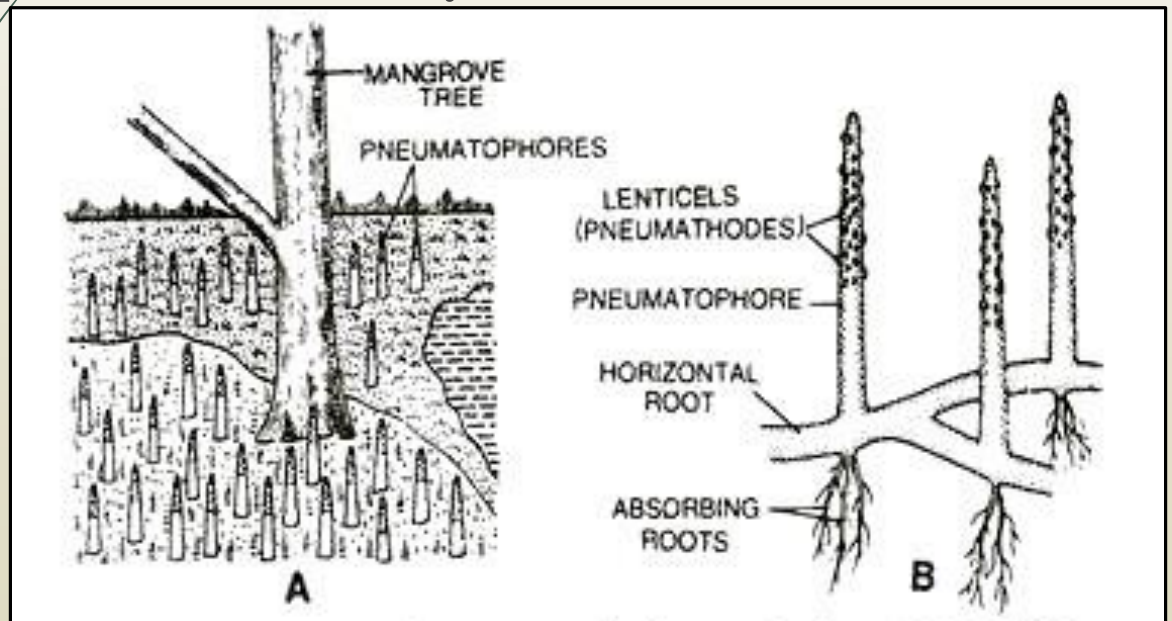


Fig. 5.9. Pneumatophores or respiratory roots. A, mangrove tree with pneumatophores coming out of mud. B, pneumatophores with lenticels.

1. Definition of Adventitious Root System

2. Typical Adventitious Roots

3. Modification.

Definition of Adventitious Root System:

Roots that grow from any part of plant other than the radicle or its branches are called adventitious roots (L. adventitious— extraordinary). They branch like the tap root. A mass of adventitious roots along with their branches constitute an adventitious root system. Adventitious root system may be underground or aerial. They generally develop from stem nodes, intermodals, leaves, etc.

Horizontal stem of creepers often develop adventitious roots from the nodes (e.g., Grass, Wood Sorrel). Branch cuttings and leaf cuttings (e.g., Rose, Sugarcane, Tapicca, Sansiviena) develop adventitious roots when placed in soil. In Coleus, the cuttings develop adventitious roots on being partially immersed in water. Hormones also induce development of adventitious roots.

Typical Adventitious Roots:

Fibrous Roots:

They are underground roots which arise in groups from the nodes of an horizontal stem (e.g., Grass, Fig. 5.10). The main roots are of equal length. They give off small branches. Both the main root and their branches are thin and thread-like. Therefore, they are called fibrous roots. The fibrous roots do not penetrate deep in the soil. They remain near the soil surface and are called surface feeders.

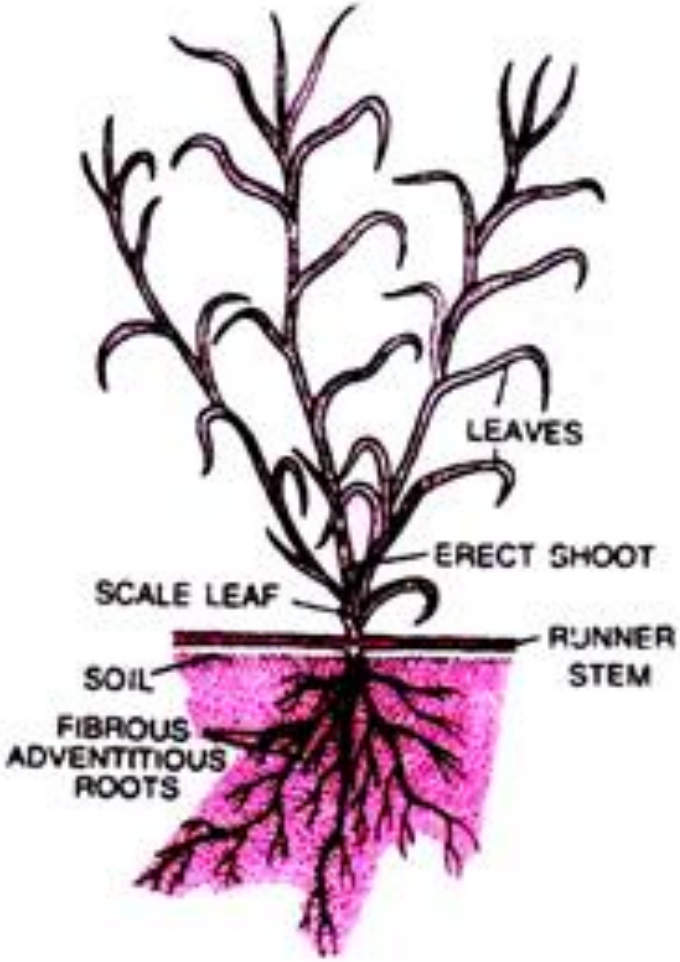


Fig. 5.10. Fibrous adventitious roots of plant.

