TRANSPORT IN PLANTS

There are two organs involved in transporting of materials in plants i.e. the xylem and the phloem.

The xylem

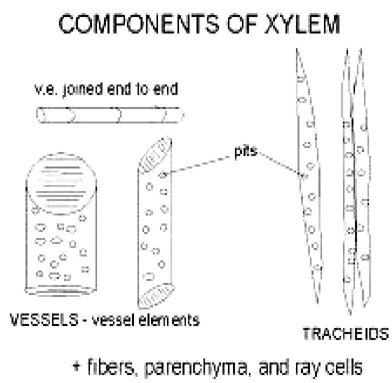
a. **Function**
The xylem transports water and dissolved mineral salts

b. **Structure**
It consists of dead cells

The cells are strengthened by deposition of **lignin** their cell walls i.e. they are said to be **lignified**

There are two types of xylem tissues; the

i. Xylem vessels
ii. Xylem tracheids



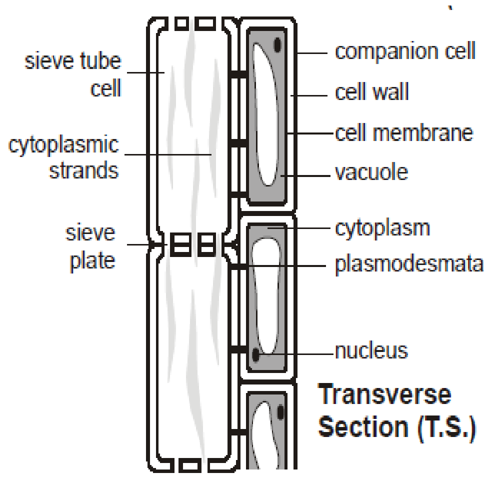
The phloem

a. **Function**
The xylem transports manufactured food throughout the plant

b. **Structure**
It consists of living cells. The living cells consist of the sieve tube and the companion cells.

The sieve tubes are channels of food whereas the companion cells provide the necessary energy for transporting the food.

Structure of the phloem



Differences between xylem and phloem

Xylem	Phloem
It consists of dead cells	It consists of living cells
The cells have lignified walls	No lignified walls
Do not have companion cells	Have companion cells
Do not have microfilaments	Have cytoplasmic filaments
Consist of open ended vessels and tapering vessels	Consists of sieve tubes with the sieve plates perforated with sieve pores

MOVEMENT OF MATERIALS INTO A PLANT

Water is absorbed from the soil into the plant by roots. The region of the root responsible for this function is the root hair.

Internal structure of the root hair

The root hair is made up of slender and flexible cells surrounded by a thin permeable membrane. The membrane surrounds a concentrated cell sap containing a lot of mitochondria.

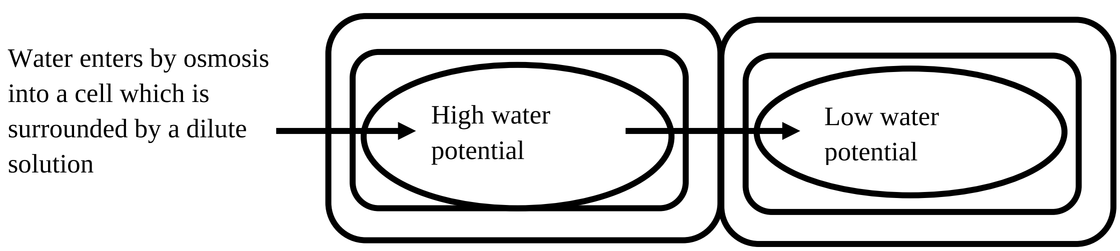
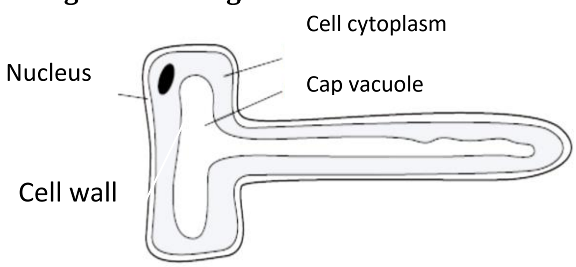


