ABSORPTION OF WATER – MODE OF WATER ABSORPTION – ACTIVE AND PASSIVE ABSORPTION AND FACTORS AFFECTING ABSORPTION.

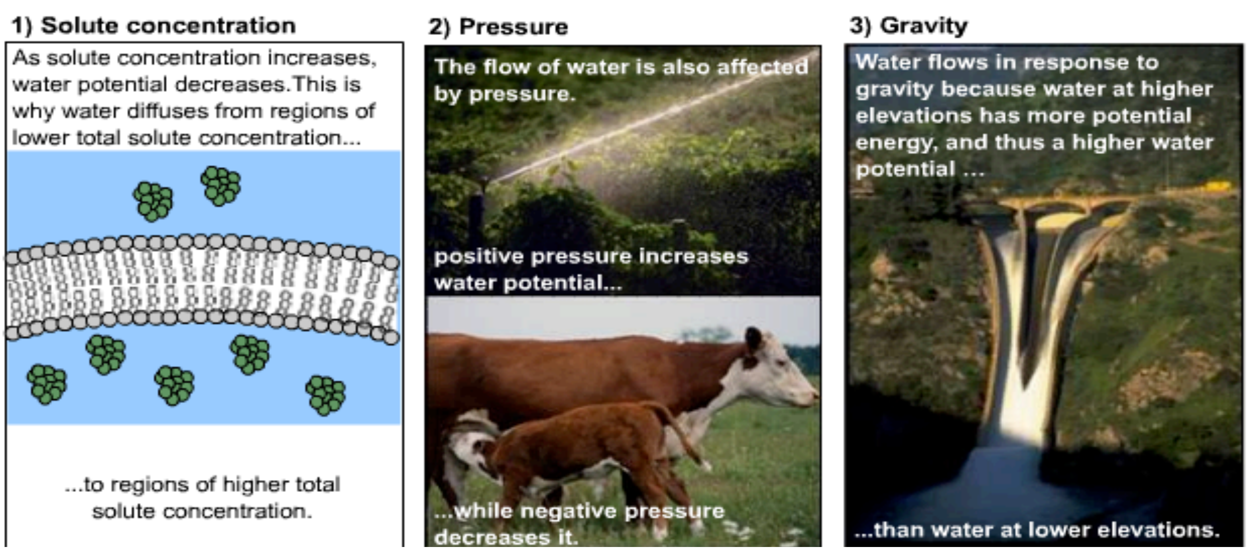
PRELUDE OF WATER POTENTIAL

Most organisms are comprised of at least 70% or more water. Some plants, like a head of lettuce, are made up of nearly 95% water. When organisms go dormant, they loose most of their water. For example, seeds and buds are typically less than 10% water, as are desiccated rotifers, nematodes and yeast cells. Earth is the water planet (that's why astronomers get so excited about finding water in space). Water is the limiting resource for crop productivity in most agricultural systems

LEARN MORE ABOUT WATER POTENTIAL

- In general, water always moves down its water potential gradient from areas of higher water potential to areas of lower water potential.
- Water potential is typically measured as the amount of pressure needed to stop the movement of water.
- The unit used to express this pressure is the megapascal (MPa).

The three factors that most commonly determine water potential are



WHAT IS WATER POTENTIAL?

Water potential is the potential energy of water relative to pure free water (e.g. deionized water) in reference conditions. It quantifies the tendency of water to move from one area to another due to osmosis, gravity, mechanical pressure, or matrix effects including surface tension. Water potential is measured in units of pressure and is commonly represented by the Greek letter Ψ (Psi). This concept has proved especially useful in understanding water movement within plants, animals, and soil.

Components of water potential

Much different potential affect the total water potential and sum of these potentials determines the overall water potential and the direction of water flow:

$$\Psi = \Psi_0 + \Psi_\pi + \Psi_p + \Psi_s + \Psi_v + \Psi_m$$

Where:

- Ψ_0 is the reference correction,
- Ψ_π is the solute potential,
- Ψ_p is the pressure potential,
- Ψ_s is the gravimetric component,
- Ψ_v is the potential due to humidity, and
- Ψ_m is the potential due to matrix effects (e.g., fluid cohesion and surface tension.)