Modifications of Adventitious Roots:

Storage of Food:

1. Fleshy Adventitious Roots:

The adventitious roots become thick and fleshy due to the storage of food.

They are of several types depending upon the shape and place of the swollen part:

(i) Tuberous Root or Single Root Tubers:

The swollen roots do not assume a definite shape. They occur singly, e.g., Sweet Potato (Ipomoea batatas, vern. Shakar Kandi, Fig. 5.11 A).

(ii) Fasciculated Fleshy Roots:

The swollen roots or root tubers occur in clusters. In Dahlia they lie at the base of the stem (Fig. 5.11 B) while in Asparagus the fasciculated fleshy roots occur at intervals on the normal roots (Fig. 5.11 C).

(iii) Palmate Roots:

The fleshy roots are thickened like the palm of human hand. They similarly possess finger-like outgrowths, e.g., Orchis (Fig. 5.11 D).

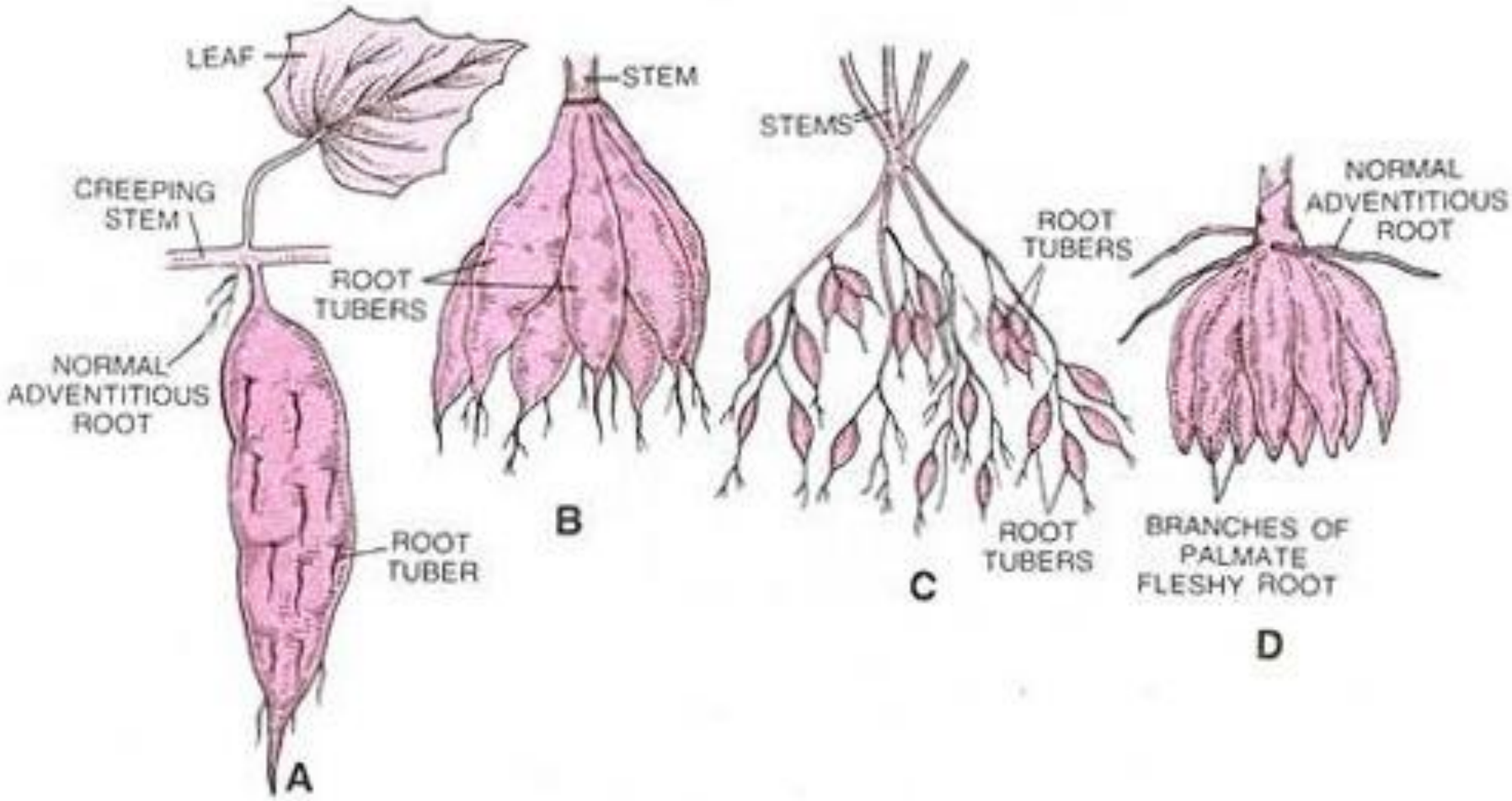


Fig. 5.11. Fleshy adventitious roots. A, root tuber of Sweet Potato (Shakar Kandi); B, fasciculated root of *Dahlia*; C, fasciculated root of *Asparagus*; D, palmate root of *Orchis*.

(iv) Nodulose Roots:

In nodulose roots the swellings occur only near the tips, e.g., Curcuma amada (Mango Ginger, Fig. 5.12 A), Maranta (Arrow-root), Turmeric.

(v) Moniliform or Beaded Roots:

The roots are swollen at regular intervals like beads of a necklace, e.g., Basella (Portulaca) rubra (Indian Spinach, vern. Kulfa), Momordica (Fig. 5.12 B), some grasses (Fig. 5.12 C).

(vi) Annulated Roots:

These thickened roots possess a series of ring-like outgrowths or swellings, e.g., Cephaelis or Psychotria (Ipecac, Fig. 5.12 D).