Diagram showing a root hair

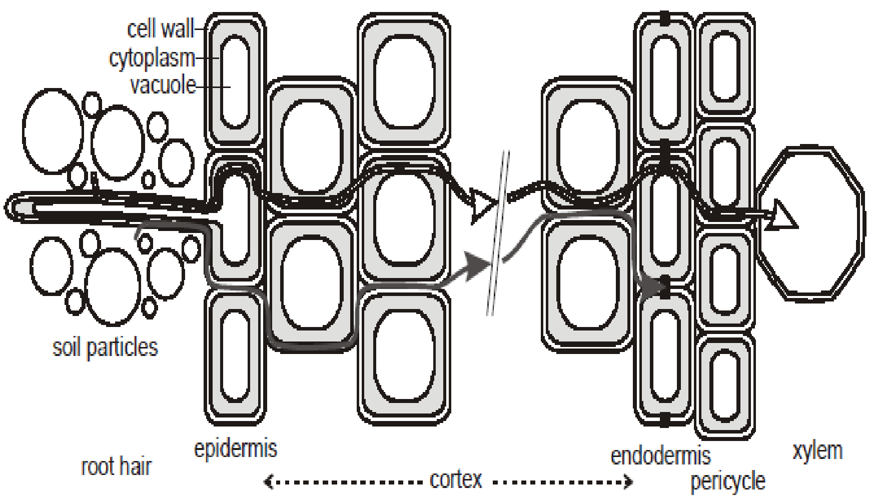


Absorption of water by plant roots

Root hairs are surrounded by soil particles containing a film of water. The cell sap inside the root hair cells is more concentrated as compared to the soil water. Water from the dilute soil water will move into the root hair cells by osmosis. The water entering the root hairs will dilute its cell sap, increasing its water potential and turgor pressure.

The addition of extra water to the cell sap of the root hair cells makes the sap dilute whereas the cell adjacent to it has a more concentrated solution. This sets up an osmotic pressure which draws water from the diluted cell sap into the more concentrated cell sap of the adjacent cells. In this way war moves from cell-to-cell in the cortex until it reaches the xylem which conducts water to the stem.

Diagram showing movement of water in the roots up to the xylem



In summary;

i. Water enters the root hairs by osmosis.
ii. Water passes across the cortex cells of a root to the xylem by osmosis.
iii. Water is drawn up in the xylem to the stem by root pressure and transpiration pull.

Adaptations of root hairs to their functions

1. They have a thin membrane to reduce on the **diffusion** distance of water into the root hairs

2. They are very many to offer maximum surface area for absorption of water
3. The roots have a concentrated cell sap to maintain a high **osmotic** gradient
4. They are very slender and flexible to penetrate any area in the soil so as to obtain water
5. They have many mitochondria in their cytoplasm which release energy in form of ATP for **active transport** of materials

From the adaptations of root hairs it can be noted that the materials which are transported in the plant are transported by three methods which may be used singly or in combination. The methods include;

A. Diffusion
B. osmosis
C. Active transport

Movement of water from root xylem to the stem

Once water has reached the xylem vessels, it moves up to the stem by the stem by the help of the following processes;

i. Root pressure
ii. Capillarity
iii. Transpiration pull

Capillarity

This is the tendency of water to rise up through very narrow tubes.

Xylem vessels have very small diameters which enables water to rise up in vessels of the plant. The processes of cohesion and adhesion constitute the capillarity forces. Water molecules attract one another by cohesive forces. The attraction between water molecules and xylem walls is known as adhesion. The cohesive and adhesive forces ensure that the water column in the xylem vessels remains continuous and there is no air bubble.

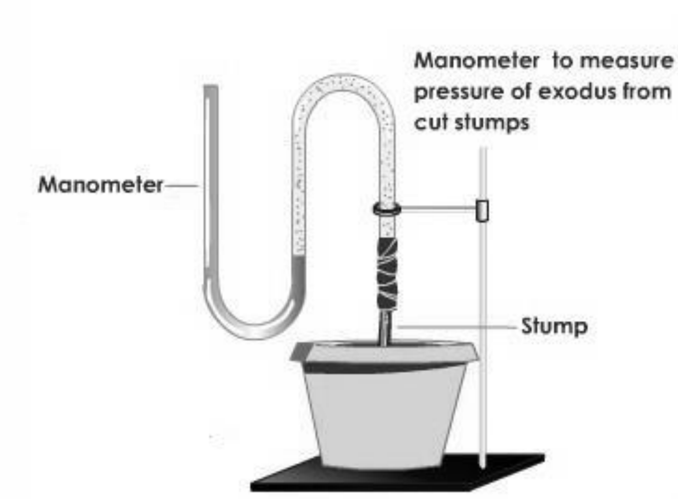
Root pressure

Water is continuously absorbed in the xylem vessels of the root. It builds up a hydrostatic pressure that pushes the water up in the stem. This pressure is referred to as root pressure.