COMPONENT OF WATER POTENTIAL

1. Pressure potential

Pressure potential is based on mechanical pressure, and is an important component of the total water potential within plant cells. Pressure potential is increased as water enters a cell. As water passes through the cell wall and cell membrane, it increases the total amount of water present inside the cell, which exerts an outward pressure that is retained by the structural rigidity of the cell wall.

The pressure potential in a living plant cell is usually positive. In plasmolysed cells, pressure potential is almost zero. Negative pressure potentials occur when water is pulled through an open system such as a plant xylem vessel. Withstanding negative pressure potentials (frequently called tension) is an important adaptation of xylem vessels.

2.Solute potential

Pure water is usually defined as having a solute potential (Ψ_π) of zero, and in this case, solute potential can never be positive. The relationship of solute concentration (in molarity) to solute potential is given by the van 't Hoff equation:

$$\Psi_\pi = -miRT$$

Where

m - The concentration in molarity of the solute,

i - The van 't Hoff factor, the ratio of amount of particles in solution to amount of formula units dissolved,

R - The ideal gas constant, and *T* is the absolute temperature.

3. Matrix potential

When water is in contact with solid particles (e.g., clay or sand particles within soil) adhesive intermolecular forces between the water and the solid can be large and important. The forces between the water molecules and the solid particles in combination with attraction among water molecules promote surface tension and the formation of menisci within the solid matrix. Force is then required to break these menisci. The magnitude of matrix potential depends on the distances between solid particles--the width of the menisci and the chemical composition of the solid matrix. In many cases, matrix potential can be quite large and comparable to the other components of water potential discussed above.

It is worth noting that matrix potentials are very important for plant water relations. Strong (very negative) matrix potentials bind water to soil particles within very dry soils. Plants then create even more negative matrix potentials within tiny pores in the cell walls of their leaves to extract water from the soil and allow physiological activity to continue through dry periods.

4. Gravity (Ψ_g):

Contributions due to gravity which is usually ignored unless referring to the tops of tall trees.

ABSORPTION OF WATER

We know from a very early age that plants obtain water through their roots, though it is not perhaps until our school biology lessons that we learn of the important role that water plays in the process of photosynthesis. Most of the water absorption is carried out by the younger part of the roots. Just behind the growing tip of a young root is the piliferous region, made up of hundreds of projections of the epidermal tissue, the root hairs.

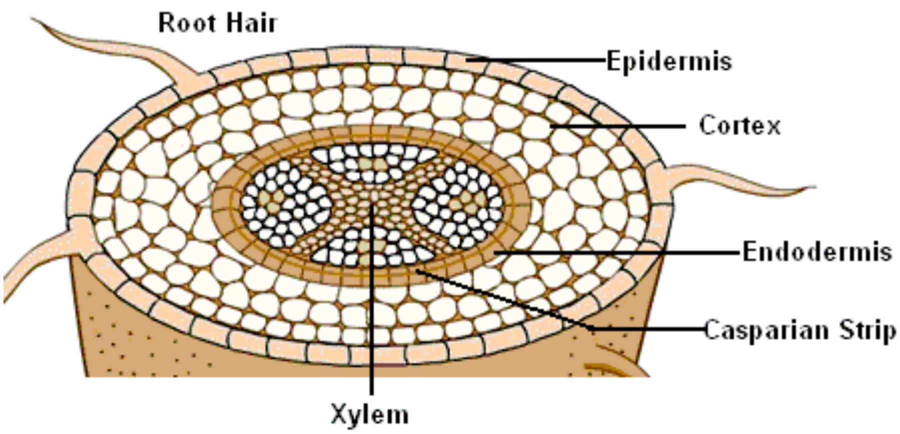
STRUCTURE INVOLVED IN WATER ABSORPTION

In higher plants water is absorbed through root hairs which are in contact with soil water and form a root hair zone a little behind the root tips. Root hairs are tubular hair like prolongations of the cells of the epidermal layer (when epidermis bears root hairs it is also known as pilloferous layer of the roots. The walls of root hairs are permeable and consist of pectic substances and cellulose which are strongly hydrophilic in nature root hairs contain vacuoles filled with cell sap. When roots elongate, the older root hairs die and new root hairs are developed so that they are in contact with fresh supplies of water in the soil. Lateral Movement of water is achieved through root. This can described as follows:

ROOTS

Often roots are overlooked, probably because they are less visible than the rest of the plant. However, it's important to understand plant root systems (Fig 1) because they have a pronounced effect on a plant's size and vigor, method of propagation, adaptation to soil types, and response to cultural practices and irrigation.