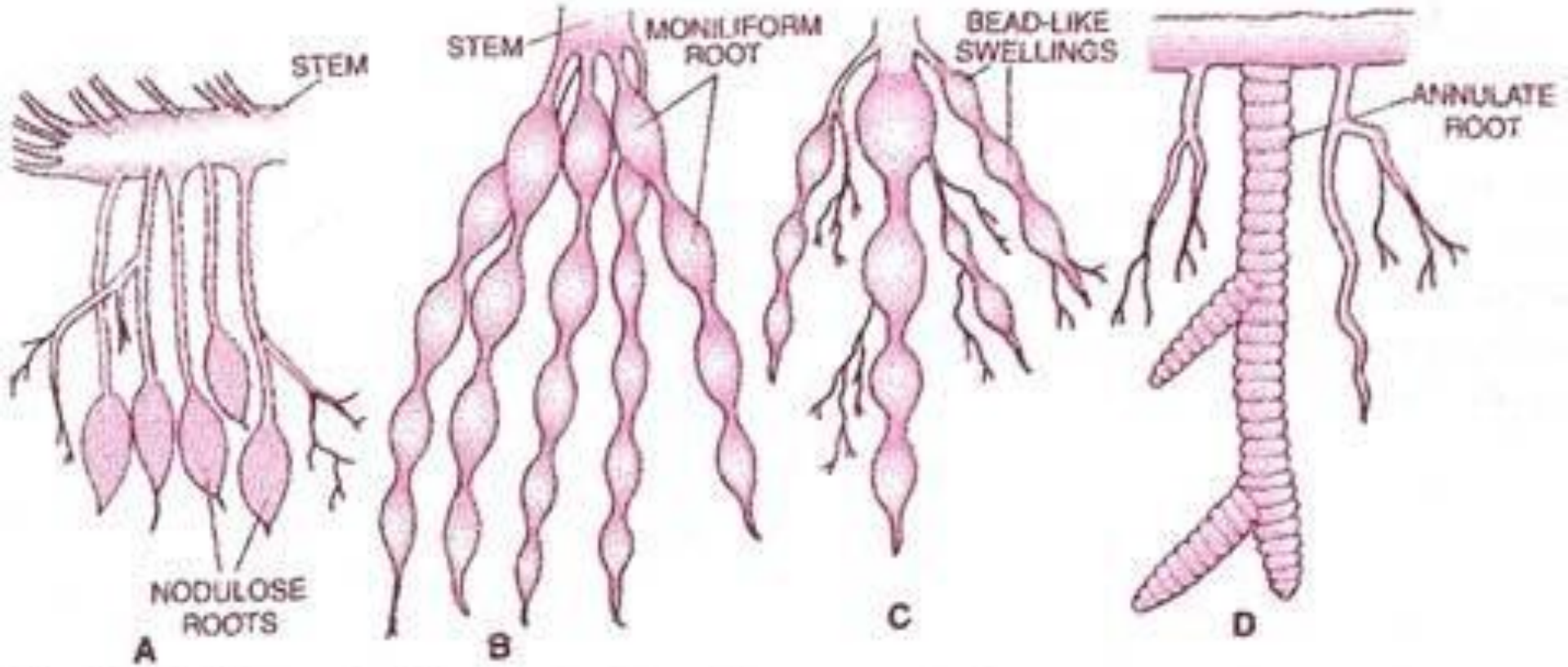


Fig. 5.12. Fleshy adventitious roots. A, nodulose roots of *Curcuma amada* (**Mango Ginger**); B, moniliform roots of *Momordica*; C, moniliform roots of a grass. D, annulated root of Ipecac.

Mechanical Support:

2. Prop or pillar (Fig. 5.13):

They are thick pillar-like adventitious roots which grow from and support heavy horizontal branches of Banyan tree. Initially the roots are aerial and hygroscopic. They become red in the moistened state. Root caps are present at their tips.