Experiment to investigate root pressure in plants

Procedure

A stem of a healthy well watered planted is cut and a glass tube is tightened to it by means of a rubber band. Coloured water is poured into the tube and its level is marked. The set up is left for two hours and observations are made.



Experiment to demonstrate root pressure-B

Observation

The coloured liquid will rise up a few centimeters in the glass tube

Conclusion

This demonstrates root pressure in plants

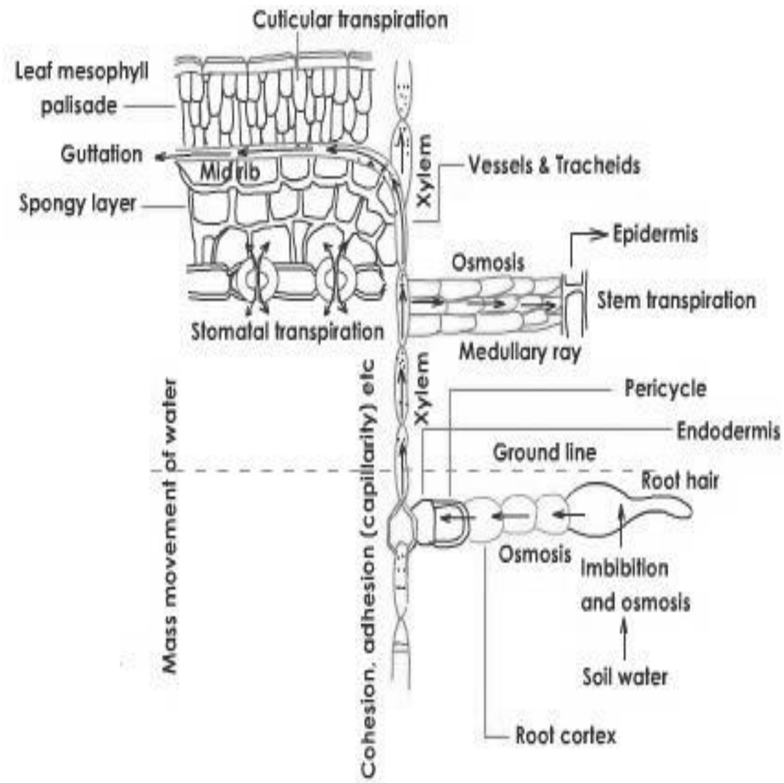
Transpiration pull

The process of evaporation of water from the leaf is called transpiration.

The flow of water through the plant from roots to leaves is called the **transpiration stream.**

Transpiration pull is believed to be a result of an interplay of several forces e.g. cohesion and adhesion. As water evaporates from the surface on the mesophyll, the vapour diffuses through the stomata to the atmosphere. This makes the cell sap of the mesophyll cells to be more concentrated. These cells then absorb water by osmosis from the neighbouring cells which in turn draw water from the cell. This creates a continuous pull of water to the leaves, from the root and a stream is thus created. The forces of cohesion and adhesion prevent the continuous transpiration stream from falling back.

Diagram illustrating water movement from roots to leaves



TRANSPORT OF MINERAL SALTS

Absorption of mineral salts The minerals salts are in form of ions dissolved in water and are absorbed by root hairs. The mineral salts present in soil are in a low concentration compared to the concentration inside the root. Mineral salts would diffuse out of the root hairs into the soil BUT, the mineral salts diffuse into the root hairs against a concentration gradient. This is called active transport and is explain why root hairs have a lot of mitochondria.

Transportation of mineral salts Mineral salts are dissolved in water and transported in the xylem in form of ions until when they reach the leaves.

TRANSPIRATION

This is process of evaporation of water from the leaf.

Types of transpiration

a. **Stomatal transpiration**
   This is the loss of water from the stomata. It accounts for 90% of the water lost. The stomata occur mostly on the leaves, and on the stems of herbaceous stems.

b. **Lenticular transpiration**

Woody trees have intervals/parts where the layer of the bark is made up of cells which are loosely packed appearing externally as raised dots. These are the **lenticels** through which water loss may occur. The water by through lenticels is very small, insignificant.

c. Cuticular transpiration

10% of the water is lost through the cuticle which is not completely impermeable to gases. The thicker the cuticle, the smaller the amount of water lost.