Fig 1. Diagrammatically the internal structure of a typical root



Roots typically originate from the lower portion of a plant or cutting. They have a root cap, but lack nodes and never bear leaves or flowers directly. Their principal functions are to absorb nutrients and moisture, anchor the plant in the soil, support the stem, and store food. In some plants, they can be used for propagation.

STRUCTURE OF ROOTS

Internally, there are three major parts of a root (Fig 2):

- The **meristem** is at the tip and manufactures new cells; it is an area of cell division and growth.
- Behind the meristem is the **zone of elongation**. In this area, cells increase in size through food and water absorption. As they grow, they push the root through the soil.
- The **zone of maturation** is directly beneath the stem. Here, cells become specific tissues such as epidermis, cortex, or vascular tissue.

A root's **epidermis** is its outermost layer of cells (Fig 2). These cells are responsible for absorbing water and minerals dissolved in water. **Cortex** cells are involved in moving water from the epidermis to the **vascular tissue** (xylem and phloem) and in storing food. Vascular tissue is located in the center of the root and conducts food and water.

Fig 2. Cross section of roots

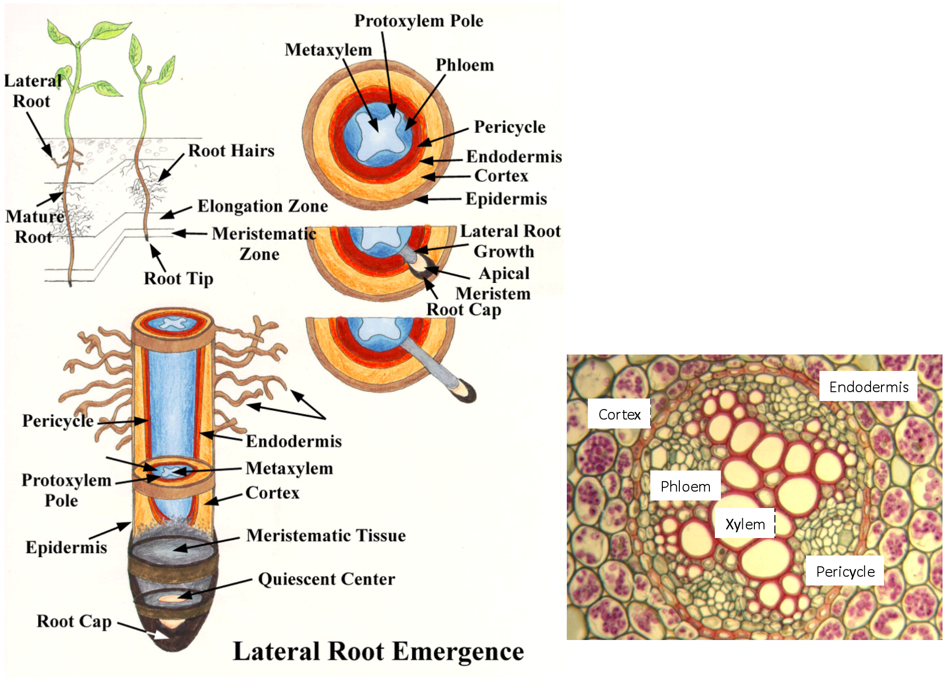
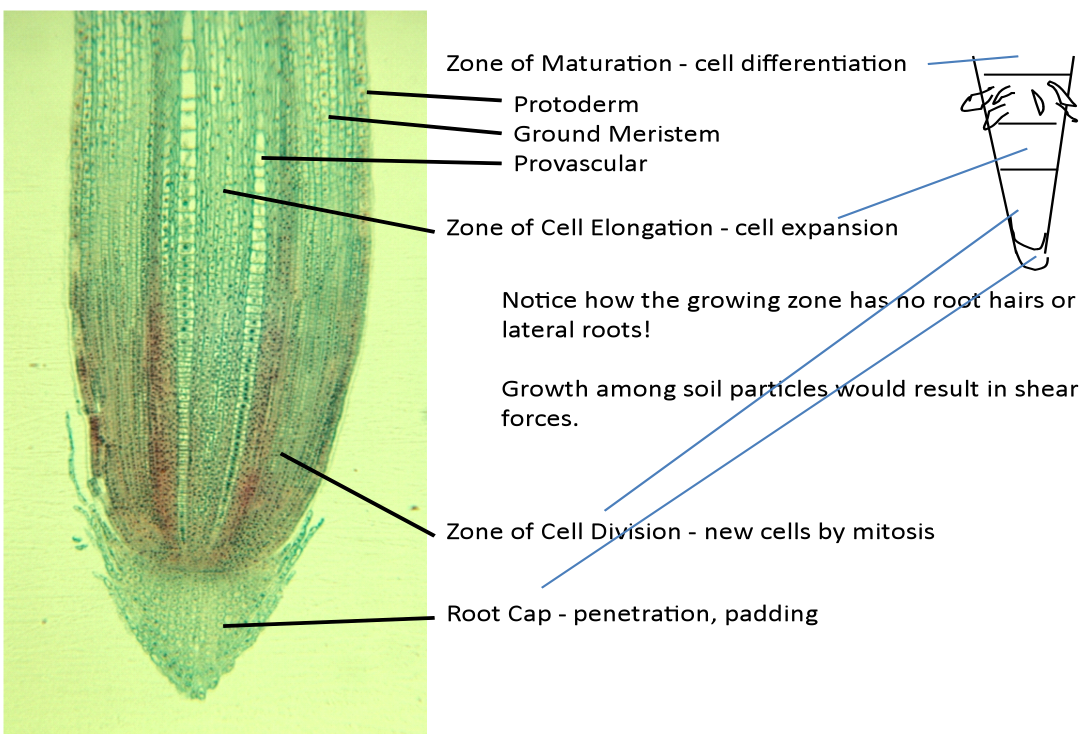


