# Unit-II : Mineral Nutrition

## ★ Major and Minor elements :-

To complete life-cycle normally, living organism requires a supply of large number of substances from outside. This supply is called nutrition.

The green plants are autotrophic & they require from outside the supply of only inorganic substances. With the exception of C, H & O, all other inorganic substances are obtained directly or indirectly from soil. As the sources of these inorganic nutrients are minerals, the elements are called mineral nutrients and the nutrition is called mineral nutrition.

In all, sixteen elements are required by the plants, of which some are required in large quantities & called major elements or macronutrients. eg : C, H, O, N, S, P, K, Mg & Ca ~~& Fe~~.

The elements which are required in small quantities are termed as minor elements or trace elements or micronutrients.
eg : Fe, B, Mn, Zn, Cu, Mo & Cl.

### (A) MACRONUTRIENTS :—

### (1) Carbon, Hydrogen and Oxygen :

These are not mineral in origin, but are a part of all organic compounds present in the plant & form major part of dry weight. Carbon is absorbed by the plant in the form of $CO_2$ from air. It is essential for synthesis of carbohydrates & fat. Hydrogen & oxygen are present in water which is absorbed by the plant from soil. Water is needed for various vital activities of the plant.

## (2) Nitrogen :—

Source :—

- The chief source of nitrogen is soil, either in the form of nitrate or ammonical salts, such as sodium nitrate, potassium nitrate, ammonium nitrate etc.
- Some bacteria fix atmospheric nitrogen & make it available to the plant.

Deficiency symptoms :—

- Inhibition of cell-division.
- Chlorosis in older leaves & their yellowing. (because $N_2$ moves rapidly from older to younger leaves.)
- Shortage of nitrogen results in acceleration in the formation of anthocyanin pigments & hence leaves become purple in color.
- Due to reduction in protein, plant growth remains stunted. As a result, cereals do not show characteristic tillering.

Role :— Nitrogen is an essential constituent of different proteins and nucleic acids.

- It is also a constituent of chlorophyll.
- Processes like protein synthesis, role of nucleic acid and chlorophyll synthesis are related to nitrogen.

## (3) Sulphur :-

**Source :-**

- Sulphur is available to plants in the form of soluble sulphates of soil.

**~~Deficiency symptoms~~ :-**

**Role :-**

- Sulphur is constituent of amino acids. (Cysteine & methionine), vitamin $B_1$, ~~and~~ coenzyme A & volatile oils. The characteristic odour of Cruciferous plants, onion & garlic is due to sulphur as constituent of volatile oils.
- Thro' different amino acids, it participates in protein synthesis.
- Sulphur affects an increase in nodule-formation in roots of leguminous plants. It adversely affects chlorophyll synthesis.

**Deficiency symptoms :-**

- Deficiency of 'S' is rare in nature. The deficient plants show symptoms similar to nitrogen deficiency.
- Cell-division is retarded.
- Fruit-formation is suppressed.
- Chlorosis of older leaves.
- Young leaves develop orange, red or purple pigment.
- Leaf fall is rapid.
- The leaf margins & tips roll inwards.

## (4) Phosphorus :-

**Source :-**

- The plants absorb phosphatous in the form of soluble phosphates, such as $H_3PO_4$ & $HPO_4$.

**Role :-**

- Phosphorus is present abundantly in fruits & seeds.
- It is an essential element in plasma membrane, nucleic acids, many coenzymes, ATP, NADP, etc.

**Deficiency symptoms :-**

- Tillering of crop plants is reduced.
- Premature leaf fall takes place.
- Growth is retarded & dead patches appear on petioles, leaves & fruits.
- Purple pigmentation in leaves.
- Flowering is delayed.

## (5) Calcium :-

**Source :-**

- It occurs in soil with variety of minerals.
- The soil derived from stone or chalk rocks contains large percentage of $CaCO_3$, while sandy soil shows Ca deficiency which is met adding lime.

