06.

Mechanism of nutrient transport in plants

Learning objectives

a. **Understand ways in which nutrients in the soil reach plant roots**
b. **To know how plant roots absorb nutrients and move inside plants**

Nutrients must reach the surface of a root for plant uptake of essential elements to occur There are three major mechanism of movement of ions from soil to roots. They are

Root interception

Root interception occurs when a nutrient comes into physical contact with the root surface. As a general rule, the occurrence of root interception increases as the root surface area and mass increases, thus enabling the plant to explore a greater amount of soil. Root interception may be enhanced by mycorrhizal fungi, which colonize roots and increases root exploration into the soil. Root interception is responsible for an appreciable amount of **calcium** uptake, and some amounts of **magnesium, zinc** and **manganese**. The CEC of roots for monocots is 10 - 30 meq/100 g and takes up monovalent cations more readily and that of Dicots is 40 - 100 meq/100 g and takes up divalent cations more readily. The quantity of nutrients intercepted by roots depends on the soil concentration of nutrients and volume of soil displaced by root system

Factors affecting root interception

a. Anything that restricts root growth
    i. Dry soil
    ii. Compaction
    iii. Low soil pH
    iv. Poor aeration
    v. Root disease, insects, nematodes
    vi. High or low soil temperature
b. Root growth is necessary for all three mechanisms of nutrient supply, but absolutely essential for root interception to occur

Mass flow:

Mass flow occurs when nutrients are transported to the surface of roots by the movement of water in the soil (i.e. percolation, transpiration, or evaporation). The rate of water flow governs the amount of nutrients that are transported to the root surface. Therefore, mass flow decreases are soil water decreases. Most of the **nitrogen, calcium, magnesium, sulfur, copper, boron, manganese** and **molybdenum** move to the root by mass flow. Quantity of nutrients transported is proportional to:

    i. Rate of flow (volume of water transpired)
    ii. Solution concentration of nutrient

Nutrients supplied primarily by mass flow are considered mobile nutrients. e.g. N, S, B

Factors affecting mass flow

a. Soil water content
    i. Dry soil where there is no nutrient movement
b. Temperature
    i. Low temperature reduces transpiration and evaporation
c. Size of root system
    i. Affects water uptake and therefore movement
    ii. Root density much less critical for nutrient supply by mass flow than for root interception and diffusion

Diffusion:

Diffusion is the movement of a particular nutrient along a concentration gradient. When there is a difference in concentration of a particular nutrient within the soil solution, the nutrient will move from an area of higher concentration to an area of lower concentration. This phenomenon is observed when adding sugar to water. As the sugar dissolves, it moves through parts of the water with lower sugar concentration until it is evenly distributed, or uniformly concentrated. Diffusion delivers appreciable amounts of **phosphorus, potassium, zinc**, and **iron** to the root surface. Diffusion is a relatively slow process compared to the mass flow of nutrients with water movement toward the root. Nutrients supplied primarily by diffusion are considered immobile nutrients e.g. P, K

Factors affecting diffusion

a. Fick's law is given as $dC/dt = De * A * dC/dX$

    dC/dt = diffusion rate (change in concentration over time)
    De = effective diffusion coefficient
    A = cross sectional area for diffusion
    dC/dX = concentration gradient (change in concentration over distance)

Diffusion rate is directly proportional to concentration gradient, diffusion coefficient, and the area available for diffusion to occur

b. Effective diffusion coefficient

Effective diffusion coefficient $De = Dw * q * (1/T) * (1/b)$ where

Dw = diffusion coefficient in water
q = volumetric soil water content
T = tortuosity factor
b = soil buffering capacity

a. Diffusion coefficient in water (Dw)
    i. Includes a temperature factor

ii. Colder = slower diffusion

b. Soil water content
   i. Drier soil = slower diffusion
   ii. Less water = less area to diffuse through

c. Tortuosity
   i. Pathways through soil are not direct
   ii. Around soil particles, through thin water films
   iii. Affected by texture and water content
      1. More clay = longer diffusion pathway
      2. Thinner water films = longer path

d. Buffering capacity
   i. Nutrients can be removed by adsorption as they move through soil, reducing diffusion rate

c. How far can nutrients diffuse in a growing season?

a. Diffusion distances are very short
   i. K ~ 0.2 cm
   ii. P ~ 0.02 cm

b. Size and density of plant root systems is very important for nutrients supplied by diffusion

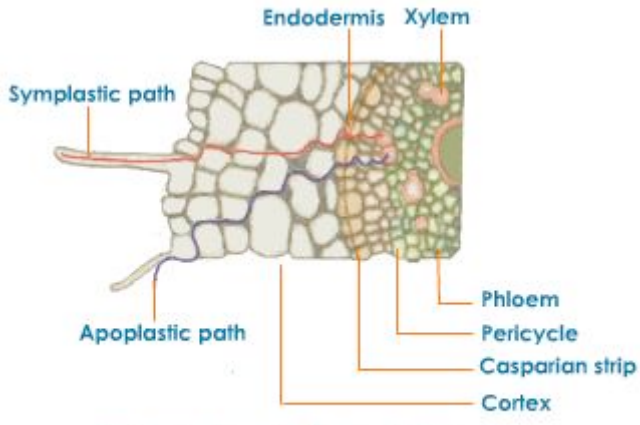
c. Has implications for fertilizer placement

Ion traffic into the root

Mineral nutrients absorbed from the root has to be carried to the xylem. This transport follows two pathways namely apoplastic pathway and symplastic pathway.

In apoplastic pathway, mineral nutrients along with water moves from cell to cell through spaces between cell wall by diffusion. The ions, which enter the cell wall of the epidermis move across cell wall of cortex, cytoplasm of endodermis, cell walls of pericycle and finally reach the xylem.

In symplastic pathway, mineral nutrients entering the cytoplasm of the epidermis move across the cytoplasm of the cortex, endodermis of pericycle through plasmodesmata and finally reach the xylem.



Anatomical aspect of symplastic and apoplastic pathways of ion absorption in the root hair region

Translocation of solutes

P.R. Stout and Dr. Hoagland have proved that mineral nutrients absorbed by the roots are translocated through the xylem vessel. Mineral salts dissolved in water moves up along the xylem vessel to be transported to all the parts of the plant body. Translocation is aided, by transpiration. As water is continuously lost by transpiration on the upper surfaces of the plant, it creates a transpirational pull, by which water along with mineral salts is pulled up along the xylem vessel.

Active absorption of energy can be achieved only by an input of energy. Following evidences show the involvement of metabolic energy in the absorption of mineral salts.

- Higher rate of respiration increases the salt accumulation inside the cell.
- Respiratory inhibitors check the process of salt uptake.
- By decreasing oxygen content in the medium, the salt absorption is also decreased.

These evidences indicate that salt absorption is directly connected with respiratory rate and energy level in the plant body, as active absorption requires utilization of energy.

References:

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Questions to ponder

1) What is contact exchange?
2) What soil factors influence diffusion of nutrients to roots?
3) What is diffusion?
4) Why is anion adsorption little important in agricultural soils?
5) What is the mechanism of active absorption of iron by roots?