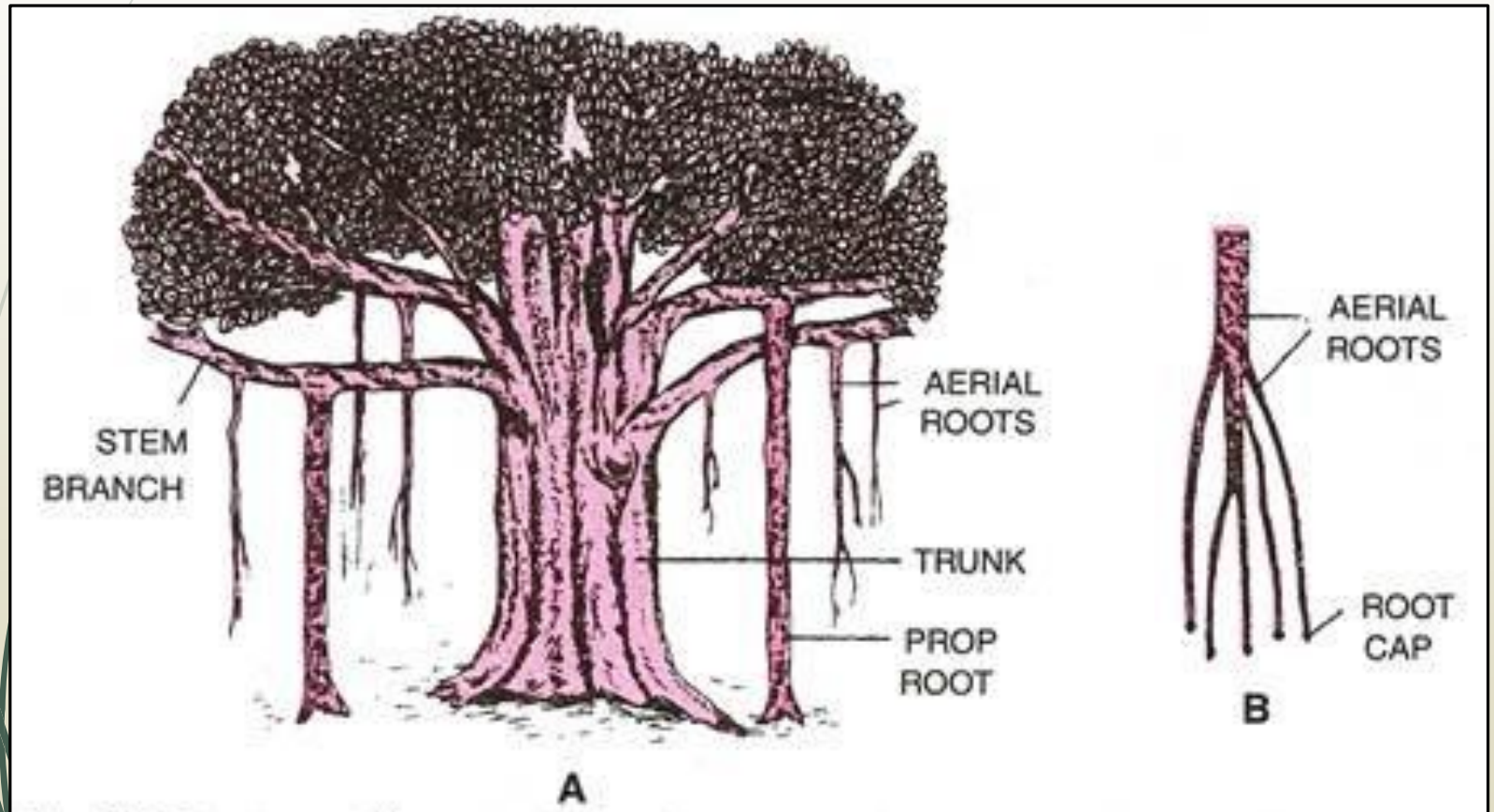


Fig. 5.13. A, prop or pillar roots of *Ficus bengalensis* (banyan tree); B, hanging aerial roots.

As the roots reach the soil, they become thick and pillar-like. The main trunk of the tree often becomes indistinguishable. Its death will not affect the growth of the tree because the crown is supported and nourished by prop roots.

A Banyan tree (Great Banyan Tree) growing in Indian Botanic Gardens, Howrah (Indian Botanical Gardens, Kolkata) has 1775 prop roots. Its main trunk has decayed. The crown of the tree has a circumference of 404 m.

The tree is over 200 years old. The largest Banyan tree grows in Thimmamma Marrimanu village of Anantapur district in Andhra Pradesh. It is spread over an area of 5.2 acres. Two other famous trees are at Adayer (=Adiyar) in Chennai and Ketohalli village near Bangalore. Rhizophora a mangrove plant also possesses prop roots on which lenticels occur.

3. Stilt Roots (Brace Roots):

They are short but thick supporting roots which develop obliquely from the basal nodes of the stem. In Sugarcane, Maize, Pennisetum and Sorghum the stilt roots grow in whorls. After penetrating the soil, they develop fibrous roots which hold the soil firmly to provide support to the long and narrow jointed and unbranched stems (culms) like the ropes of pole or tent (Fig. 5.14).

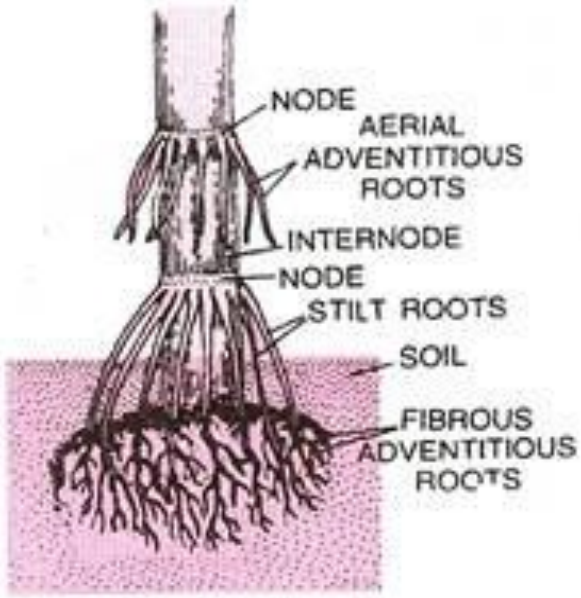


Fig. 5.14. Stilt roots of Maize.

Additionally they allow for better absorption of water and mineral salts. In Screwpine or Pandanus odoratissimus the stilt roots develop only from the lower surface of the oblique stem to provide support. Being one sided, they are also called prop roots. The supporting roots of Pandanus bear much folded multiple root caps (Fig. 5.15).

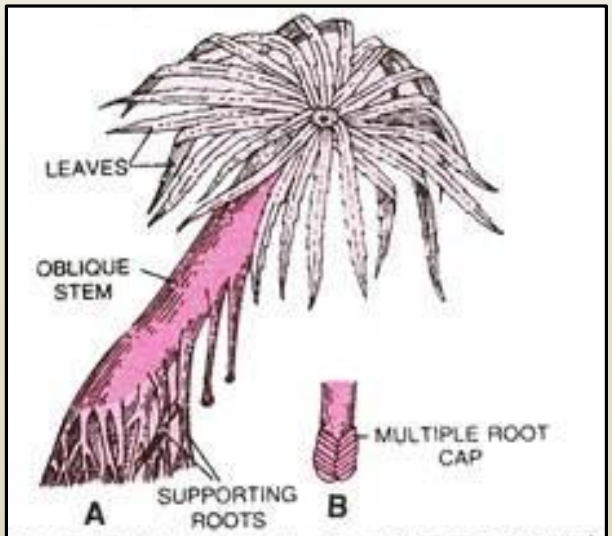


Fig. 5.15. *Pandanus* showing oblique stem and supporting roots having multiple root caps.

4. Clinging or Climbing Roots:

These are non-absorptive adventitious roots which are found in climbers. They may arise from the nodes (e.g., Tecoma, Betel), intemodes (Ficus pumila) or both (e.g., Ivy). The clinging roots penetrate the cracks or fissures of the support.