**Role :-**

- A large quantity of Ca is found in leaves & relatively low quantity of it is found in the seeds and fruits.
- Calcium is main constituent of plants as calcium

pectate of middle lamella of cell-wall.
- It is concerned with growing root apices.
- It is not easily transportable, & therefore, its conc.$^{n}$ in older parts is higher than younger parts. It may be the reason for development of early deficiency symptoms at the tips of shoots and growing points.
- It is essential for fat metabolism, formation of membrane, carbohydrate metabolism, binding of nucleic acids, etc.

Deficiency symptoms :-
- Deficiency appears in young leaves & near the growing points of stem & roots.
- Leaf margins become irregular in shape & show brown spots.
- Chlorosis is seen along leaf margins.
- Growing points are killed.

## (6) Potassium :—

Source :-
- Potassium is widely distributed in soil minerals. It is strongly fixed in soil.

Role :-
- Potassium is a constituent of proteins, fats, chlorophyll, carbohydrates, etc.
- It is found in large proportion at growing points & mobile within the plant tissues.
- It is concerned with form$^{n}$ of carbohydrates & proteins, photosynthesis, synthesis of nucleic

acids, & chlorophyll, enzyme action, translocation of solutes, etc.

Deficieney symptoms :-
- Shoots may die back, eventually plant may die.
- Plants may become stunted.
- Little or no flowering.
- Leaves may become dull or bluish green.
- Chlorosis in interveinal regions.
- In older leaves, buring of tips & development of brown spots near margins ~~appear~~ occurs.
- Reduced internodes of stem & reduced productio of grains.

## (7) Magnesium :-

Source :- Mg occurs as carbonates in soil. It is easily leached & for this reason may become deficient in sandy soils during wet periods.

Role :-
- It is a constituent of chlorophyll & therefore, essential for formation of this pigment.
- It is mobile & Transferred from older to young tissues. As a result, deficieney symptoms develop first on older leaves.
- It is essential for synthesis of fats and metabolism of carbohydrates & phosphorus.

Deficiency Symptoms :-
- Deficieney symptoms develop on older leaves and proceed towards younger leaves.

- Chlorosis & defoliation occurs.
- Leaves, sometimes, develop necrotic spots.

## (B) MICRONUTRIENTS :-

### (1) Iron :-

**Source :-** It is present in the form of oxides giving red or brown colour to the soil. In well-irrigated areas, ferric compounds are predominantly found & in water-logged soils, ferrous compounds are formed. It is absorbed in ferric state, but metabolically it is active in ferrous state.

**Role :-**

- Though iron is not a constituent of chlorophyll, yet it is closely concerned with it & probably it plays a role of catalyst.
- Iron also acts as catalyst & electron carrier in respiration.
- It is constituent of cytochromes, ferredoxin, catalase, peroxidase, etc.
- It is immobile in plant tissues & hence its deficiency first develops in younger leaves.

**Deficiency symptoms :-**

- Chlorosis of leaves occurs & younger leaves are most severely affected. Principal veins may remain green.
- Chlorosis may show mottled (spotted) pattern or leaf may show complete bleaching (cause to become white or much lighter by chemical process). In extreme conditions, scorching (stroll) of leaf margins & tips may occur.

(8)

## (2) Manganese :-

**Source :-**

- Oxide forms of manganese are common in soil, but the more highly oxidised forms (manganese dioxide) are of very low availability to plants. Sometimes, oxidising bacteria in soil may make manganese available in soil.

**Role :-**

- Manganese acts as an activator of some oxidases, peroxidases, dehydrogenases, kinases, etc.
- It is essential for formation of chlorophyll.
- It also decreases the solubility of iron by oxidation. Hence, abundance of manganese leads to iron deficiency in plants.

**Deficiency symptoms :-**

- Chlorosis of leaves is most common symptoms.
- Dead tissue spots are found on leaves.
- The tissue may turn ~~brr~~ brown & brown area may wither.
- Root system is poorly developed & plant may die
- Grain formation is reduced.