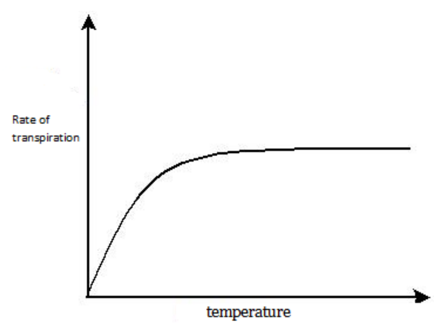
Factors affecting the rate of transpiration

The term transpiration rate refers to the amount of water lost from the shoot of a plant per unit time. The factors affect that affect the transpiration rate may be internal or external factors.

External factors

1. Temperature

A change in temperature affects both the kinetic movement of water molecules and the relative humidity of air.

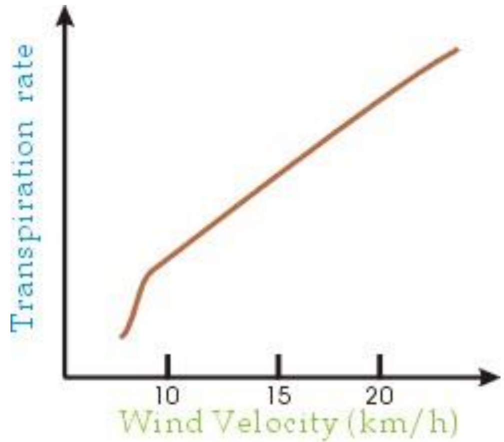


An increase in temperature increases the rate of transpiration if other factors are kept constant. The air expands because as temperature increases, it increases the kinetic energy of the molecules of the air which then move faster in space since they are in a warm environment. The water molecules in the air around the leaf move further apart, so their concentration reduces which increases their rate of diffusion from the leaf.

2. Wind

Under stills conditions, a layer of humid air surrounds the leaf. This is because the region around the leaf surface is saturated with moisture and this blocks the stomata, hence preventing water loss from the leaf. This reduces on the rate of transpiration

On a windy day, the saturated vapour is continuously swept away from the stomata hence exposing the stomata to less humid air. This increases on the rate of transpiration.



3. Light intensity

Sunlight leads to opening of stomata by the plants to allow in carbon dioxide for photosynthesis (this explains why guard cells are the only mesophyll cells with chlorophyll). Water vapour then moves out of the leaves via the open stomata.

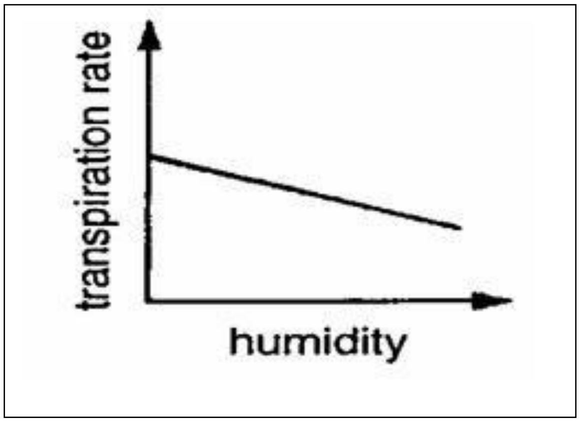
Increasing the light intensity, leads to an increase in the size of the stomatal pore hence more is lost from the leaves. An increase in light intensity also causes an increase in the internal leaf temperature, thus increasing the rate of evaporation/transpiration.

4. Humidity

Humidity is the amount of water vapour in the atmosphere.

If water molecules outside the leaf increase i.e. the humidity rises, the rate of transpiration will decrease. Humidity may increase due to transpiration or rainfall e.t.c.

If the there's no loss of water by transpiration, it accumulate in the leaf and ooze out of the stomata and drip from the leaf, a process called **guttation.**



5. Atmospheric pressure

At high altitudes, water potential decreases which in turn increase the transpiration rate. Therefore the rate transpiration increases with decrease in atmospheric atmosphere.

High altitude plants therefore show structural adaptations to reduce the transpiration rate.

6. Water supply

For transpiration to take place, the cellular walls of the spongy mesophyll cells must be fully saturated i.e. fully turgid. Fully turgid mesophyll cells open the stomata widely hence increasing the transpiration rate. Transpiration rate therefore increases with an increase in water supply.

Internal factors

1. Leaf area

The higher the total surface area of the leaf of a plant, the greater the rate of cuticular transpiration regardless of the number of stomata

2. Cuticle

The cuticle is a waxy covering over the leaf surface. The thicker the cuticle, the lower the rate of cuticular transpiration

3. Density of stomata

The greater the number of stomata for a given area, the higher the rate of transpiration

4. Distribution of stomata

There are more stomata on the lower surface as compared to the upper surface. This is because the upper surface is subjected to a greater temperature increase since it is facing the sunlight. Transpiration is therefore potentially greater from the upper surface.