They hold the support firmly by forming claws (e.g., Tecoma), swollen discs or secreting a sticky juice at their tips (e.g., Ivy). Examples are found in juvenile stage of Ivy (Hedera nepalensis, Fig. 5.16A), Pothos (Money Plant, Fig. 5.16 C), and Betel (vern. Paan, Piper. Floating betle, Fig. 5.16 B), Black Pepper (Piper nigrum), Tecoma (Fig. 5.16 D).

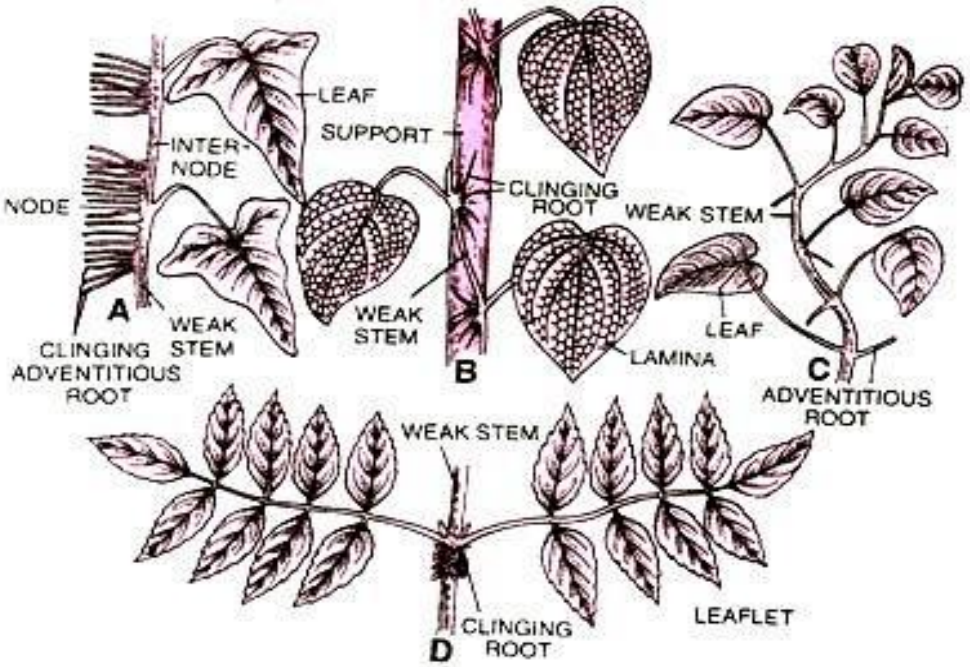


Fig. 5.16. Climbing or clinging roots. A, *Hedera nepalensis* (Ivy, juvenile stage). B, Betel (*Piper betle*, **Paan**). C. *Pothos* (Money Plant). D. *Tecoma* (*Campsis*) *radicans* (Trumpet Flower).

Vital Functions

5. Assimilatory Roots:

They are green roots which are capable of photosynthesis. In Trapa (Water Chestnut, vern. Sanghara, Fig. 5.17) the green assimilatory roots are submerged like other roots.

They develop from the stem nodes and are highly branched to increase photosynthetic area. Photosynthetic roots are also found in Tinospora (vern. Gilo, Gillow, Gurcha, Fig. 5.18). They are like green hanging threads which arise from the stem nodes during the rainy seasons and shrivel during drought.

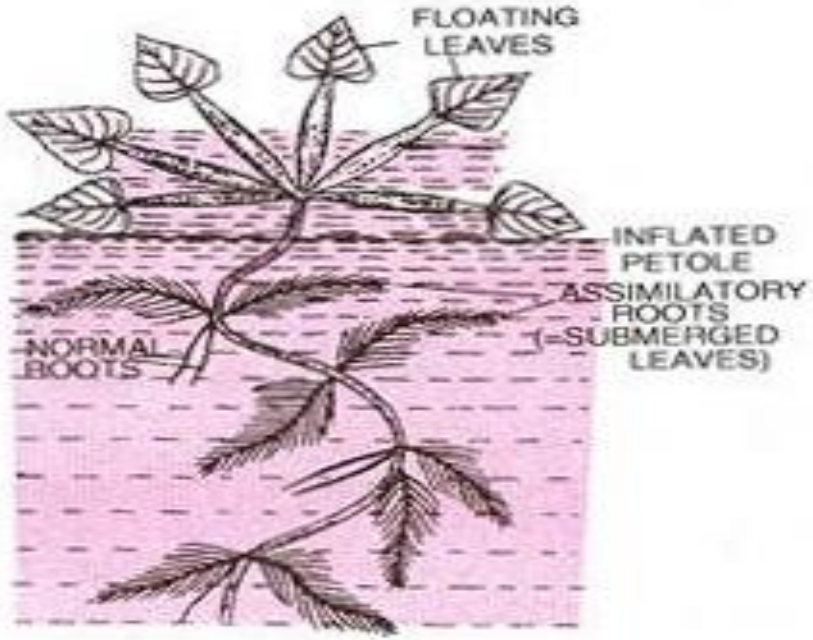


Fig. 5.17. *Trapa* showing assimilatory roots and inflated petioles.