## (3) Copper :-

**Source :-**

- Copper is found in small quantity in soils.
- Factors affecting its availability to plant are little known, but organic matter, ~~or~~ soil organisms, pH are all important.

Role :-
- Copper is constituent of ascorbic acid oxidase, laccase, tyrosinase, phenoloxidase, plastocyanin, etc.
- It is essential for photosynthesis, respiration, carbohydrate / nitrogen balance.

Deficiency symptoms :-
- Both vegetative & reproductive growth are reduced
- Burning of leaf margins or chlorosis occurs.
- Young leaves wither & show marginal chlorosis
- Heads are dwarfed, distorted & tips are chlorotic.
- Grain formation is restricted.
- Die back disease in Citrus is caused.

## (4) Zinc :-

Source :-
- It is found in soils in very small quantities & largely it results from concentration and addition from growing plants & added residue.

Role :-
- It is component of enzymes like carbonic anhydrogenase, alcohol hydrogenase, lactic dehydrogenase, alkaline phosphatase, etc.
- It is essential for $CO_2$ evolution & utilization, carbohydrate & phosphorus metabolisms and syntheses of RNA & auxins.

Deficiency symptoms :-
- It causes mottle leaf of citrus.

- It also causes little leaf of apples, vines, etc.
- In deficiency symptoms in broad-leaved crops are interveinal chlorosis, redue with pigmentation, reduced leaf size, shortening of internodes, etc.

## (5) Molybdenum :-

Source :- It is found in small amount in soils, but relatively higher concentration occurs in mineral oils & coal ashes.

Role :-
- It is important constituent of nitrate reductase system.
- It acts as an activator for some dehydrogenases & phosphatases & as cofactors in synthesis of ascorbic acid.
- It is necessary for nodule-formation in of legumes for fixation of atmospheric nitrogen.

Deficieney symptoms :-
- Chlorosis in leaves occurs.
- Necrosis of leaf tissue may occur in acute deficiency.
- In oats, failure of grain-formation occurs.
- In cauliflower, whip tail occurs.

dark water spots on leaves in black colour

## (6) Boron :-

Source :- Boron occurs in rocks & marine sediments. It is absorbed in the form of borate ions.

Role :-
- Boron is necessary for translocation of sugars & involved in reproduction & germination of pollen
- It regulates intake of water into the cell.
- It is concerned with nitrogen metabolism.

Deficiency symptoms :-
- Boron deficiency is responsible for several diseases diseases such as "Heart rot of sugar beet and marigold", hollow stem of cauliflower, etc.
- Leaves show white stripe, scorching & curling.
- Stem shows die-back of apex, abnormal tillering curling, etc.
- Flowers are produced in lesser number & steri
- Fruits are deformed & useless.

## (7) Chlorine :-

Souree :-
- Chlorine occurs commonly in soil as chlorides.

Role :- No general statement can be made on the ~~- In tobacco~~ role of chlorine in plant metabolism.
- In tobacco, chlorine increase water content of cells and also affect carbohydrate metabolism.
- Chlorine may speed up photosynthesis in vitro.

Deficiency symptoms :-

- Chlorosis, necrosis & leaf wilting are main deficieney symptoms of chlorine.

# ★ Mineral Salt absorption :-

Plants are in need of mineral salts for various activities. The only source of the minerals is soil. The mineral salts are absorbed by roots, which are in contact with soil. Various theories have been proposed to explain absorption of mineral salts.

## (1) Passive Absorption :-

When the absorption of mineral salts takes place without expenditure of metabolic energy (ATP) & simply by diffusion in plant cells, it is called as passive absorption.

