PLANT NUTRITION

Introduction

Organism require many organic and inorganic substances to complete their life cycle. All such substances which they take from outside constitute their nutrition. On the basis of their nutritional requirements, organisms can be classified into autotrophs and heterotrophs. Autotrophs are those organisms which manufacture their organic food by themselves and require only inorganic substance from outside. Thus the nutrition of plants is only inorganic. All green plants (except for some saprophytes and parasites) and photosynthetic bacteria are autotrophs. The heterotrophs, on the other hand, require both organic and inorganic substances from outside. All non-green plants and animals, including human beings, are heterotrophs.

Autotrophic green plants obtain their nutrition from inorganic substances which are present in soil in the form of minerals, which are known as **mineral elements** or **mineral nutrients** and this nutrition is called **mineral nutrition**.

4.1 Essential mineral elements

A variety of mineral elements is present in the soil but all of them are not essential for plants growth. Besides, a particular element may be needed for the growth of one plant and may not be required at all by other plants. An essential element is defined as 'one without which the plant cannot complete its life cycle, or one that has a clear physiological role'. Therefore, in 1939 **Arnon** and **Stout** proposed the following characters for judging the criteria of essentiality of an element in the plant :

- The element must be essential for normal growth and reproduction, which cannot proceed without it.
- The requirement of the element must be specific and cannot be replaced by another element.
- The requirement must be direct that is, not the result of any indirect effect *e.g.* for relieving toxicity caused by some other substance.

Essential elements are divided into two broad categories, based on the quantity in which they are required by plants. Macro-elements and micro-elements. Their ionic forms are respectively called macronutrients and micronutrients. Cations may be absorbed on the surface of negatively charged clay particles. Anions (*e.g.*, nitrate, phosphate, chloride, sulphate, borate) are held to soil particles to a lesser extent. Mineral salts dissolved in soil solution are constantly passing downwards along with percolating (gravitational) water. The phenomenon is called **leaching**. Leaching is more in case of anions.

(1) **Macronutrients (Macroelements or major elements) :** Which are required by plants in larger amounts (Generally present in the plant tissues in concentrations of 1 to 10 *mg per* gram of dry

matter). The macronutrients include carbon, hydrogen, oxygen, nitrogen, phosphorous, sulphur, potassium, calcium, magnesium.

(2) **Micronutrients (Microelements or minor elements or trace elements) :** Which are required by plants in very small amounts, *i.e.*, in traces (equal to or less than 0.1 *mg* per gram dry matter). These include iron, maganese, copper, molybdenum, zinc, boron and chlorine. Recent research has shown that some elements, such as cobalt, vanadium and nickel, may be essential for certain plants.

The usual concentration of essential elements in higher plants according to D.W. Rains (1976) based on the data of Stout are as follows :

Element	**% of dry weight**
Carbon	45
Oxygen	45
Hydrogen	6
Nitrogen	1.5
Potassium	1.0
Calcium	0.5
Magnesium	0.2
Phosphorus	0.2
Sulphur	0.1
Chlorine	0.01
Iron	0.01
Manganese	0.005
Boron	0.002
Zinc	0.002
Copper	0.0001
Molybdenum	0.0001

4.2 Plant analysis

(1) **Ash analysis :** This is the simplest method. The plant tissue is subjected to a very high temperature (550-600°C) in an electric muffle furnace and is reduced to ash. The organic matter of the plant is completely oxidised. All carbon, hydrogen and oxygen molecules in the tissue are converted into carbon dioxide and water, both of which escape into the atmosphere as vapours. Besides some nitrogen is also lost as nitrogen gas and ammonia. The plant ash left behind forms a very small proportion of plants dry weight ranging from 2 to 10% only. Analysis of plant ash shows that about 92 mineral elements are present in different plants. Out of these, 30 elements are present in each and every plants and rest are in one or other plants. Out of these 30 elements, **16 elements** are necessary for plants and are called **essential elements**. The ash is chemically analysed to determine these elements.

(2) **Solution culture (Hydroponics) :** In this method plants are grown in nutrient solutions containing only desired elements. To determine the essentiality of an element for a particular plant, it is grown in a nutrient medium that lacks or is deficient in this element.

If the plant grows normally, it indicates that the element is not essential. However, if the plant shows deficiency symptoms then it indicates that the element is essential for that particular plant.

The growing of plants with their roots in dilute solutions of mineral salts instead of soil led to increased understanding of plant nutrition. This cultivation of plants by placing the roots in nutrient solution is called hydroponics. Probably the first recorded use of soilless culture was by **Woodward** in 1699. In early nineteenth century, plants were grown with their roots immersed in water solutions with inorganic salts alone, without the addition of soil or organic matter. By 1860, the culture solution technique was modernized by **Sachs** and he showed the essentiality of nitrogen for plant growth. Another significant worker for studying the essentiality of elements was **Knop** (1865). The method of growing plants in aqueous nutrient solutions as employed by Sachs and Knop is used experimentally and commercially today and known as hydroponic culture. The nutrient solution composition proposed by Knop (1865) and Arnon and Hoagland's (1940) are commonly used. Arnon and Hoagland's nutrient medium has the advantage, that it contains micro-nutrients also. Iron was added in the form of ferrous sulphate which often precipitated out. Now a days a chelating agent Na^2-EDTA (Disodium salt of ethylene diamine tetra acetic acid. EDTA is a buffer which is used in tissue cultures) is added.

Hydroponics or soilless culture helps in knowing

(i) The essentiality of mineral element.

(ii) The deficiency symptoms developed due to non-availability of particular nutrient.

(iii) Toxicity to plant when element is present in excess.

(iv) Possible interaction among different elements present in plant.

(v) The role of essential element in the metabolism of plant.

(3) **Solid medium culture :** In this method either sand or crushed quartz is used as a rooting medium and nutrient solution is added to it. The nutrient medium is provided by one of the following methods :

(i) **Drip culture :** It is done by dripping over the surface.

(ii) **Slop culture :** It is done by having the medium over the surface.

(iii) **Sub-irrigation :** Here the solution is forced up from the bottom of the container.

4.3 MAJOR ROLE OF NUTRIENTS

Various elements perform the following major role in the plants :

(1) **Construction of the plant body :** The elements particularly C, H and O construct the plant body by entering into the constitution of cell wall and protoplasm. They are, therefore, referred to as **frame work elements**. Besides, these (C, H and O) N, P and S also enter in the constitution of protoplasm. They are described as **protoplasmic elements**.

(2) **Maintenance of osmotic pressure :** Various minerals present in the cell sap in organic or inorganic form maintain the osmotic pressure of the cell.

(3) **Maintenance of permeability of cytomembranes :** The minerals, particularly Ca^{++}, K^{+} and Na^{+} maintain the permeability of cytomembranes.

(4) **Influence the pH of the cell sap :** Different cations and anions influence on the *pH* of the cell sap.

(5) **Catalysis of biochemical reaction :** Several elements particularly *Fe, Ca, Mg, Mn, Zn, Cu, Cl* act as metallic catalyst in biochemical reactions.

(6) **Toxic effects :** Minerals like *Cu, As,* etc. impart toxic effect on the protoplasm under specific conditions.

(7) **Balancing function :** Some minerals or their salts act against the harmful effect of the other nutrients, thus balancing each other.

4.4 SPECIFIC ROLE OF MACRONUTRIENTS

The role of different elements is described below :

(1) **Carbon, hydrogen and oxygen :** These three elements, though can not be categorised as mineral elements, are indispensible for plant growth. These are also called **'framework elements'**. Carbon, hydrogen and oxygen together constitute about 94% of the total dry weight of the plant. Carbon is obtained from the carbon dioxide present in the atmosphere. It is essential for carbohydrate and fat synthesis. Hydrogen and oxygen would be obtained from water which is absorbed by the plants from the soil. Some amount of oxygen is also absorbed from the atmosphere.

(2) **Nitrogen**

(i) **Source :** The chief source of nitrogen for green plants is the soil. It is absorbed mainly in the form of nitrate ions (NO_3^-). The major sources of nitrate for the plants are sodium nitrate, potassium nitrate, ammonium nitrate and calcium nitrate. Under suitable conditions, ammonium ions (NH_4^+) may substitute for nitrate ions, being easily absorbed by plants. Ordinary green plants cannot utilize elemental nitrogen which constitutes about 79% of the air. It is also trapped by nitrogen fixing bacteria which live symbiotically in root nodules of the plants.