ADAPTATIONS OF PLANTS TO WATER LOSS CONTROL (TRANSPIRATION CONTROL)

The structural modifications of certain plants enable them to reduce water loss, particularly from their leaves and stems, are called **xeromorphic adaptations.**

Xerophytes are plants that are adapted to live in conditions in which there is either a scarcity of water in the soil, or the atmosphere is dry enough to cause excessive transpiration, or both.

1. Having hairy leaves

These trap a layer of still moist air on the leaf surface which covers the stomata thus reducing the rate of transpiration

2. Waxy cuticle

Most plants, especially those living in arid areas, have their leaves covered a waxy substance made by the epidermal cells. The wax water-proofs the leaves and prevents excess water loss by transpiration

3. Rolling leaves

Grasses roll their leaves during dry weather. This reduces on the surface area exposed to the external environment and encloses air, both of which serve to reduce the transpiration rate.

4. Shading off of leaves

Some plants shed their leaves during the dry periods to control the loss of water through the stomata, and regenerate them during the wet season.

5. Closing of the stomata

Some plants open their stomata during the night and close them during the day. This is common to plants that live in arid areas.

6. Reducing the surface area of the leaves

In some plants, the leaves are needle-like e.g. pines and cactus. This reduces on the surface area for transpiration hence conserving water in the plant.

7. Sunken stomata

Pines have sunken stomata. **Still** and **mois**t air is trapped around the stomata, which reduces on the rate of transpiration. The air around the stomata is as concentrated as that in the leaf's air space.

8. Orientation of leaves

The ***compass plant*** has leaves which constantly change their leaves so that the sun strikes them obliquely. This reduces their temperature and hence the transpiration rate.

Importance of transpiration to plants (functions)

1. It provides a mechanism through which mineral elements are transported in the plant.
2. It serves to cool the leaves since excess heat is lost with the excess heat is lost with the escaping vapour.
3. It leads to absorption of water by the plant roots from the soil
4. It serves as the driving-force for the uptake of water up the xylem vessels.

Note. If the leaves lose more water to the atmosphere, than the roots can absorb to replace, the plant **wilts**. This makes transpiration a necessary evil. Wilting (temporary) in spinach, is used as a mechanism to control transpiration.

Experiment to show that transpiration occurs in plants

Requirements

- Polythene bag
- Potted leafy plant
- Anhydrous copper sulphate

Procedure

i. A stem of a well watered potted plant is covered with the polythene bag, leaving the soil in the pot out.

ii. The point of attached between the stem and polythene bag is smeared with Vaseline to prevent the loss of water, which would have transpired by the plant, from escaping.

iii. The set-up is then placed in sun light for one hour and observations are made.

Observation

After one hour, droplets of a colourless liquid will be seen on the sides on the polythene bag.

If the water is removed from the polythene and tested with anhydrous copper (II) sulphate, the liquid changes it (copper (II) sulphate) from white to blue.

Conclusion

Plants lose water to the atmosphere through the leaves.

Note. A control experiment is set up using the same plant with similar conditions but without the leaves and flowers.

No observable change on the sides of the polythene, indicating that transpiration does not occur.

Experiment to show which surface of a leaf loses more water

Requirements

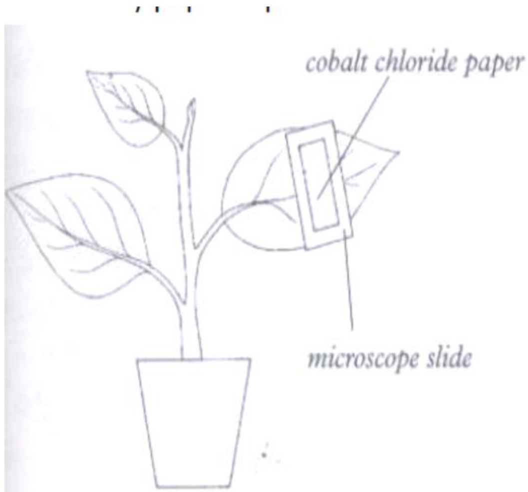
- Cobalt chloride paper
- Microscope slide
- Leafy plant.