~~Following~~ Mechanism of passive absorption :-

### Ion exchange theory :-

According to this theory, anions or cations adsorbed on the plant cells are exchanged ~~from~~ with the anions or cations of the equivalent charges from the external medium in which tissue is immersed. The process of ion exchange takes place by two methods, as follows :-

(a) Direct ion exchange or contact exchange theory :-

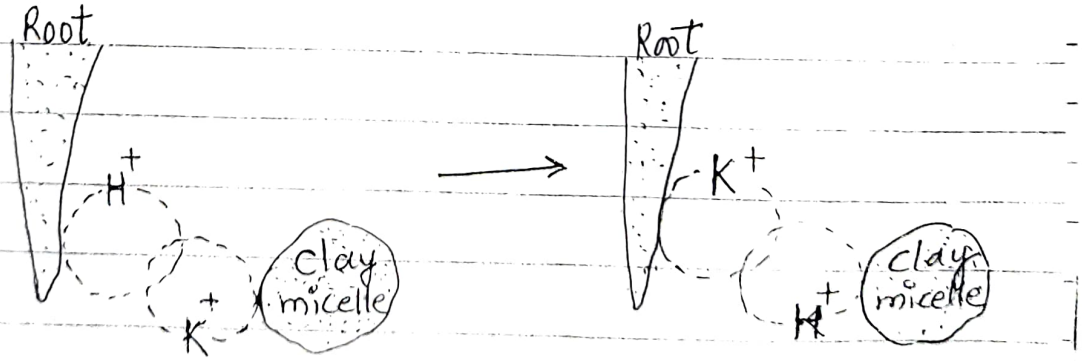



Fig: Diagrammatic representation of the Contact exchange theory

According to this theory, the ions are transferred from soil particles to the root or vice-versa. The ions adsorbed to the surface of root cells or clay particles are not held tightly, but oscillate within the small volume of space. It is termed as oscillation volume. When the oscillation volumes of two ions with the same charge overlap, one ion is exchanged with other. This process is called as contact exchange. The contact exchange of ions takes place not only between soil particles, but also between soil particles & the root surface.

move or swing back and forth in regular rhythm.

Suppose $H^+$ is adsorbed to root cell surface & $K^+$ is adsorbed on the clay micelle & both oscillate in such a way that the oscillation volume of $H^+$ overlaps with that of $K^+$. It will result in the transfer of $H^+$ to the clay micelle & $K^+$ to the root surface.

(b) Indirect ion exchange or Carbonic acid exchange theory :-

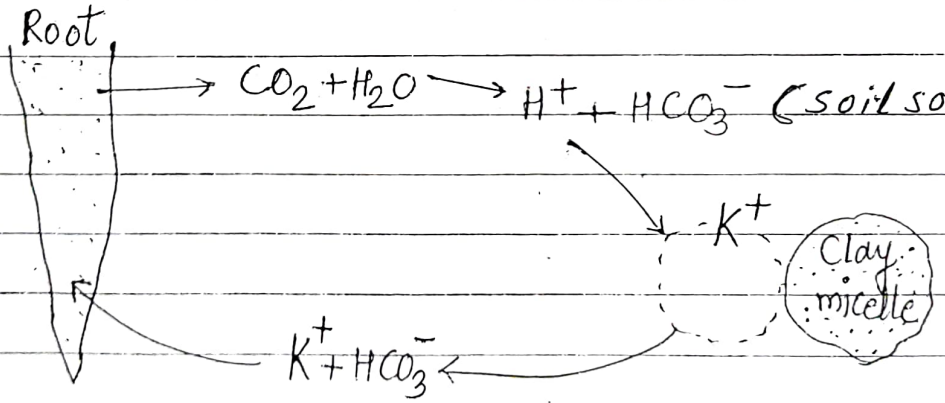



Fig. Diagrammatic representation of the Carbonic acid exchange theory

Positive charge (ion) — cation (ex $H^+$)
Negative " " — Anion (ex $HCO_3^-$)



According to this theory, the $CO_2$ released during respiration of root cells combines with water to form carbonic acid ($H_2CO_3$) in the soil solution. Carbonic acid dissociates into $H^+$ and $HCO_3^-$ (anion). A cation eg. $K^+$, adsorbed on the clay micelle may be exchanged with $H^+$ of the soil solution. This cation ($K^+$) may diffuse to the root surface in exchange for $H^+$ ion.