(ii) **Functions :** Nitrogen is an essential constituent of proteins, nucleic acids, vitamins and many other organic molecules as chlorophyll. Nitrogen is also present in various hormones, coenzymes and

ATP etc. It plays an important role in protein synthesis, respiration, growth and in almost all metabolic reactions.

(iii) **Deficiency symptoms :** The symptoms of nitrogen deficiency are as follows :

(a) Impaired growth

(b) Yellowing of leaves due to loss of chlorophyll, *i.e.*, **chlorosis**.

(c) Development of anthocyanin pigmentation in veins, sometimes in petioles and stems.

(d) Delayed or complete suppression of flowering and fruiting.

Excessive supply of nitrogen produces following symptoms :

(a) Increased formation of dark green leaves.

(b) Poor development of root system.

(c) Delayed flowering and seed formation.

(3) **Phosphorus**

(i) **Source :** Phosphorus is present in the soil in two general forms, organic and inorganic. Plants do not absorb organic phosphorus, either from the solid or solution phase of soil. However, organic compounds are decomposed and phosphorus is made available to plants in inorganic form. Soil solution contains phosphorus in inorganic forms as the phosphate ions $H_2PO_4^-$ and HPO_4^{2-}. When *pH* is low phosphate ions are present in the form of $H_2PO_4^-$. When *pH* is high, phosphate ions are represented in HPO_4^{2-}.

(ii) **Functions**

(a) Phosphorous is present abundantly in the growing and storage organs such as fruits and seeds. It promotes healthy root growth and fruit ripening by helping translocation of carbohydrates.

(b) It is present in plasma membrane, nucleic acid, nucleotides, many coenzymes and organic molecules as ATP.

(c) Phosphorus plays an indispensable role in energy metabolism *i.e.*, hydrolysis of pyrophosphate and various organic phosphate bonds being used to drive chemical reactions. Thus it is required for all phosphorylation reactions.

(iii) **Deficiency symptoms**

(a) Leaves become dark green or purplish.

(b) Sometimes development of anthocyanin pigmentation occurs in veins which may become necrotic (**Necrosis** is defined as localised death of cells).

(c) Premature fall of leaves.

(d) Decreased cambial activity resulting in poor development of vascular bundles.

(e) Root and shoot growth is checked.

(f) Prolonged dormancy.

(g) Sickle-leaf disease.

(4) **Sulphur**

(i) **Source :** Sulphur is present as sulphate SO_4^{2-} in mineral fraction of soil. It is also found in *FeS* and FeS_2 forms, which are not available to plants. In industrialized areas, atmospheric sulphur dioxide (SO_2) and sulphur trioxide $(SO_3$; in low concentration) may be important sources of sulphur nutrition.

(ii) **Functions**

(a) Sulphur is a constituent of amino-acids like cystine, cysteine and methionine; vitamins like biotin and thiamine, and coenzyme A.

(b) It increases the nodule formation in the roots of leguminous plants. It favours soluble organic nitrogen and there is decrease in the quantity of soluble nitrogen with its increase.

(c) The characteristic smell of mustard, onion and garlic is due to the presence of sulphur in their volatile oils.

(d) Sulphur in plants is required in stem and root tips and young leaves. It is remobilised during senescence.

(iii) **Deficiency symptoms**

(a) Leaves remain small and turn pale green *i.e.*, symptoms of chlorosis. Chlorosis affects young leaves more because of immobile property of the sulphur. The young leaves develop orange, red or purple pigment.

(b) Leaf tips and margins roll downwards and inwards *e.g.*, tobacco, tea and tomato.

(c) Premature leaf fall.

(d) Delayed flowering and fruiting.

(e) Apical growth is retarded whereas premature development of lateral buds starts.

(f) The tea yellow disease is caused in tea plants.

(g) Decrease in stroma lamellae and increase in grana stacking.

(h) Increase in starch and sucrose accumulation, and decrease in reducing sugars.

(5) **Potassium**

(i) **Source :** Source of K^+ to the plants is inorganic compounds like potassium sulphate, potassium nitrate, etc. Potassium is usually present in sufficient amount in clay soils, where it is firmly bound (largely as an exchangeable base). It is prevalent cation in plants and may be involved in the maintenance of ionic balance in cells. It contains approximately 0.3 to 6.0 percent of whole plant. In seeds, it is found in less amount.

(ii) **Functions**

(a) It differs from all other macronutrients in **not being a constituent** of any metabolically important compound.

(b) It is the **only monovalent cation** essential for the plants.

(c) It acts as an activator of several enzymes including DNA polymerase.

(d) It is essential for the **translocation** of photosynthates, opening and closing of **stomata**, phosphorylation, synthesis of nucleic acid and chlorophyll.

It takes part in the formation of cell membrane and it is also responsible for maintenance of turgidity of cells. It is considered that whole of potassium in plant is found in soluble form and most of it is contained in cell sap and cytoplasm.

(iii) **Deficiency symptoms**

(a) **Mottled chlorosis** followed by the development of necrotic areas at the tips and margins of the leaves.

(b) K^+ deficiency inhibits proteins synthesis and photosynthesis. At the same time, it increases the rate of respiration.

(c) The internodes become shorter and root system is adversely affected.

(d) The colour of leaves may turn bluish green.

(e) Widespread blackening or scorching of leaves may occur as a result of increased tyrosinase activity.

(f) Rosette or bushy habit of growth may be seen in plants.

(g) Reduction of stem growth, weakening of stem.

(h) Lowered resistance to pathogens.

Destruction of pith cells of tomato and increased differentiation of phloem elements.

(6) **Calcium**

(i) **Source :** The element is abundant in most soils and plants under natural conditions are seldom deficient in it. It is absorbed by the plants in the form of Ca^{2+} from calcium carbonate etc. It occurs abundantly in a non-exchangeable form such as anorthite $(CaAl_2.Si_2O_8)$. Much of the exchangeable calcium of the soil is absorbed onto the surface of clay micelle.

(ii) **Functions**

(a) It is necessary for formation of middle lamella of plants where it occurs as calcium pectate.

(b) It is necessary for the growth of apical meristem and root hair formation.

(c) It acts as activator of several enzymes, *e.g.*, ATPase, succinic dehydrogenase, adenylate kinase, etc.

(d) Along with Na^+ and K^+ it maintains the permeability of plasma membrane.

(e) It is involved in the organisation of spindle fibres during mitosis.

(f) It antagonises the toxic effects of Na^+ and Mg^{++}.

It is essential for fat metabolism, carbohydrate metabolism, nitrate assimilation and binding of nucleic acids with proteins.

(iii) **Deficiency symptoms**

(a) Ultimate death of meristems which are found in shoot, leaf and root tips.

(b) Chlorosis along the margins of young leaves, later on they become necrotic.

(c) Distortion in leaf shape.

(d) Roots poorly developed or may become gelatinous.

(e) Young leaves show malformation and leaf tips becomes hooked.

(f) Its deficiency checks flowering and causes the flowers to fall early.

(7) **Magnesium**

(i) **Source :** Magnesium occurs in the soil in the form of magnesite ($MgCO_3$), dolomite ($MgCO_3$, $CaCO_3$), magnesium sulphate ($MgSO_4$) and as silicates. It is absorbed from the soil in the form of (Exchangeable cation) ions (Mg^{++}). It is easily leached and thus become deficient in sandy soils during rainy season.

(ii) **Functions**

(a) It is an important constituent of **chlorophyll**.

(b) It is present in the **middle lamella** in the form of magnesium pectate.

(c) It plays an important role in the metabolism of carbohydrates, lipids and phosphorus.

(d) It acts as **activator** of several enzymes.

(e) It is required for binding the larger and smaller subunits of **ribosomes** during protein synthesis.

(f) It is readily mobile and when its deficiency occurs, it is apparently transferred from older to younger tissues, where it can be neutralised in growth processes.

(iii) **Deficiency symptoms**

(a) **Interveinal** chlorosis followed by anthocyanin pigmentation, eventually necrotic spots appear on the leaves. As magnesium is easily transported within the plant body, the deficiency symptoms first appear in the mature leaves followed by the younger leaves at a later stage.

(b) Stems become hard and woody, and turn yellowish green.

(c) Depression of internal **phloem** and extensive development of **chlorenchyma**.