Fig 3. Structure of root hair



Externally, there are two areas of importance: the root cap and the root hairs (Figure 3). The **root cap** is the root's outermost tip. It consists of cells that are sloughed off as the root grows through the soil. Its function is to protect the root meristem.

Root hairs are delicate, elongated epidermal cells that occur in a small zone just behind the root's growing tip. They generally appear as fine down to the naked eye. Their function is to increase the root's surface area and absorptive capacity. Root hairs usually live 1 or 2 days. When a plant is transplanted, they are easily torn off or may dry out in the sun.

WATER MOVEMENT MECHANISM IN PLANTS

In plants, following two pathways are involved in the water movement. They are

(1) Apoplastic pathway

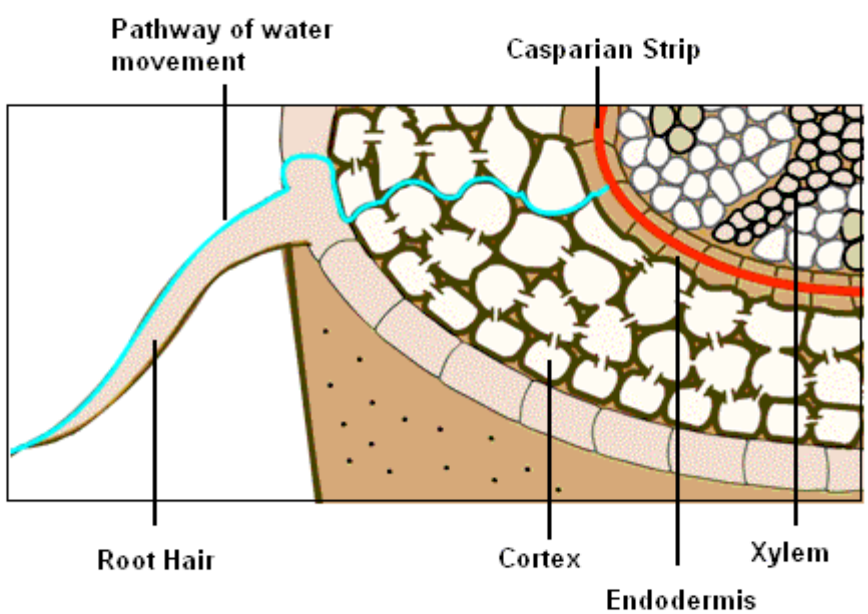
(2) Symplastic pathway

(3) Transmembrane pathway

1. Apoplastic pathway (Fig 4)

The apoplastic movement of water in plants occurs exclusively through the **cell wall** without crossing any membranes. The cortex receive majority of water through apoplastic way as loosely bound cortical cells do not offer any resistance. But the movement of water in root beyond cortex apoplastic pathway is blocked by casparian strip present in the endodermis.

Fig 4



2. Symplastic pathway (Fig 5)

The movement of water from one cell to other cell through the **plasmodesmata** is called the symplastic pathway of water movement. This pathway comprises the network of cytoplasm of all cells inter-connected by plasmodermata.

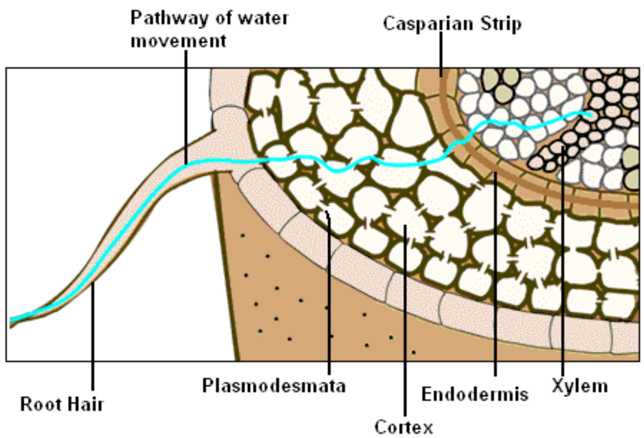
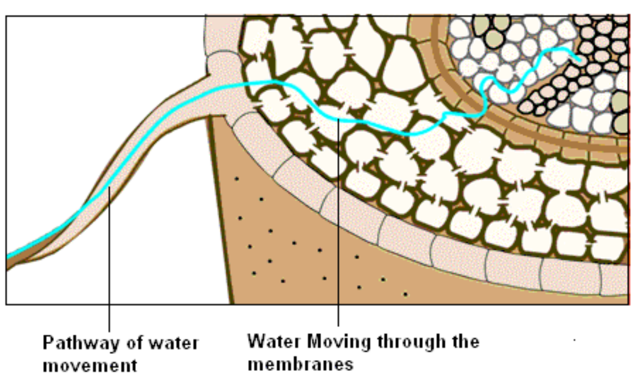


Fig 5

3. Transmembrane pathway (Fig 6)

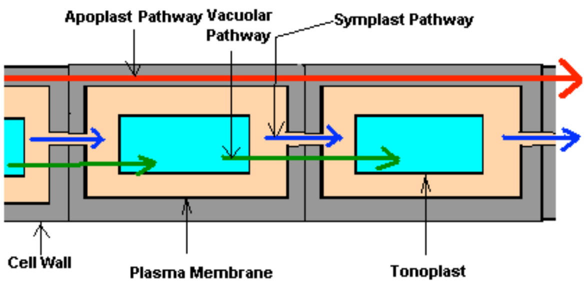
In plant roots, water movement from soil till the endodermis occurs through apoplastic pathway i.e. only through cell wall. The casparian strips in the endodermis are made-up of wax -like substance suberin which blocks water and solute movement through the cell wall of the endodermis. As a result water is forced to move through cell membranes and may cross the tonoplast of vacuole. This movement of water through cell membranes is called transmembrane pathway.

Fig 6.