## (2) Active absorption :-

When the ~~exchange of~~ absorption of mineral salts takes place with the help of metabolic energy, it is called as active absorption.

### Mechanism of active absorption :-

### Carrier Concept theory :- (Honert, 1937)

The cell membrane plays an important role in active absorption. The cell membrane is semi-permeable in nature & allows only selected material to pass through it, & impermeable to other ions. On the membrane surface, certain substances like cytochromes, lipoproteins act as carriers which combine with mineral ions and ion-carrier complex is formed. This complex moves across the membrane and reaches the inner surface of membrane where the complex breaks. Ions are released inside the cell and carrier comes again to the outer surface of cell membrane to receive more ions to repeat every step in this mechanism. The energy requir to the carriers is supplied in the form of ATP. This energy is obtained from respiration & hence active absorption is more prominent in young cells of

growing point, which respire vigorously.

The carrier concept theory has following supports :—

(i) Several workers used radioactive ions to ~~study~~ study carrier concept. They found that, the ions failed to diffuse through a cell membrane. This fact implies that, the diffusion might be accomplished by ~~some~~ the carriers.

(ii) It has been observed that, the rate of absorption of ions does not increase beyond a maximum level, even if the concentration is increased very much. This is supposed ~~to~~ to be due to presence of limited carriers.

~~(iii) The~~

## ★ Translocation of organic solutes. :—

Plants are autotrophs and synthesize their own food. The food is manufactured in green cells of leaves. It is stored in various storage organs of the plant. These two parts (leaves & storage organs) of plant act as the supply end (source) of the food material. The food is translocated rapidly from supply ends (source) to different parts of plants (Sink) for consumption & utilization in metabolic process.

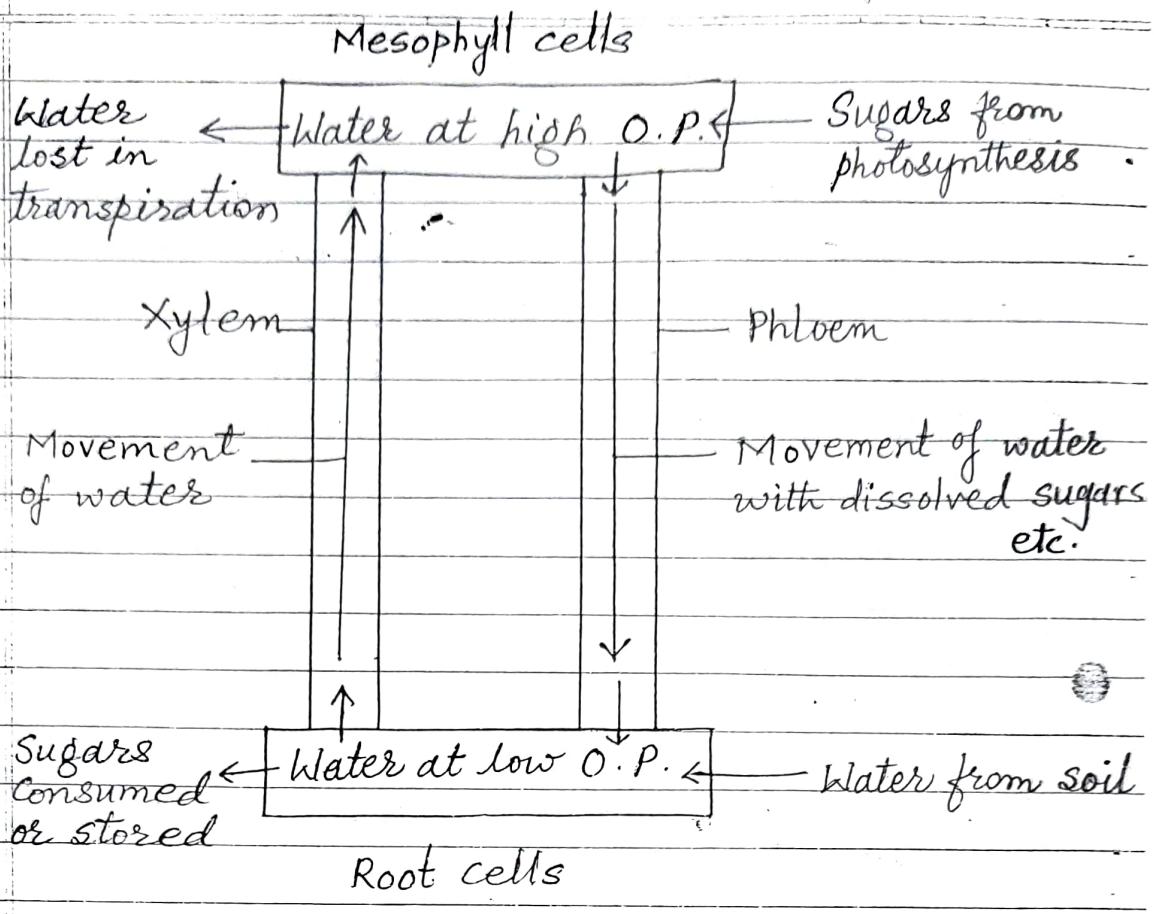
"Movement of solutes from one part of the plant to another is called as translocation or transport." "Transport of sugar in sieve tubes is called translocation".