4.5 Specific role of micronutrients

(1) **Iron**

(i) **Source :** It is present in the form of oxides in the soil. It is absorbed by the plants in ferric as well as ferrous state but metabolically it is active in ferrous state. Its requirement is intermediate between macro and micro-nutrients. Therefore, sometimes it is also considered as a macronutrients.

(ii) **Functions :** (a) Iron is a structural component of ferredoxin, flavoproteins, iron prophyrin proteins (Cytochromes, peroxidases, catalases, etc.)

(b) It plays important roles in energy conversion reactions of photosynthesis (phosphorylation) and respiration.

(c) It acts as activator of nitrate reductase and aconitase.

(d) Although iron is not a component of the chlorophyll molecules, it is essential for the synthesis of chlorophyll.

(iii) **Deficiency symptoms**

(a) Chlorosis particularly in younger leaves, the mature leaves remain unaffected. (b) It inhibits chloroplast formation due to inhibition of protein synthesis. (c) Stalks remain short and slender. (d) Extensive interveinal white chlorosis in leaves. (e) It may develop necrosis aerobic respiration severely affected. (f) In extreme deficiency scorching of leaf margins and tips may occur.

(2) **Manganese**

(i) **Source :** Like iron, the oxide forms of manganese are common in soil. However, manganese dioxide (highly oxidised form) is not easily available to plants. It is absorbed from the soil in bivalent form (Mn^{++}). Increased acidity leads to increase in solubility of manganese. In strong acidic soils, manganese may be present in toxic concentrations. Oxidising bacteria in soils render manganese unavailable to plants at *pH* ranging from 6.5 to 7.8.

(ii) **Functions**

(a) It acts as activator of enzymes of respiration (malic dehydrogenase and oxalosuccinic decarboxylase) and nitrogen metabolism (nitrite reductase).

(b) It is essential for the synthesis of chlorophyll.

(c) It is required in photosynthesis during photolysis of water.

(d) It decreases the solubility of iron by oxidation. Hence, abundance of manganese can lead to iron deficiency in plants.

(iii) **Deficiency symptoms :** (a) Chlorosis (interveinal) and necrosis of leaves. (b) Chloroplasts lose chlorophyll, turn yellow green, vacuolated and finally perish. (c) Root system is poorly developed. (d) Formation of grains is badly affected.

(e) **'Grey spot disease'** in oat appears due to the deficiency of manganese, which leads to total failure of crop.

(f) **'Marsh spot's** in seeds of pea. (g) Deficiency symptoms develop in older leaves.

(3) **Copper**

(i) **Source :** Copper occurs in almost every type of soil in the form of complex organic compounds. A very small amount of copper is found dissolved in the soil solution. The bivalent copper cation Cu^{2+} is available in plants in exchangeable forms. It is found in natural deposits of chalcopyrite ($CuFeS_2$).

(ii) **Functions**

(a) It activates many enzymes and is a component of phenolases, ascorbic acid oxidase, tyrosinase, cytochrome oxidase.

(b) Copper is a constituent of plastocyanin, hence plays a role in photo-phosphorylation.

(c) It also maintains carbohydrate nitrogen balance.

(iii) **Deficiency symptoms**

(a) Both vegetative and reproductive growth are reduced.

(b) The most common symptoms of copper deficiency include a disease of fruit trees called '**exanthema**' in which trees start yielding gums on bark and '**reclamation of crop plants**', found in cereals and legumes.

(c) It also causes necrosis of the tip of the young leaves (*e.g.*, *Citrus*). The disease is called **'die back'**.

(d) Carbon dioxide absorption is decreased in copper deficient trees.

(e) Wilting of entire plant occurs under acute shortage.

(f) Grain formation is more severely restricted than vegetative growth.

(4) **Molybdenum**

(i) **Source :** Molybdenum occurs in the soil in three forms – dissolved, exchangeable and nonexchangeable forms. It is available to the plants mostly as molybdate ions. It is required in extremely small quantities by plants. It is found relatively in higher concentration in mineral oil and coal ashes.

(ii) **Functions**

(a) Its most important function is in nitrogen fixation because it is an activator of **nitrate reductase**.

(b) It is required for the synthesis of ascorbic acid.

(c) It acts as activator of some dehydrogenases and phosphatases.

Deficiency symptoms

(a) Mottled chlorosis is caused in the older leaves as in nitrogen deficiency, but unlike nitrogen-deficient plants, the cotyledons stay healthy and green.

(b) It is also known to inhibit flowering, if they develop, they fall before fruit setting.

(c) It leads to drop in concentration of ascorbic acid.

(d) Its deficiency causes **'whiptail disease'** in cauliflower and cabbage. The leaves first show an interveinal mottling and the leaf margins may become gray and flaccid and finally brown.

(5) **Zinc**

(i) **Source :** Zinc occurs in the soil in the form of ferromagnesian minerals like magnetite, biotite and hornblende. When weathering of these minerals takes place, zinc is liberated in bivalent Zn^{2+} form. Increase in soil *pH* decreases the availability of zinc.

Bivalent form of zinc (Zn^{++}) is exchangeable and is readily available in the soil. Plants require this mineral only in traces and its higher concentrations are highly toxic.

(ii) **Functions :** (a) It is required for the synthesis of tryptophan which is a precursor of indole acetic acid-an auxin.

(b) It is a constituent of enzymes like carbonic anhydrase, hexokinase, alcohol dehydroge-nase, lactic dehydrogenase and carboxypeptidase.

(c) It is required for metabolism of phosphorus and carbohydrates.

(d) Zinc also appears to play an important role in protein synthesis because in its absence there is substantial increase in soluble nitrogenous compounds.

(iii) **Deficiency symptoms :** (a) The first symptom appears in the form of interveinal chlorosis of the older leaves, starting at the tips and the margins.

(b) Growth becomes stunted due to formation of smaller leaves and shortened internodes. Reduced stem growth is due to less synthesis of auxin.

(c) The leaves become distorted and sickle shaped and get clustered to form rosettes. This effect is known as **'little leaf disease'**.

(d) In maize, zinc deficiency produces **'white bud disease'** which leads to greatly reduced flowering and fruiting as well as poorly differentiated root growth.

(e) Its deficiency causes **khaira disease** of rice and mottled leaf of apple, *Citrus* and walnut.

(6) **Boron**

(i) **Source :** Boron is present in the soil in very small amounts. It appears in exchangeable soluble and nonexchangeable forms in the soil BO_3^{3-} or $B_4O_7^{2}$. It occurs in highly complex forms such as borosilicates, boric acids and calcium and manganese borates. It is absorbed from the soil as boric acid (H_3BO_3) and tetraborate anions. Its calcium and magnesium salts are soluble. Its availability to plant decreases with increase in *pH*.

(ii) **Functions**

(a) It facilitates the translocation of sugars.

(b) It is involved in the formation of pectin.

(c) It is also required for flowering, fruiting, photosynthesis and nitrogen metabolism.

(d) Boron is required for uptake and utilisation of Ca^{2+}, pollen germination, seed germination and cell differentiation.

(e) It regulates cellular differentiation and development.

(iii) **Deficiency symptoms**

(a) The first major symptom of boron deficiency is the death of shoot tip because boron is needed for DNA synthesis.

(b) Generally flowers are not formed and the root growth is stunted.

(c) The leaves develop a thick coppery texture, they curve and become brittle.

(d) Some of the physiological diseases caused due to boron deficiency are **internal cork of apple, top rot of tobacco, cracked stem of celery, browning of cauliflower water core of turnip, hard fruit of Citrus and heart rot of sugar beets and marigold**. These diseases can be cured by application of small doses of sodium tetraborate in the soil.

(e) Fruits when affected are severely deformed and useless.

(f) Its deficiency checks the cells division of cambium but continues cell elongation.

(7) **Chlorine**

(i) **Source :** It is absorbed from the soil as chloride ions. It is required in very small amounts and almost all types of soils contain enough chlorine for the plants. Hence, it is rarely supplied as fertilizer.

(ii) **Functions**

(a) It is required for photolysis of water during photosynthesis in photosystem-II.

(b) In tobacco, it increases water volume inside the cell and also regulates carbohydrate metabolism.

(c) With Na^+ and K^+, chlorine helps in determining solute concentration and anion cation balance in the cells.

(d) It is essential for oxygen evolution in photosynthesis.

(iii) **Deficiency symptoms :** (a) The deficiency symptoms of chlorine consist of wilted leaves which later become chlorotic and finally attain a bronze colour.