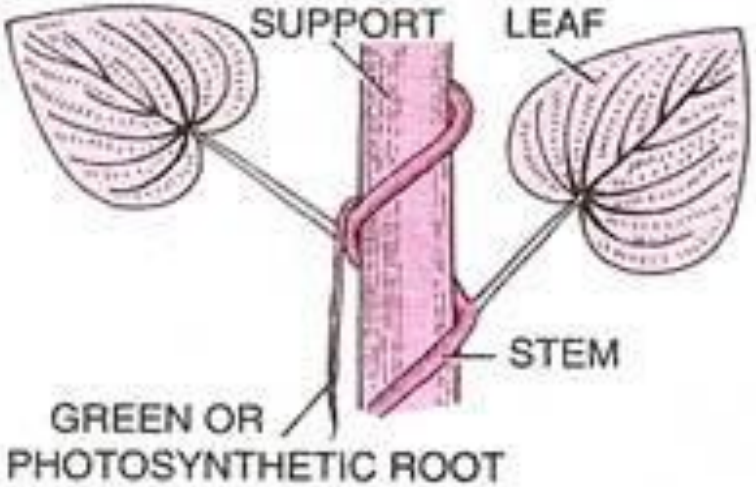


Fig. 5.18. Photosynthetic or assimilatory root of *Tinospora*.

6. Haustorial or Parasitic Roots:

The roots occur in parasites for absorbing nourishment from the host. Hence, they are also called sucking roots or suckers. Cuscuta (Dodder, vem. Amarbel or Akashbel, Fig. 5.19) has nongreen stems and scale leaves. It does not have any connection with the soil. The parasite sends haustorial roots into the host (e.g., Duranta, Zizyphus, Citrus, Acacia, Clerodendrum).

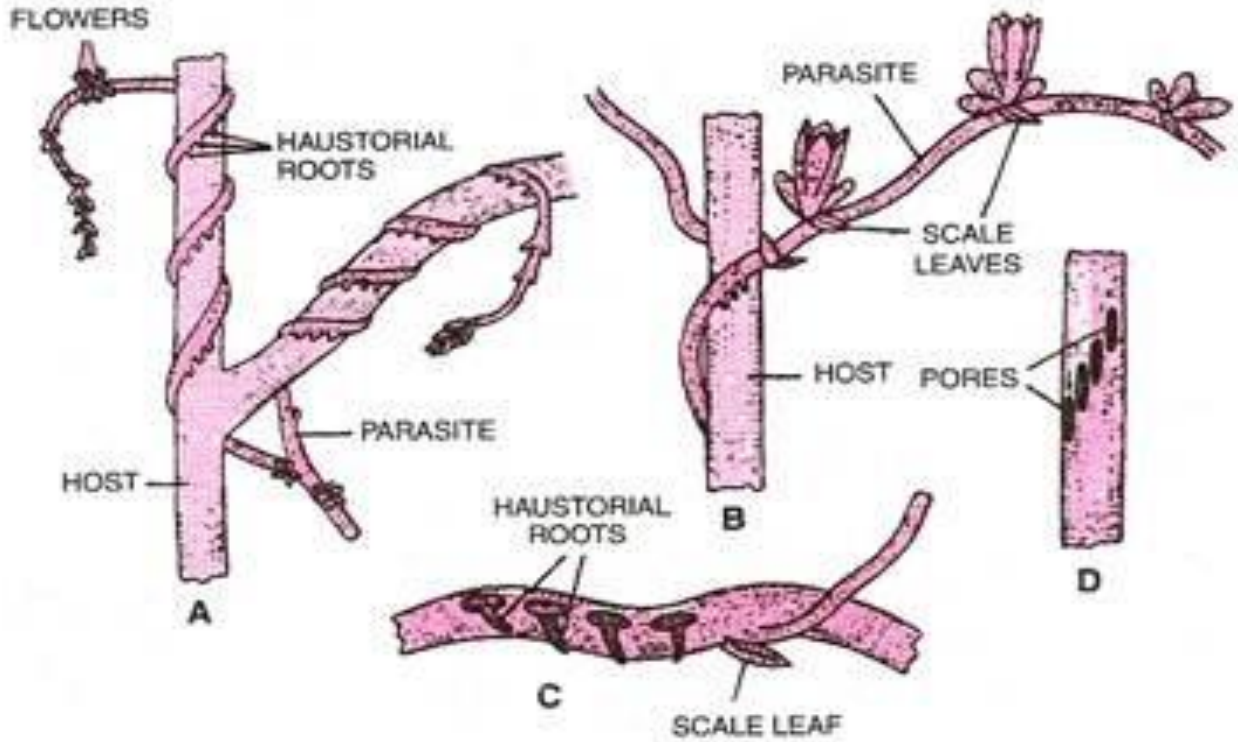


Fig. 5.19. *Cuscuta*. A, parasite on host. B, part of *Cuscuta* on host showing flowers and haustoria. C, stem of *Cuscuta* showing haustoria. D, stem of host showing pores or holes through which haustoria had entered.

They make connections with both xylem (water channel) and phloem (food channel) of the host absorbing both water and food (Fig. 5.20). The partial parasite of Viscum (Mistletoe) is green. It sends a primary haustorium into the host from which secondary haustoria arise making connections with the xylem channels of the host for absorbing water and mineral salts only.