### Mechanism of translocation :—

### Munch Mass Flow Hypothesis / Pressure Flow Theory

① This hypothesis was proposed by Munch. (1930). According to this theory, the protoplast of a row of sieve tubes is connected with each-other by means of plasmodesmata forming a continuous system 'symplast'. It enables the solute to flow as 'mass' under certain conditions.

According to the hypothesis, when food is manufactured in leaf, the osmotic pressure of mesophyll cells is very much increased. This causes absorption of water from the xylem elements of the leaf, resulting in the increase of their turgour pressure. This succeeds in forcing some of the cell solution into & down the sieve tubes. The osmotic potential in the phloem falls. On the other




Fig(a) Diagrammatic representation of Munch Mass flow hypothesis.

hand, in the cells of the root or the storage organs, the food is either consumed or is converted into insoluble forms. This decreases their osmotic pressure & consequently, their turgour pressure also gets lowered. Under the conditions mentioned above, a Turgour pressure gradient is established ~~in~~ between the supply end in the leaf (source) & the consumption end in the root (sink) and therefore, a "mass flow" of water (containing dissolved solutes) / food solution takes place in the phloem from the upper end to the lower end of the plant. At the consumption end, water diffuses out into the xylem elements of the root due to the lowering of osmotic pressure & will be Translocated to the leaf through xylem

to be available to the mesophyll cells again. A sort of cyclic circulatory system is formed as shown in figure (a).

The principle of "mass flow" can be illustrated with the help of a simple experiment. The two chambers with semipermeable walls 'A' and 'B' are connected by a tube 'C' containing water to form a closed system. [Fig (b)].