(b) Roots become stunted or thickened and club shaped and fruiting is reduced.

(c) Photosynthesis is also inhibited.

4.6 Mechanism of absorption of mineral elements

Plants absorb the minerals from the soil and translocate them to other parts of the body. Soil serves as a main source of mineral salts in which clay crystals with a central nucleus is called **micelle**. The micelles are negatively charged. To maintain the balance, they hold positively charged ions on their surface. When this balance is disturbed by salt absorption, the equilibrium is again restored by transferring some of the absorbed ions into the solution. The movement of ions is called as **flux**. The movement of ions into the cell is called **influx** and outward migration of ions is known as **efflux**.

Various theories have been proposed to explain the mechanism of mineral salt absorption and can be placed under the following two categories.

(1) Passive absorption

(2) Active absorption

(1) **Passive absorption :** Absorption of ions without the use of metabolic energy is known as passive absorption. This type of absorption is carried out by purely physical forces.

In most of the cases, the movement of mineral ions into root occurs by diffusion. Diffusion of molecules is their net movement down a free energy or chemical potential gradient. The rate of diffusion varies with the chemical potential gradient or the difference in activity (essentially equivalent to concentration) across the diffusion distance.

Briggs and Robertson (1957) demonstrated the passive absorption of ions by root system. They showed :

- Mineral salt absorption is not affected by temperature and metabolic inhibitors.

- Rapid uptake of ions occurs when plant tissues are transferred from a medium of low concentration to high concentration.

Some of the important theories explaining the mechanism of passive absorption of minerals are given below :

(i) **Mass flow hypothesis :** According to **Hylmo** (1953, 1955), the ion absorption increases with increase in transpiration. The ions have been considered to move in a mass flow with water from the soil solution through the root and eventually to the shoot. The theory was supported by **Kramer** (1956), **Russel** and **Barber** (1960), etc. Later, **Lopushinsky** (1960) using radioactive P^{32} and Ca^{45}, has supported this experiment.

(ii) **Simple diffusion hypothesis :** According to this hypothesis, if the concentration of solutes inside the plant is lower than the soil, the mineral ions are thought to migrate into the root by simple diffusion. As a result, a state of equilibrium is reached. The part of plant cell or tissue that permits free diffusion is sometimes called outer space. The apparent volume that accomodates these ions has been referred to by some workers as **apparent free space**. In the model of plasma membrane proposed by Danielli and Davson 1935, there are pores of 7Å diameter through which ions can diffuse into the cytoplasm. However, these pores are thought to be unstable in the fluid mosaic model. The accumulation of ions in the cell against concentration gradient can not be explained by this concept.

(iii) **Facilitated diffusion hypothesis :** According to this concept, the ions are transported across the membrane by a carrier protein. When the ions enter the cell through protein channels and not through the lipid layer the phenomenon is called facilitated diffusion. The ions combine with the carrier before they move to and fro across the membrane by thermal diffusion. In bacteria this action is performed by certain antibiotics, which are small polypeptide units. These antibiotics are called **ionophores**. They transport cations into the cell. In this phenomenon there is no participation of metabolic energy.

(iv) **Ion exchange hypothesis :** According to this view the ions adsorbed to the cell surface are exchanged from the external medium. A cation is exchanged for a cation and anion for anion. If a particular ion is absorbed by the plant, in exchange it offers H^+ or OH^- ions which are made available by the dissociation of water molecule.

There are two theories to explain the mechanism of ion exchange.

(a) **Contact exchange theory :** According to this theory, ions are not completely static, they are always oscillating around their absorption surface and when the oscillation volume of the ions on the roots and on the colloidal particles overlap each other, ion exchange occurs. An equilibrium is maintained between the dissolved fractions as any depletion in the soil solution is covered by movement of ions.

(b) **Carbonic acid exchange theory :** In this case, CO_2 released by roots during respiration reacts with water to produce carbonic acid which dissociates into hydrogen ions and bicarbonate ions. Hydrogen ion exchanges itself with the cations adsorbed on the colloidal particles and the bicarbonate ions release the adsorbed anions to supply both anions and cations nearby.

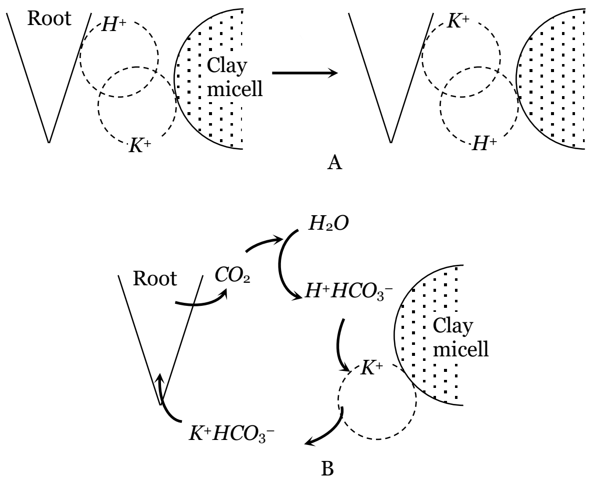


Fig : Diagrammatic representation of (A) the contact-exchange theory and (B) the carbonic acid exchange theory

(v) **Donnan equilibrium :** This mechanism, given by **F.G. Donnan** (1927), takes into account the effect of non-diffusible ions, which may be present on one side of the membrane. Unlike diffusible ions, the membrane is not permeable to non-diffusible ions. Such ions are termed as **fixed ions**. They may be anions or cations. In a system, in which there are no fixed ions, there are equal number of anions and cations on both sides of the membrane at equilibrium. But in Donnan equilibrium, in order to balance the charge of the fixed ions (say anions), more ions of the other charge (say cations) would be required.

Mathematically, the Donnan equilibrium may be represented by following equation :

$$[C_i^+][A_i^-] = [C_o^+][A_o^-]$$

Here : C_i^+ = Cations inside; C_o^+ = Cations outside

A_i^- = Anions inside; A_o^- = Anions outside

$$\frac{\text{Positive ions inside}}{\text{Positive ions outside}} = \frac{\text{Negative ions outside}}{\text{Negative ions inside}}$$

Let us denote these indiffusible anions as R^- which are electrically balanced by an equal amount of cations say K^+. If the anion Cl^- enters the cell due to diffusion gradient, it is accompanied by an equal amount of cations. The absorption of this cation may be against concentration gradient. The equilibrium so achieved is called **donnan equilibrium**.

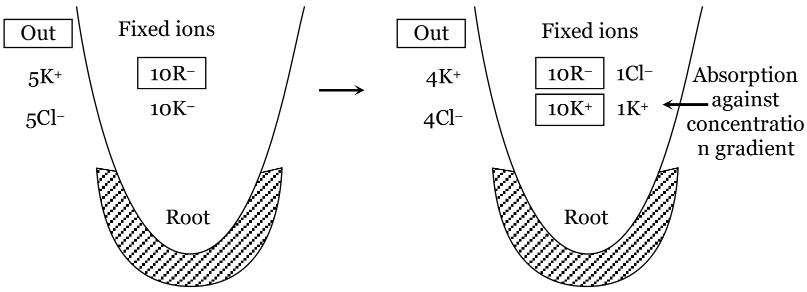


Fig : The concept of Donnan equilibrium

(2) **Active absorption :** Generally, the lipid-protein membrane of a cell is largely permeable to free ions. The energy is considered to be involved in the transport of such free ions across the membrane. The absorption of ions, involving use of metabolic energy, is called active absorption. Energy used in these mechanisms comes from metabolic activities, especially respiration. Mineral absorption is mainly active process. **Hoagland** (1944) indicated active ion absorption and their (ions) accumulation against concentration gradient in green algae *Nitella* and *Valonia*.

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.