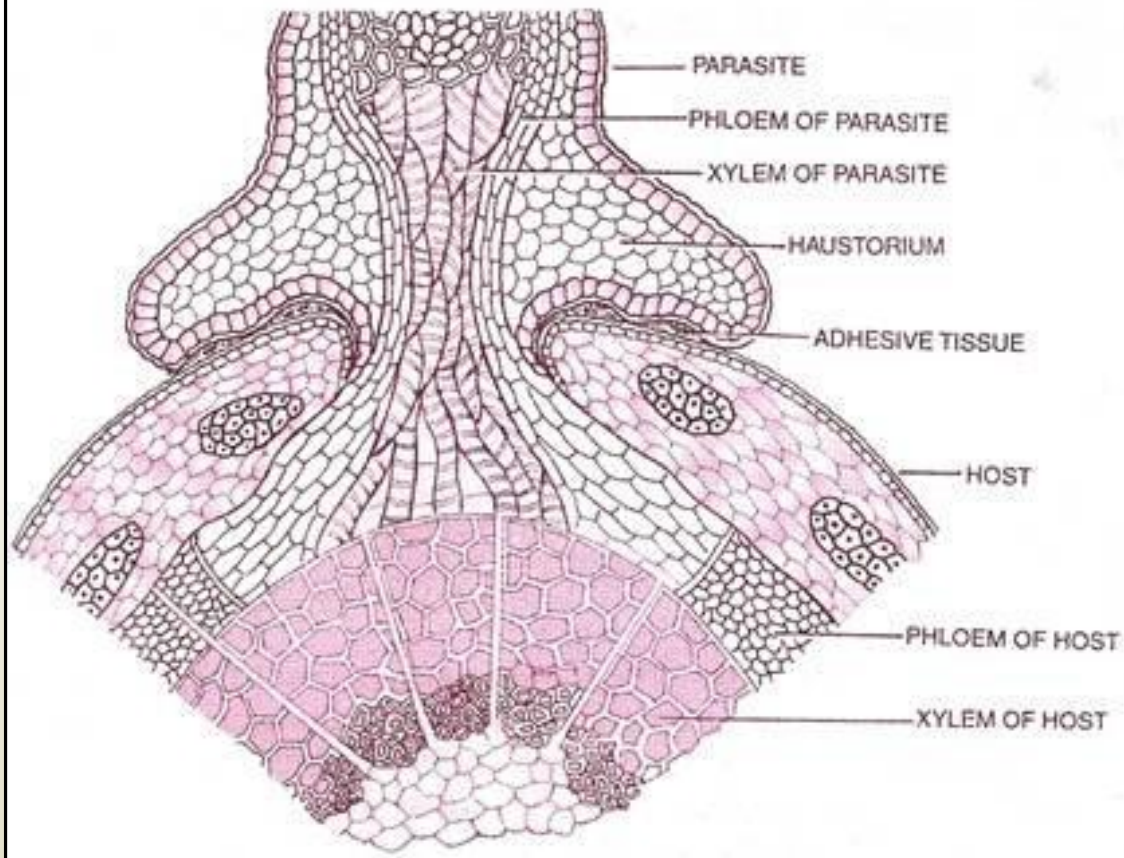


Fig. 5.20. Haustorial connection between *Cuscuta* and host.

7. Epiphytic or Aerial Roots (Hygroscopic Roots, Fig. 5.21):

The roots occur in epiphytes (plants living on the surface of other plants for shelter and space only; hence also called space parasites). Epiphytes bear three types of roots — clinging (for fixation), absorbing (for absorbing mineral salts and moisture from dust collected on bark) and hygroscopic aerial or epiphytic.

The aerial or epiphytic roots are thick, irregular and hang down in the air. They do not have root caps and root hair. Instead they possess a covering of dead spongy tissue known as velamen. With the help of velamen, the epiphytic roots are able to absorb water from moist atmosphere, dew and rain, e.g., Vanda, Dendrobium.

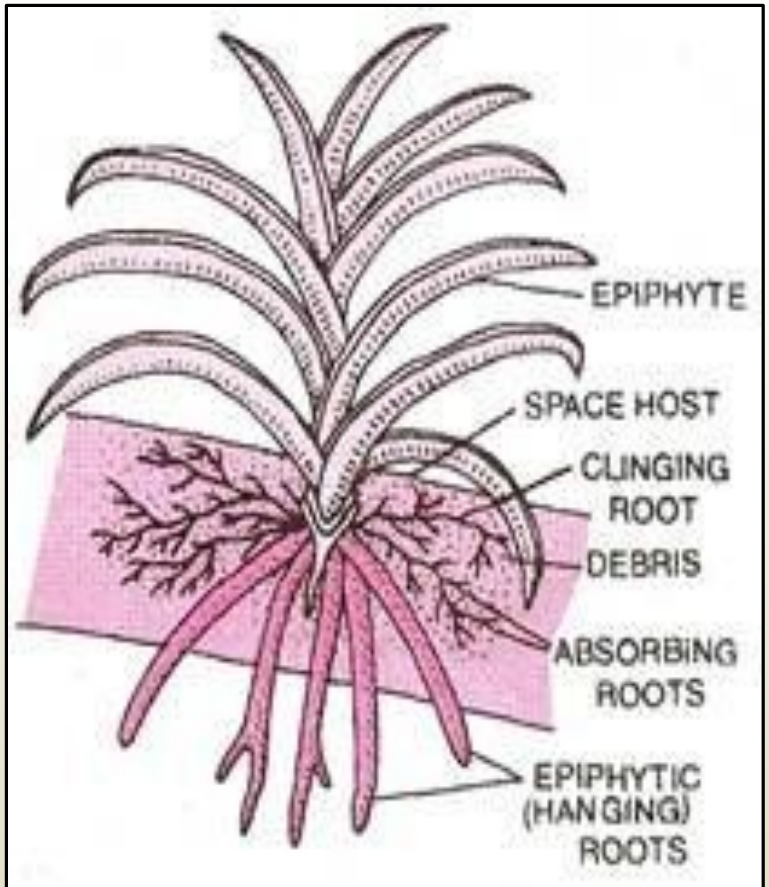


Fig. 5.21. *Vanda* showing thicker epiphytic roots, and narrow clinging and absorbing roots.

8. Floating Roots (Root Floats, Fig. 5.22): They occur in Jussiaea (= Ludwigia). Here a number of adventitious roots arise from each node. Some of them store air, become inflated, project out of water, make the plant light and function as floats. The root floats help the plant in floating on the surface of water. They also help in gaseous exchange (hence also respiratory roots).