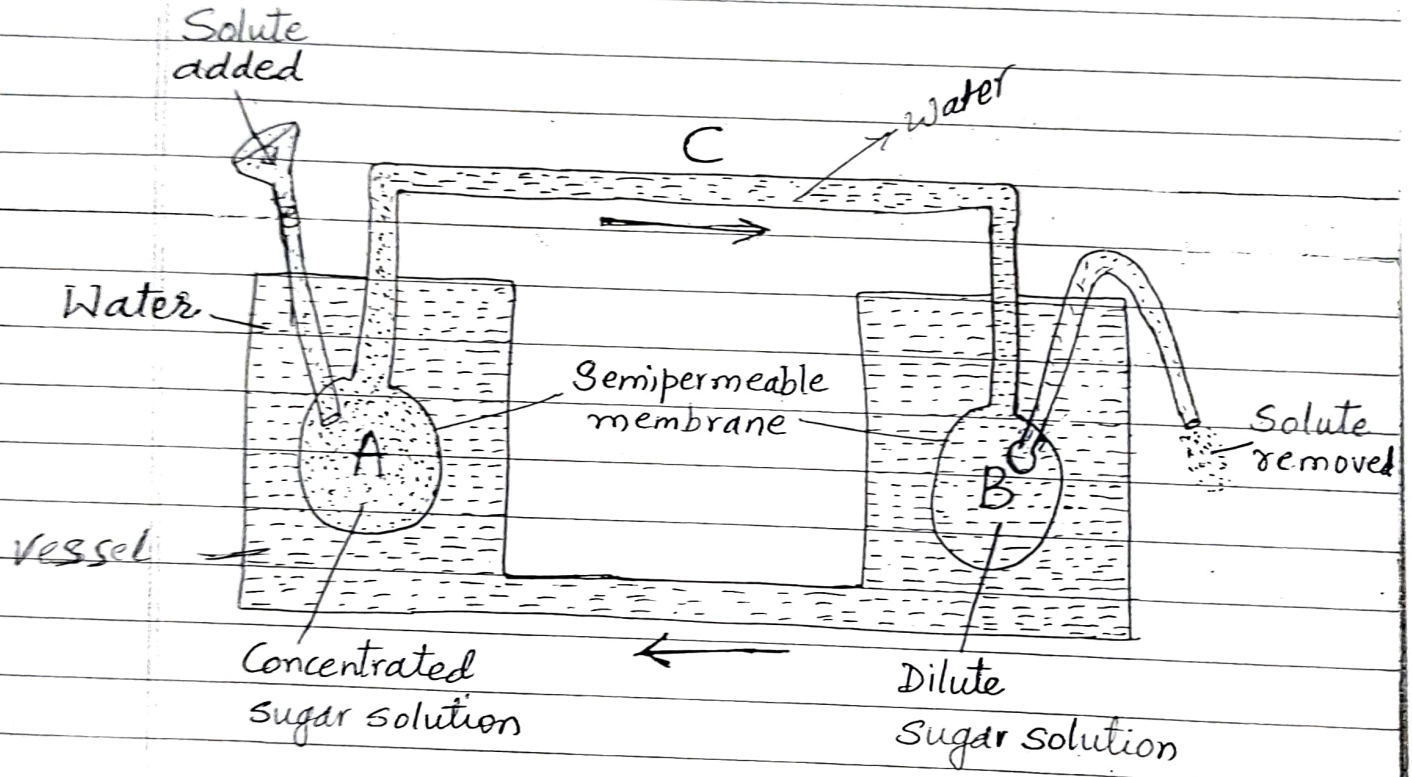



Fig (b) Experimental representation of Munch Mass flow hypothesis.

Chamber 'A' contains highly concentrated sugar solution, while chamber 'B' contains dil. sugar sol. The system is dipped in a water-filled vessel. Chamber 'A' corresponds with the supply end in the leaf, chamber 'B' corresponds with the receiving end in the root & tube 'C' corresponds with the longitudinal sieve tube system.

The outer vessel corresponds with the xylem elements. The concentrated sugar solution in chamber 'A' will cause rapid diffusion of water into it, resulting into the development of very high turgour pressure gradient till the solutions in both the chambers attain the same concentration, at which the process will come to a stop. If however, sugar could be continuously added to the chamber 'A' and removed from the chamber 'B', a continuous mass flow of solution will take place from 'A' to 'B' through the tube 'C'. On reaching the chamber 'B', water will diffuse out into the vessel and can again pass through it to chamber 'A'. An analogous situation is found in plants.