Active transport in necessary for living cells because certain substances must be concentrated and others must be excluded. Active uptake of minerals by roots mainly depends on availability of oxygen. Depending upon the nature of the carrier and participation of metabolic energy, several theories are proposed to explain the mechanism of active absorption. Some of these are discussed below :

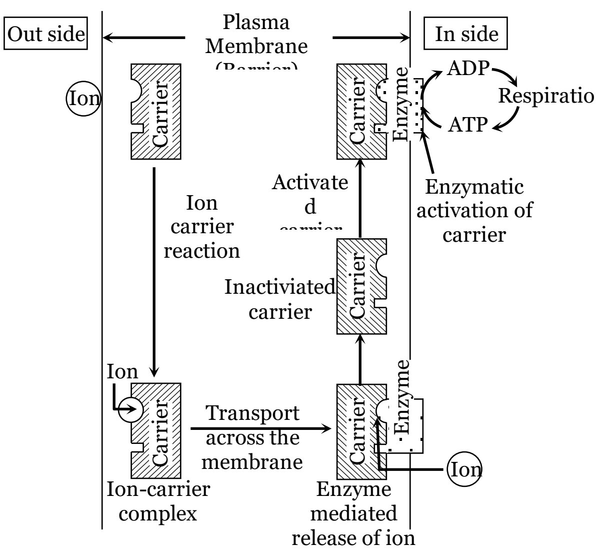


Fig : The ion-carrier hypothesis

(i) **Carrier concept :** This concept was proposed by **Van den Honert** (1937). The space in a cell or tissue where mineral ions enter by the usage of metabolic energy is called **inner space**. The boundries of outer and inner spaces are not well defined. Perhaps the two are separated by the plasma membrane. According to this concept there are separate carriers for cations and anions. A carrier forms an **ion-carrier complex** on the outer surface of the membrane. This complex breaks up and releases the ion into the inner space and this release is perhaps mediated by the enzyme *phosphatase*. The inactivated carrier is again activated by the enzyme *kinase* and in this process an ATP is used up. ATP molecule combine with carrier molecules and allow passage of substances against concentration gradient. The activated carrier again accepts new ions and the entire cycle is repeated.

$$\text{Carrier* + Ion (+/–)} \longrightarrow \text{Ion – Carrier complex*}$$

$$\text{Ion – Carrier complex*} \xrightarrow{Phosphatase\,(?)} \text{Carrier + Ion}$$

$$\underset{\text{(Inactivated)}}{\text{Carrier}} + \text{ATP} \xrightarrow{Kinase} \underset{\text{(Activated)}}{\text{Carrier *}} + \text{ADP}$$

(ii) **Cytochrome – pump hypothesis :** This theory was proposed by **Lundegardh** (1950, 1954). According to this explanation only anions are absorbed actively, *i.e.*, anion uptake requires energy and the absorption of cations does not require energy, (*i.e.*, they are absorbed passively). At the outer surface of the membrane, the cytochrome undergoes oxidation and loses one electron and in exchange picks up an anion. This is then transported to the inner side of the membrane through to the cytochrome chain and on the inner surface of the membrane the anion is released and the cytochrome gets reduced by the action of dehydrogenase involved in respiration.

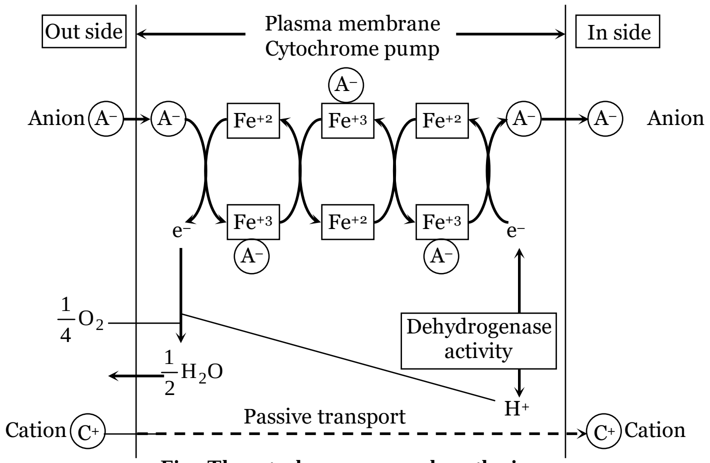


Fig : The cytochorome pump hypothesis

The cations move passively along the electrical gradient created by the accumulation of anions at the inner surface of the membrane.

The evidence in favour of Lundegardh's hypothesis is that the respiration increased when a plant is transferred from water to salt solution. The increased respiration was called **salt respiration** or **anion respiration**.

This theory was critised on the following grounds –

(a) It is applicable to absorption of anions only.

(b) It fails to explain selective absorption of ions.

(c) It has been observed that even cations can stimulate respiration.

(d) ETS is poorly developed in anaerobically respiring forms.

(iii) **Protein-lecithin carrier concept : Bennet-Clark** (1956) proposed that the carrier could be some amphoteric molecule which can carry anions as well as

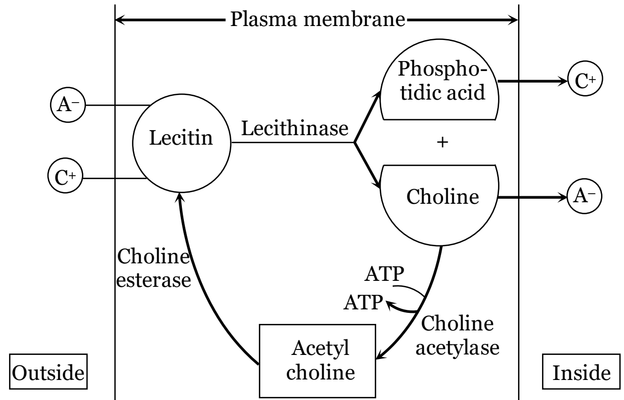


Fig : The protein-lecithin carrier concept

cations. He suggested it to be a membrane-bound protein which is conjugated with a **phosphatide** called as lecithin. Lecithin functions as a carrier. According to this theory, the phosphate group in the phosphatide acts as the cation binding site and choline acts as the anion binding site. During transport, ions are picked up by lecithin to forms an ion-lecithin-complex. The ions are released on the inner surface of the membrane due to hydrolysis of lecithin by the enzyme lecithinase into phosphatidic acid and choline.

Lecithin is resynthesised from these components in the presence of enzyme choline acetylase and choline esterase which requires ATP.

Goldacre, 1952 proposed a mechanism of ion transport where contractile proteins act as ion carrier. They bind ions in unfolded condition on the outer face of the membrane and then contract releasing the ion into the cell and again become unfolded. The energy for this folding and unfolding is provided by ATP.

In hydrophytic plants, water and salts are absorbed by outer layer of plants.

4.7 Factors affecting mineral absorption

The process of mineral absorption is influenced by the following factors :

(1) **Temperature :** The rate of absorption of salts and minerals is directly proportional to temperature. But it holds good only within a narrow range.

The absorption of mineral ions is inhibited when the temperature has reached its maximum limit, perhaps due to denaturing of enzymes.

(2) **Light :** The effects of light on mineral absorption are indirect and are mainly due to the effect of light on transpiration and photosynthesis. Transpiration is responsible for mass flow and photosynthesis provides energy and oxygen. When there is sufficient light, more photosynthesis occurs. As a result more food energy becomes available and salt uptake increases.

(3) **Oxygen :** A deficiency of O_2 always causes a corresponding decrease in the rate of mineral absorption. It is probably due to unavailability of ATP. The increased oxygen tension helps in increased uptake of salts.

(4) ***pH* :** It affects the rate of mineral absorption by regulating the availability of ions in the medium. At normal physiological *pH* monovalent ions are absorbed more rapidly whereas alkaline *pH* favours the absorption of bivalent and trivalent ions.

(5) **Interaction with other minerals :** The absorption of one type of ions is affected by other type. The absorption of K^+ is affected by Ca^{++}, Mg^{++} and other polyvalent ions. It is probably due to competition for binding sites on the carrier. However, the uptake of K^+ and Br^- becomes possible in presence of Ca^{++} ions. There is mutual competition in the absorption of *K*, *Rb* and *Cs* ions.

(6) **Growth :** A proper growth causes increase in surface area, number of cells and in the number of binding sites for the mineral ion. As a result, mineral absorption is enhanced.

4.8 Mineral translocation

P.R. Stout and **D.R. Hoagland** (1939) proved that mineral salts are translocated through xylem.

After absorption of minerals by root, ions are able to reach xylem by two pathways.

(i) Apoplast

(ii) Symplast

In apoplast pathway, inflow of water takes place from the cell to cell through spaces between cell wall polysaccharides. Ions thus are able to move from cell wall of epidermis to cell walls of various cells in cortex, cytoplasm of endodermis, cell wall of pericycle and finally into xylem. **In symplast pathway**, ions move through cytoplasm of epidermis and finally move through cytoplasm of cortex, endodermis, pericycle through plasmodesmata and finally into xylem.