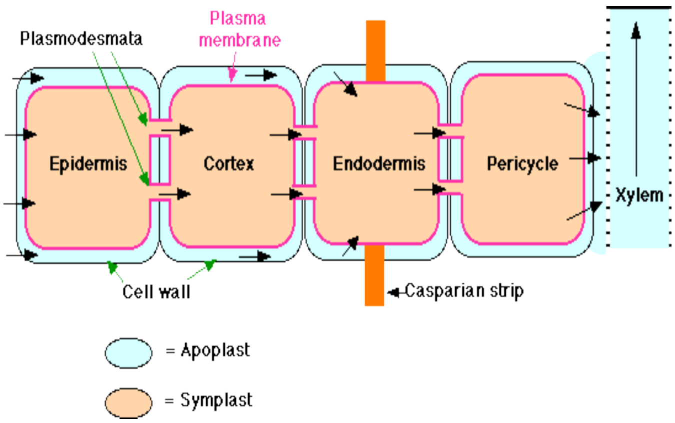


Following schematic diagram showing the apoplastic and symplastic pathway of water movement through root (Fig 7)

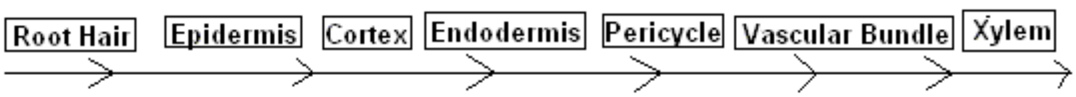
Fig 5



Apoplastic (Red) and symplastic (Blue) and transmembrane (green) pathways of movement of substances in a plant cell



With the help of the following schematic arrow flow chart, you can understand the path of water from soil to root xylem.



MECHANISM OF WATER ABSORPTION

1. Active absorption of water

In this process the root cells play active role in the absorption of water and metabolic energy released through respiration is consumed active absorption may be of two kinds.

Steps involved in the active osmotic absorption of water

First step in osmotic the osmotic absorption of water is the imbibition of soil water by the hydrophilic cell walls of root hairs. Osmotic pressure of the cell sap of root hairs is usually higher than the OP of the soil water. Therefore, the DPD and suction presume in the root hairs become higher and water from the cell walls enters into them through plasma membrane by osmotic diffusion. As a result, OP, suction pressure and DPD of root hairs how become lower, while their turgor pressure is increased.

Now the cortical cells adjacent to root hairs have high OP, SP & DPD in comparison to the root hairs. Therefore, water is drawn into the adjacent cortical cells from root hairs by osmotic diffusion. In the same way, by cell to cell osmotic diffusion gradually reaches the inner most cortical cells and the endodermis.

Osmotic diffusion of water into endodermis takes place through special thin walled passage cells because the other endodermis cells have casparian strips on thin walls which are impervious to water.

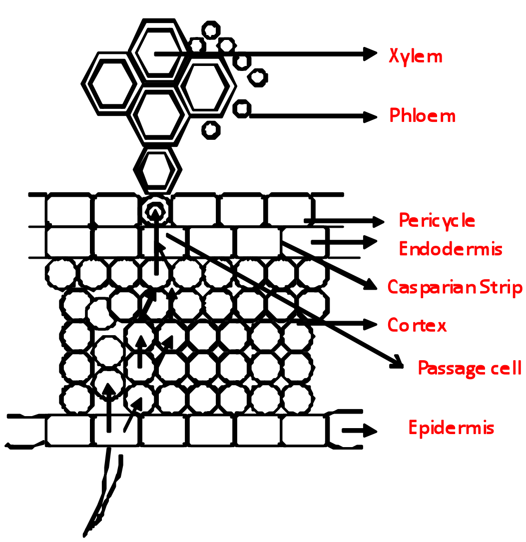
Water from endodermis cells is down into the cells of pericycle by osmotic diffusion which now become turgid and their suction pressure in decreased.

In the last step, water is drawn into xylem from turgid pericycle cells (In roots the vascular bundles are radical and protoxylem elements are in contact with pericycle). It is because in the absence of turgor presume of the xylem vessels, the SP of xylem vessels become higher than SP of the cells of the pericycle when water enters into xylem from pericycle a presume is developed in the xylem of roots which can raise the water to a certain height in the xylem. This pressure is called as root pressure.

(A) Osmotic absorption

Water is absorbed from the soil into the xylem of the roots according to osmotic gradient.