The strongest evidence in favour of the hypothesis comes from the fact that, sap exudation containing high sugar content takes place at a rapid rate from a cut made into the phloem of woody or herbaceous stem for a period of more than 24 hours. This suggests that mass flow of sap occurs under pressure in the phloem elements of intact stems.

## Hydroponic technique

- The science of soil-less gardening is called hydroponics.
- It basically involves growing healthy plants without the use of a traditional soil medium by using a nutrient like a mineral rich water solution.
- The term hydroponics has been used for growth of plants in water and sand cultures.
- The terms soil less agriculture, test-tube farming, tank farming have also been used.
- Commercially hydroponic cultures are maintained in large shallow tanks made up of concrete, cement, wood or metal-sheets.
- The hydroponics have been used for the production of horticultural and floricultural crops. The gardeners are utilizing hydroponic methods in such localities where good soil is not available.

### * Advantages of Hydroponics

- It is possible to provide whatever nutrient environment is desirable.
- This method is cheaper and more favourable medium than soil for growing plants.
- The nutrition can be changed at any time to coordinate with fluctuations in the weather, especially changes in light and temperature.
- The equipment can be made automatic, avoiding the labour charges and expense of watering the plants.

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- By using pumping devices, the solutions may be circulated, thus enabling regularity of aeration.
- mulching, changing of soil and weeding are eliminated.

* Disadvantages of Hydroponics.

- As compared with field production, production by hydroponics is limited.
- In the economic sense, its use under greenhouse conditions is generally limited to high-value crops.
- considerable technical skill is required to design equipment and handle its problems.
- If a disease appears, it may affect all plants in the container because circulation of the nutrient solution tends to spread pathogenic organisms to the roots of all plants.

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# * Foliar Nutrition

- Foliar nutrition or feeding is a technique of feeding plants by applying liquid fertilizer directly to the leaves.
- Plants are able to absorb essential elements through their leaves. The absorption of nutrients takes place through the stomata of leaves and also their epidermis.
- In this method, first the dilute solution of soil deficient minerals is prepared and then sprayed over the young leaves of the plants. These minerals are absorbed by the surface of leaves.
- Foliar feeding is generally done in the early morning or late evening, preferably at temperatures below 24°C, because heat causes the pores on leaves to close.
- The term foliar feeding was put forward by H.B. Tukey, head of Michigan state University in 1950.
- Foliar feeding maintains a nutrient balance within the plant quickly as compared to nutrition by roots.
- Foliar feeding provides fast, on the spot nutrition to ensure high yields in plants.

# Translocation of solutes

## ★ Mass flow hypothesis / pressure flow theory

- proposed by Munch (1930)
- According to this theory, the protoplast of a row of sieve tubes is connected with each other by means of plasmodesmata forming a continuous system 'symplast'.
- It enables the solute to flow as 'mass'.
- According to the hypothesis, when food is manufactured in leaf, the osmotic pressure of mesophyll cells

→ osmotic pressure of mesophyll cells increased.
→ due to this absorption of water from the xylem elements of the leaf / resulting in the increase of ~~their~~ (mesophyll cells) turgour pressure.
→ Therefore forcing some of the cell sap into and down the sieve tubes. / osmotic potential falls in the phloem

Phloem components — sieve tubes, phloem parenchyma, companion cells, phloem fibres

1) Osmosis :- A process by which molecules of a solvent tend to pass through a semipermeable membrane from a less concentrated soln into a more concentrated one.
2) Osmotic pressure - the pressure that would have to be applied to a pure solvent to prevent it from passing into a given soln by osmosis.
3) Turgor pressure :- is the force within the cell that pushes the plasma membrane against the cell wall.
4) Osmotic potential :- The potential of water molecules to move from a hypotonic soln (more water, less solutes) to a hypertonic soln (less water, more solutes) across a semipermeable membrane.
5) Turgor pressure gradient :-

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