Minerals in xylem are carried along with water to other parts of the plant along transpiration stream. Minerals reaching leaves take part in assimilation of organic compounds and then transported to other parts of the plant through phloem.

4.9 Nitrogen nutrition in plants

Nitrogen is an essential constituent of protoplasm. Nitrogen is the component of amino acids, proteins, enzymes, nucleotides and nucleic acids.

Nitrogen is picked up as inorganic compound and is changed into organic form by plants and some prokaryotes. Though atmosphere contains 79% of nitrogen in gaseous state, yet animals cannot use it directly. Nitrogen is a highly inert gas and it is energetically difficult for most of the living organisms, including the higher plants, to obtain it directly for their use. It must be fixed (*i.e.*, combined with other elements such as *C*, *H* and *O*) to form nitrates, nitrites, ammonium salts, etc. before it is absorbed and utilized by the plants. Higher plants generally utilize the oxidized forms such as nitrate (NO_3^-) and nitrite (NO_2^-) or the reduced form (NH_4^+) of nitrogen which is made available by a variety of nitrogen fixers. Nitrogen can be fixed by three methods :

Process of Nitrogen fixation

On the basis of agency through which the nitrogen is fixed the process is divided into two types :

(i) **Atmospheric nitrogen fixation :** By photochemical and electrochemical reactions, oxygen combines with nitrogen to form oxides of nitrogen. Now they get dissolved in water and combine with other salts to produce nitrates.

(ii) **Biological nitrogen fixation :** Some blue-green algae (*Anabaena, Nostoc*), symbiotic bacteria (*Rhizobium*) and free living bacteria (*Azotobacter*) pick up atmospheric nitrogen, reduce it to ammonia, combines with organic acid to form amino acids.

(iii) **Industrial nitrogen fixation :** Nitrogen and hydrogen combines to form ammonia industrially, under pressure and temperature.

(1) **Physical nitrogen fixation :** Out of total nitrogen fixed by natural agencies approximately 10% of this occurs due to physical processes such as lightening (*i.e.*, electric discharge), thunder storms and atmospheric pollution.

Due to lightening and thundering of clouds, N_2 and O_2 of the air react to form nitric oxide (NO). The nitric oxide is further oxidised with the help of O_2 to form nitrogen peroxide (NO_2).

$$N_2 + O_2 \xrightarrow{\text{Lightening}} 2NO$$

$$NO + O_2 \xrightarrow{\text{Oxidation}} 2NO_2$$

NO_2 combines with H_2O to form nitrous acid (HNO_2) and nitric acid (HNO_3). The acid falls along with rain water. Now it acts with alkaline radicals to form water soluble NO_3^- (nitrates) and NO_2^- (nitrites).

$$2NO_2 + H_2O \longrightarrow HNO_2 + HNO_3$$

$$HNO_3 + Ca \text{ or } K \text{ salts} \longrightarrow Ca \text{ or } K \text{ Nitrates}$$

The nitrates are soluble in water and are directly absorbed by the plants.

(2) **Biological nitrogen fixation :** The conversion of atmospheric nitrogen into inorganic or organic usable forms through the agency of living organisms is called biological nitrogen fixation. The process is carried by two main types of microorganisms, those which are "free living" or asymbiotic and those which live in close symbiotic association of with other plants.

(i) **Asymbiotic biological nitrogen fixation :** This is done by many aerobic and anaerobic bacteria, cyanobacteria (blue green algae) and some fungi *e.g.* :

(a) **Free living bacteria**

Aerobic – *Azotobacter*

Anerobic – *Clostridium*

Photosynthetic – *Chlorobium*

Chemosynthetic– *Thiobacillis*

(b) **Cyanobacteria** (blue-green algae) *e.g.*, *Anabaena, Nostoc, Tolypothrix cylindrospermum, Calotherix and Aulosira* etc.

(c) **Free living fungi** *e.g.*, Yeast cells and *Pullularia*.

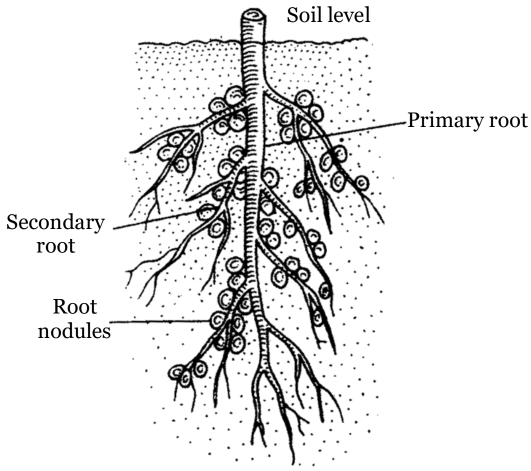


Fig : Nodulated root

(ii) **Symbiotic biological nitrogen fixation :** Symbiotic bacteria are found in the root nodules of the members of family **Leguminosae.** The best known nitrogen fixing symbiotic bacterium is *Rhizobium leguminosarum* (*Bacillus radicicola*).

Members of the family *Leguminosae* such as beans, gram, groundnut and soyabean etc. on their secondary, tertiary and sometimes primary roots bear small nodule like swellings. *Rhizobium* penetrates to the cortex of root through infection thread. Simultaneously cortical cells or root are stimulated to divide more vigorously to form nodules on the root. Neither bacterium nor plant alone can fix nitrogen in such cases. Nitrogen fixation is actually the outcome of symbiotic relationship between the two. When a section of root nodules is observed the presence of a pigment, **leghaemoglobin** is seen to impart pinkish colour to it. This pigment is closely related to haemoglobin and helpful in creating optimal condition for nitrogen fixation. Like haemoglobin, leghaemo-globin is an oxygen scavenger. Fixation of nitrogen is done with the help of enzyme **nitrogenase**, which functions under anaerobic conditions. Leghaemo-globin combines with oxygen and protects nitrogenase.

Symbiotic bacteria have also been found to occur in root nodules of *Casuarina, Cycas, Alnus,* etc. Leaf nodules develop in some members of family **Rubiaceae**, the bacteria being *Mycobacterium*. Some cyanobacteria also have symbiotic association with plants *e.g.*, lichens; *Anthoceros* (a liverwort) and *Azolla* (a water fern).

Mechanism of biological nitrogen fixation : It is believed that nitrogen is bound to the enzyme surface and is not releasd until it is completely reduced to ammonia. Nitrogen bound to the enzyme surface is reduced in step-wise reaction before *N–N* bond is ruptured. Several schemes incorporating such idea have been proposed and Burris (1966) accepts that the total reduction of nitrogen occurs on an enzyme complex (Nitrogenase) without release of intermediates less reduced than ammonia.

The enzyme complex nitrogenase consists of two sub-units

- A non-heme iron protein commonly called *Fe* protein (or dinitrogen reductase, component I)
- An iron molybdenum protein called *MoFe* protein (or dinitrogenase, component II)

According to Burris (1966) hypothesis for nitrogen fixation suggesting the function of ATP and ferredoxin at each step in the reduction of nitrogen. The pretty function of ATP donor is furnished by pyruvate which also acts as electron donor for N_2 reduction as well.

Pyruvate on one hand acts as ATP donor while on other hand it supplies hydrogen ions and electrons for nitrogen reduction via $NADH_2$ and ferredoxin. The nitrogenase enzyme require 16 ATP molecules, 8 hydrogen ions and 8 electrons to reduce one molecule of nitrogen to $2NH_3$ molecules.

$$N_2 + 8e^- + 8H^+ + 16\,ATP \rightarrow 2NH_3 + H_2^+ + 16\,ADP + 16\,Pi$$

Explaining the mechanism of nitrogenase activity, its now believed that electrons are transferred from the reducing agent (Ferredoxin, Flavoprotein or Dithionite) to complex of *Mg*-ATP and Fe-protein (component II). From here electrons flow to *Mo-Fe* protein (component I) and then to substrate (nitrogen) which is finally reduced (to NH_3).