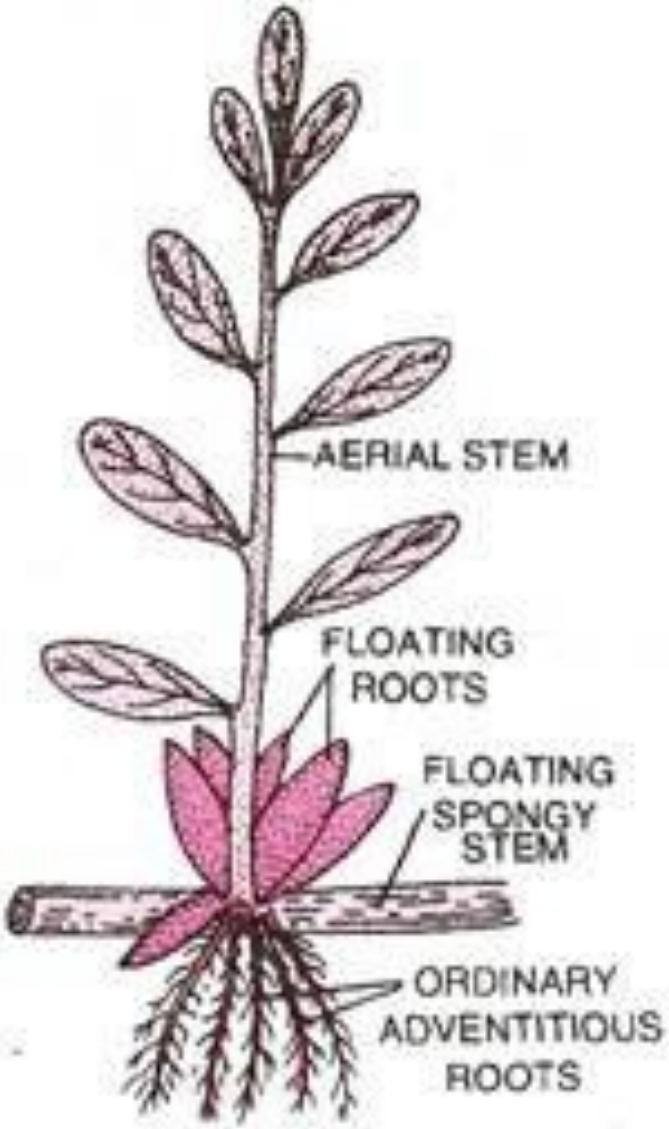


Fig. 5.22. Floating roots of *Jussiaea* (= *Ludwigia*).

9. Reproductive Roots:

These adventitious roots are generally fleshy and develop adventitious buds. The adventitious buds can grow into new plants under favourable conditions. Such roots are called reproductive roots, e.g., Sweet Potato (vern. Shakar Kandi, Fig. 5.23), Dahlia.

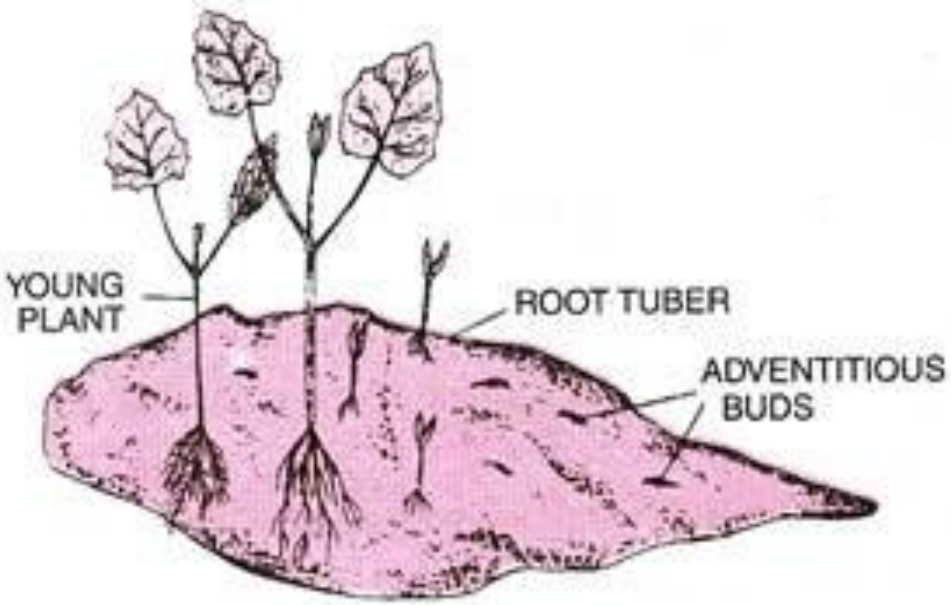


Fig. 5.23. Reproductive root of Sweet Potato with sprouts.

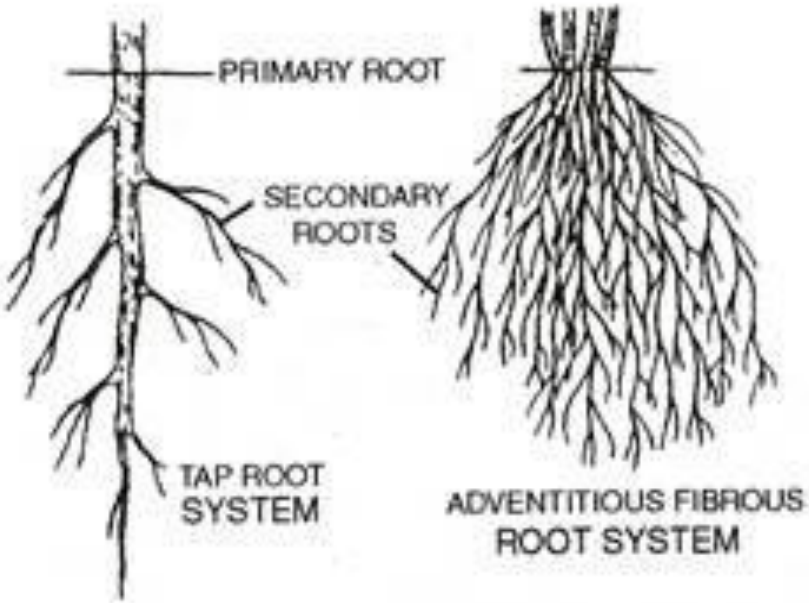


Fig. 5.24. Tap and adventitious root systems.

Thank You….!