Osmotic absorption



Steps involved

Imbibition of soil water by hydrophilic cell wall

↓

O.P Cell sap > O.P soil water

↓

DPD in root hair becomes higher

↓

Water from cell wall enter into them thro' membrane by osmotic diffusion

↓

As a result, O.P, DPD of root becomes lower and T.P increased

↓

Now the cortical cell adjacent to root hair have higher O.P, DPD in comparison to root hair by osmotic diffusion

Likewise, water moves by osmotic diffusion and reaches endodermis

↓

Endodermis water moves thro' passage cell (because casparian cell)

↓

Now water reaches pericycle, pericylce becomes turgid and their DPD is decreased

↓

Last step, water is drawn into xylem from turgid pericycle cells (protoxylem in contact)

↓

Pressure is developed in the xylem of root by water entry – Root pressure

(B) Non-osmotic absorption

Water is absorbed against the osmotic gradient. Sometimes, it has been observed that absorption of water takes place even when OP of soil water is high than OP of cell sap. This type of absorption which is non-osmotic and against the osmotic gradient requires the expenditure of metabolic energy probably through respiration.

2. Passive absorption of water

It is mainly due to transpiration, the root cells do not play active role and remain passive.

STEPS:

Transpiration creates tension in water in the xylem of the leaves

↓

Tension is transmitted to water in xylem of root thro' xylem of stem and water rises upward to reach transpiring surface

↓

Hence soil water enters cortical cells thro' root hairs to reach xylem of roots to maintain the supply of water.

↓

The force for entry of water in leaves is due to rapid transpiration and root cells remain passive

2. Passive absorption of water

Passive absorption of water takes place when rate of transpiration is usually high. Rapid evaporation of water from the leaves during transpiration creates a tension in water in the xylem of the leaves. This tension is transmitted to water in xylem of roots through the xylem of stream and water rises upward to reach the transpiring surfaces. As the results soil water enters into the cortical cells through root hairs to reach the xylem of roots to maintain the supply of water. The force of this entry of water is created in leaves due to rapid transpiration and hence, the root cells remain passive during this process.

External factors affecting absorption of water

1. Available soil water

Sufficient amount of water should be present in the soil in such form which can easily be absorbed by the plants. Usually the plants absorb capillary water i.e water present in films in between soil particles other forms of water in the soil eg. Hygroscopic water, combined water, gravitational water etc. is not easily available to plants.

Increased amount of water in the soil beyond a certain limit results in poor aeration of the soil which retards metabolic activities of root cells like respiration and hence, the rate of water absorption is also retarded.

2. Concentration of soil solution

Increased concentration of soil solution (due to presence of more salts in the soil) results in higher OP. If OP of soil solution will become higher than the OP of cell sap in root cells, the water absorption particularly the osmotic absorption of water will be greatly suppressed. Therefore, absorption of water is poor in alkaline soils and marshes.

3. Soil air

Absorption of water is retarded in poorly aerated soils because in such soils deficiency of O_2 and consequently the accumulation of CO_2 will retard the metabolic activities of roots like respiration. This also inhibits rapid growth and elongation of the roots so that they are deprived of fresh supply of water in the soil. Water logged soils are poorly aerated and hence, are physiologically dry. They are not good for absorption of water.

4. Soil temperature

Increase in soil temperature up to about 30°C favours water absorption. At higher temperature water absorption is decreased. At low temperature also water absorption decreased so much so that at about 0°C, it is almost decreased. This is probably because at low temperature.

1. The viscosity of water and protoplasm is increased
2. Permeability of cell membrane is decreased
3. Metabolic activity of root cells are decreased
4. Root growth and elongation of roots are checked.

Quiz

1. Roots have a **root cap**, but lack nodes and never bear leaves or flowers directly
2. The **meristem** is at the tip and manufactures new cells; it is an area of cell division and growth.
3. Behind the meristem is the **zone of elongation**
4. The **zone of maturation** is directly beneath the stem. Here, cells become specific tissues such as epidermis, cortex, or vascular tissue.
5. **Root hairs** are delicate, elongated epidermal cells that occur in a small zone just behind the root's growing tip.
6. The movement of water from one cell to other cell through the **plasmodesmata** is called the symplastic pathway of water movement.
7. The casparian strips in the endodermis are made-up of wax -like substance **suberin** which blocks water and solute movement through the cell wall of the endodermis.