Flavodoxin or Ferredoxin or Dithimite $\xrightarrow{e^-}$ Fe-protein (reduced) $2(Mg^{2+}$ ADP $\xrightarrow{e^-}$ Mo-Fe protein (reduced) → $N \cong N$, $CH \cong CH$

Flavodoxin or Ferredoxin ← Fe protein (oxidised) $2(Mg^{2+}$ ADP) ← Mo-Fe protein (oxidised) ← $2H^+$, $2NH_3$, $CH_2 = CH_2$, H_2

In most diazotrophs (N_2- fixing organisms) ferredoxin and flavodoxin are probably the natural electron carriers for the reduction of *Fe*-protein. The reduced *Fe*-protein binds to *Mg*-ATP (Mg^{2+} ATP), creating a complex with *Mo-Fe* protein. Dissociation of two proteins occur between electron transfer events. The oxidised Fe-protein dissociates and becomes reduced again which recombines randomly with another nitrogenase untill all the electrons needed for reduction of substrate (e.g. 8 for N_2) are accumulated. Apart from H^+, substrates such as $N \cong N$ or $HC \cong CH$ are believed to be bound to the same site in *Mo-Fe* protein (component I).

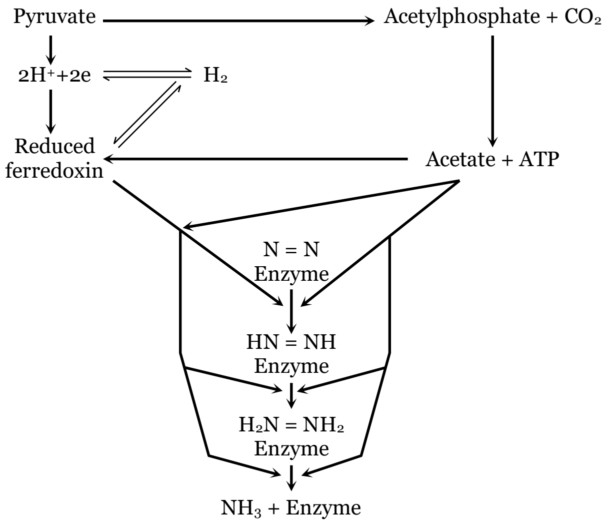


Fig : Scheme suggesting the role of ATP and ferredoxin at each step in the reduction of nitrogen. Enzymes is nitrogenase (Burris, 1966)

The ammonia formed in biological nitrogen fixation is not liberated. It is highly toxic and is immediately converted into amino acids.

Ammonia + α-ketoglutarate + NADH $\xrightarrow{\text{Dehydrogenase}}$ Glutamate + NAD^+ + H^2O.

The amino acids are transported through phloem to other parts of the plant.

Ammonification and nitrification

Thus symbiotic nitrogen fixing organisms give a part of their fixed nitrogen to the host in return for carbohydrate food and shelter. But the free living nonsymbiotic nitrogen fixing organisms do not enrich the soil immediately. It is only after their death that the fixed nitrogen enters the cyclic pool by the two steps namely the **ammonification and nitrification**.

• **Ammonification :** The nitrogenous organic compounds in the dead bodies of plants and animals are converted into ammonia or ammonium ions in the soil. This is carried out by ammonifying bacteria. Ammonia is toxic to the plants but ammonium ions can be safely absorbed by the higher plants.

• **Nitrification :** Once ammonia has been produced it is converted into nitrates by nitrifying activities and process is called nitrification. Soil bacteria such as *Nitrosomonas* and *Nitrosococcus* convert ammonia into nitrite (NO_2^-) ions.

$$2NH_3 + 3O_2 \xrightarrow{Nitrosomonas \text{ and } Nitrosococcus} 2HNO_2 + 2H_2O$$

Nitrites are then oxidised to nitrates by *Nitrobacter*.

$$2HNO_2 + O_2 \xrightarrow{Nitrobacter} 2HNO_3$$

The nitrifying bacteria are **chemoautotrophs** and are benefited by utilising energy released in oxidation, which is used in chemosynthesis. At soil temperatures $30°C$ – $35°C$ in alkaline soils and with sufficient moisture and aeration, the activity of ammonifying and nitrifying bacteria is found to be maximum.

Some bacteria such as *Thiobacillus denitrificans, Pseudomonas aoruginosa and Micrococcus denitrificans* also occur in the soil which convert the nitrate and ammonia into atmospheric free elemental nitrogen. Such bacteria are called denitrifying bacteria and the process is called **denitrification**. These bacteria act very well in soil where there is more water and less oxygen and there are high level of the carbohydrate.

Nitrate assimilation in plans

Nitrate is the most important source of nitrogen for the plants but it cannot be used as such. It is first reduced to ammonia and then incorporated into organic compounds.

The process of nitrate reduction to ammonia occurs in the following steps :

Nitrate $\rightarrow$ Nitrite $\rightarrow$ Hyponitrite $\rightarrow$ Hydroxylamine $\rightarrow$ Ammonia

• **Reduction of nitrate to nitrites :** First the nitrate is reduced to nitrite by an enzyme called **nitrate reductase**. The reductase enzyme is a flavoprotein and contains FAD (Flavin adenine dinucleotide) as prosthetic group which receives hydrogen from reduced NADP or NAD. **Molybdenum** in enzyme serves as electron carrier.

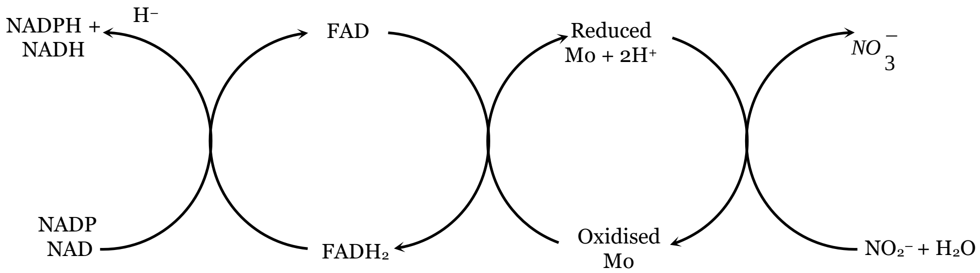


Fig : Steps for nitrate reduction

• **Reduction of nitrites :** The nitrite ions are reduced to ammonia by an enzyme called **nitrite reductase**. This change occurs in leaves in the presence of light more rapidly and in dark with lesser speed. This is due to the reducing power of reaction from photochemical splitting of water.

$$2HNO_2 + 2H_2O \rightarrow 2NH_3 + 3O_2$$

Nitrite reductase does not need molybdenum but may require the presence of iron and copper. NADH and NADPH act as hydrogen donors.

Application of fertilizers

Application of fertilizers : Most of the soil usually contain sufficient amounts of essential mineral elements for the better crop production. Some of them are, however, deficient in certain elements. These elements are required to be supplemented externally by adding the appropriate fertilizers. Moreover, constant agricultural cultivation in field may also cause depletion of certain elements which must be replenished in order to improve the fertility of soil. The important elements need to be replenished in crop fields are nitrogen, phosphorus and potassium. These are grouped as nitrogenous fertilizers, phosphate fertilizers and potash fertilizers. These are abbreviated as NPK. Common sources of NPK are ammonium chloride, ammonium sulphate, ammonium nitrate, bone meal, calcium magnesium phosphate and nitrate of soda.

The common fertilizers that supplements NPK is nitrophosphate with potash in varying proportions. The percentage of nitrogen, phosphorous and water soluble potassium are labelled on the bags as 17-18-9 or 15-15-15 and so on. The amount of fertilizer needed varies according to change in season, soil, nature of crop and other climatic conditions.

Important Tips

- **Woodward** (1699) reported that plants grow better in muddy water as compared to fresh rain water.
- **De Saussure** (1804) first of all demonstrated that plants obtain minerals from soil through root system.
- Liebig for the first time discovered the presence of elements in plant ash.
- Liebig's law of minimum states that the productivity of soil depends upon the proportionate amount of that essential element which is deficient in that soil.
- **Tracer elements :** These are radioactive isotopes of elements, which are used to detect various metabolic pathways in plants, e.g., C^{14}, N^{15}, P^{32}, S^{35}, etc.).
- If dried plant parts are heated in silica crucible at 600°C, all organic substances vaporize and the remaining plant ash contains only inorganic substances or mineral elements.
- **Aeroponics :** Growing plants in stands provided with fine mist of solution having all the required inorganic nutrients.
- Hydroponics developed by Geriche.
- Sodium (Na) regulates the transport of amino acids to the nucleus.
- Aluminium (Al) is accumulated in fern.
- Veledium (V) is required by alga Scenedesmus.
- Selenium (Se) is required by Atriplex and Astragalus.