Procedure

i. Pieces of cobalt chloride paper are fixed on the lower and upper surfaces of a leaf which is still attached to the stem of a plant

ii. The cobalt chloride paper is fixed on the leaf using the microscope slides

iii. The time taken for the cobalt chloride paper to turn from blue to pink is noted for both sides



Observation

The pink colour develops faster on the lower side than the upper side

Explanation

The lower surface has more stomata than the upper surface. This is because the upper surface receives direct sunlight which would bring about too much loss of water that would wilt (dry) the plant.

Conclusion

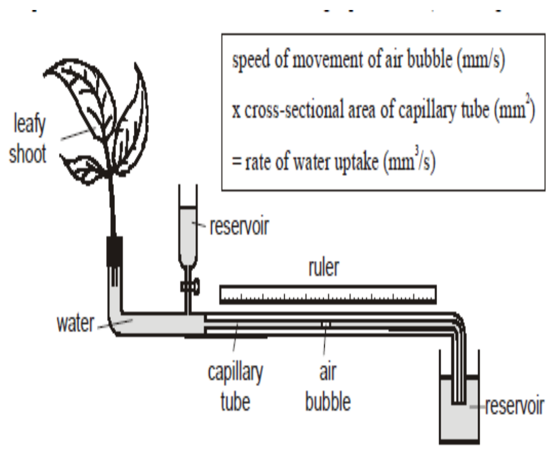
The lower surface loses more than the upper surface.

Experiment to investigate the rate transpiration in a plant (using a potometer)

It is not east to measure how much water is lost from the leaf of the plant but much easier to measure how much water the plant takes up.

The rate at which a plant loses water to the atmosphere can be measured on a cut shoot by measuring water uptake using an instrument called a **potometer**. The potometer measures *indireclty* the rate of tranpiration but *directly* it measures water up take.

The potometer works on the assumption that the amount of water lost equals to the amount of water taken up.



Functions of the different parts of a potometer

1. Reservoir

It stores water which is used to reset the air bubble. This is done by releasing the water in reservoir by opening the tap.

2. Air bubble

It acts as an indicator because it is the rate of movement of the air bubble in water that shows the rate of transpiration.

3. Scale/ruler

It used to measure the speed at which the air bubble moves during transpiration.

4. Capillary tube

This is used to determine the speed of movement of the air bubble.

Procedure

1. In setting up a potometer, the shoot of a leafy plant that is to be used in the experiment is cut under water to avoid air entering the xylem because it blocks them.

2. The whole apparatus is filled water and then the shoot is placed in its position tied so tightly to avoid leakage. Vaseline is smeared around the shoot to prevent air from entering.

3. The tap of the reservoir is closed but only opened when the potometer needs refilling

4. The initial position of the air bubble in the capillary tube is than recorded.

5. The potometer is allowed is allowed to stand in various conditions e.g. light or darkness or wind or still air for four hours.

Observations

The air bubble in the capillary tube will start moving towards the shoot indicating that water is being taken up by the shoot which is finally lost to the atmosphere

Mathematically, the volume of water lost from the leafy shoot in this experiment is calculated using the formula. $\boldsymbol{V = \pi r^2 \mathrm{h}}$

r = radius of the capillary tube

h = distance moved by the air bubble

$\boldsymbol{\pi} = 3.14$

Precautions taken when setting up a potometer

i. The bubble must be one

ii. The whole apparatus should be full of water and air tight

iii. The stem should be cut under water so that the xylem vessels are not blocked by air

iv. The shoot used should have many leaves i.e. leafy

STORAGE OF FOOD IN PLANTS

A storage organ is a part of a plant specifically modified for storage of excess energy (generally in the form of carbohydrates, lipids or proteins) or water stored in order to be used for future growth usually in biannual or perennial plants. Storage organs often grow underground, where they are better protected from attack by herbivores. Plants that have an underground storage organ are called geophytes. Storage organs often, but not always, act as perennating organs which enable plants to survive adverse conditions (such as cold, excessive heat, lack of light or drought).

They include True roots e.g. tuberous root or root tuber and storage taproot .e.g. carrot. Modified stems e.g. Corm .e.g. *Crocus*, Stem tuber .e.g. potato. Rhizome .e.g. *Iris pseudacorus* (yellow flag iris). Pseudobulb .e.g. *Pleione* (windowsill orchid). Caudex .e.g. *Adenium* (desert-rose) others include: Storage hypocotyl (the stem of a seedling) e.g. sometimes called a tuber, as in *Cyclamen*. Bulb (modified leaf bases) — e.g. *Lilium*, *Narcissus*, onion