- Iodine is required by marine alga Polysiphonia.
- The elements taken in the form of gas by prokaryotes only is nitrogen.
- Critical elements are the elements in which soil is generally deficient e.g. N, P and K. These are given in form of fertilizers.
- In addition to 16 essential elements, some plants require some more essential micronutrient elements such as

  (i) **Silica :** Found in grasses and diatoms.

  (ii) **Sodium :** Found in halophytes.

  (iii) **Cobalt :** Found in ferns (e.g. Lycopodium), taking part in growth.

  (iv) Nickel : Enzyme urease used it to hydrolyse urea by living organisms.
- In Rhizobium cobalt play an important role in nitrogen fixation and is an essential constituents of vitamin B_{12}. It is used in 'cancer therapy'.
- **Cytozyme** is a water soluble commercial preparation which contains essential mineral element for use as foliar spray.
- Khaira disease of rice and white bud of maize is due to zinc deficiency.
- Die back of Citrus and reclamation disease of cereals and legumes and exanthema in fruit trees are due to deficiency of Cu.
- Whiptail disease of cauliflower is caused by Mo deficiency.
- The symptoms produced by the deficiency of mineral substances are called 'hunger sign'.
- Mineral salt absorption is independent of water absorption.
- Maximum mineral salt absorption occurs by zone of elongation. No mineral salt absorption occurs by hair zone. Mineral salt absorption occurs directly by cells of epiblema and not by root hair.
- Mineral salts are absorbed mostly in form of ions i.e. anions and cations.
- Path of transport of mineral salts is xylem.
- Cytochromes act as anion carriers.
- Phytotron is the place or laboratory where plants can be maintained and studied under wide range of controlled conditions.
- Nif gene : Nitrogen fixing gene is nif gene. A cluster of 18 genes (nif gene) encode the protein required for nitrogen fixation in Klebsiella.

4.10 Special modes of nutrition

Nutrition is an important characteristic of living organisms. Plants need energy for its various life activities. Energy is provided by the oxidation of different foods. The method of taking in and synthesis of various types of foods by different plants and animals is called nutrition.

Generally plants are autotrophic in their mode of nutrition, but there are some examples which are heterotrophic in their mode of nutrition. These plants are unable to manufacture their own food due to lack of chlorophyll or some other reasons, *e.g.*, some bacteria, fungi, some bryophytes, pteridophytes and few angiospermic plants also, but special mention is of angiospermic plants.

There are 4 special modes of nutrition.

(1) Parasites

(2) Saprophytes

(3) Symbiotic plants

(4) Insectivorous plants

(1) **Parasites :** These plants obtain either their organic food prepared by other organisms or depend upon other plants only for water and minerals with the help of which they can synthesize their own food. The living organism from which the parasite obtains its organic food or water and minerals is called **host**. Any part of the body of parasite is modified into a special organ called **haustorium** which enters into the cells of host and absorbs food or water and minerals from the host.

A plant parasite may live on the root or stem of the host plant partially or totally. The total parasites remain permanently attached to the host whereas the association of partial parasites is only short lived. Accordingly, parasites can be classified into two categories :

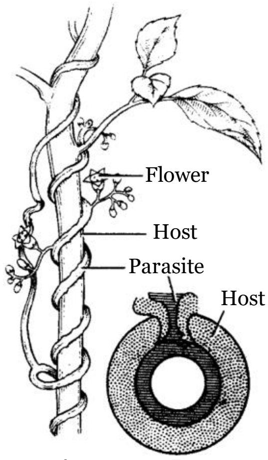
(i) Total parasites.

(ii) Semiparasites or partial parasites.

(i) **Total parasites :** These plants never possess chlorophyll, hence they always obtain their food from the host. They may be attached to branches, stem (stem parasites) or roots (root parasites) of the host plants.

(a) **Total stem parasite :** *Cuscuta* is a rootless, yellow coloured, slender stem with small scale leaves, which twines around the host. The parasite develops haustoria (Small adventitious sucking roots) which enter the host plant forming contact with xylem and phloem of the host. It absorbs prepared food, water and minerals from the host plant.

(b) **Total root parasite :** Total root parasites are common in the families like Orobanchaceae, Rafflesiaceae, Balanophoraceae, etc. *Orobanche, Rafflesia* and *Balanophora* are some of the common root parasites.



A B

Fig : *Cuscuta* (dodder), a total parasite
A : Parasite coiled around host plant
B : Relationship between vascular tissues of host and parasite

Orobanche is commonly known as **broom rape**. It has scale leaves and pinkish or bluish flowers. The tip of the root of parasite makes haustorial contact with the root of host and absorbs food from the host. *Orobanche* is usually parasitic upon brinjal, tobacco. In *Rafflesia* (stinking corpse lily) another root parasite, vegetative parts of the plant are highly reduced and represented by cellular filaments resembling fungal mycelium. These filaments get embedded in the soft tissue of the host while the flowers emerge out in the forms of buds.

Balanophora occurs as a total stem parasite in the roots of forest trees.

(ii) **Semiparasite or partial parasite :** Such parasitic plants have chlorophyll and, therefore, synthesize their organic food themselves. But they fulfill their mineral and water requirements from their host plants.

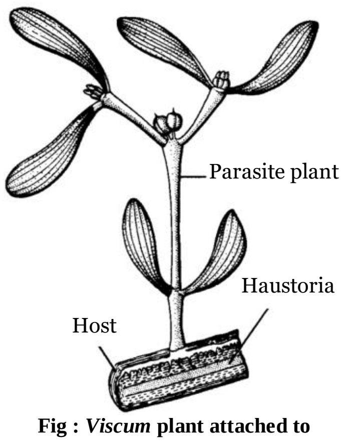


Fig : *Viscum* plant attached to the host stem (part of host stem is cut open to show the haustorium

Like total parasites, they grow on the stem and roots of the host plants and can be grouped into following two categories :

(a) **Partial stem parasites :** The well known example of partial stem parasite is *Viscum album* (mistletoe) which parasitizes a number of shrubs and trees. The mature plant of *Viscum* is dichotomously branched with green leaves born in pairs attached on each node of stem. The shoots are attached to the host by means of haustoria. The primary haustoria reaches upto cortex of the host which runs logitudinally. It sends secondary haustoria which make connection with the xylem of the host and absorb water and minerals *Loranthus* is another partial stem parasite.

(b) **Partial root parasites :** The common example of partial (semi-parasite) root parasite is *Santalum album* (Sandal wood tree) which is an evergreen partial root parasite which grows in South India. It grows on the roots of *Dalbergia sisso, Eucalyptus*. Like other partial parasites, it also has green leaves and absorbs only minerals and water from the host plants.

Similarly, *Striga* on roots of sugarcane and *Thesium* on the roots of grasses are other partial root parasites.

(2) **Saprophytes :** These plants live upon dead organic matter and are responsible for conversion of complex organic substances into simple inorganic substances (minerals), *e.g.,* some bacteria, some fungi (*Yeast, Mucors, Penicillium, Agaricus*), few algae (*Polytoma*), few bryophytes (*Buxbaumia, Hypnum* and *Splanchnum*), few pteriophytes (like *Botrychium*) and some angiosperms (*Monotropa* and *Neottia*) also.

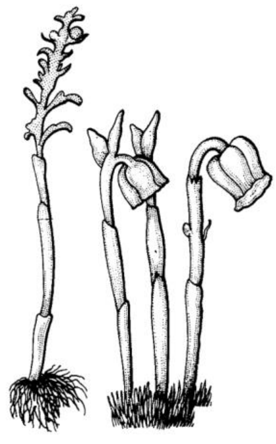


Fig : Saprophytic plants
(A) : *Neottia* (Birds nest plant)
(B) : *Monotropa* (Indian pipe)

Monotropa, commonly known as **Indian pipe**, lacks chlorophyll and is colourless or ivory white. It is found in Khasi hills and in the dense forests of Shimla. *Monotropa*, though usually referred to as a saprophyte, actually gets its nourishment from fungal mycelium which surround its roots. Such association between roots of higher plants and fungi is known as **mycorrhiza**. *Neottia* (Bird's nest orchid) grows in the humus rich soil of the forests. It has very few reduced leaves and thick pale yellow stem. The roots lack root hairs and the nutrients are absorbed by mycorrhiza.

(3) **Symbiotic plants :** Sometimes two different species of organisms spend much or all of their lives in close physical association, deriving mutual benefit. Such an association is known as **symbiosis** and each organism is known as **symbiont**. Symbiotic association is so close that symbionts appear to be different parts of the same plant.

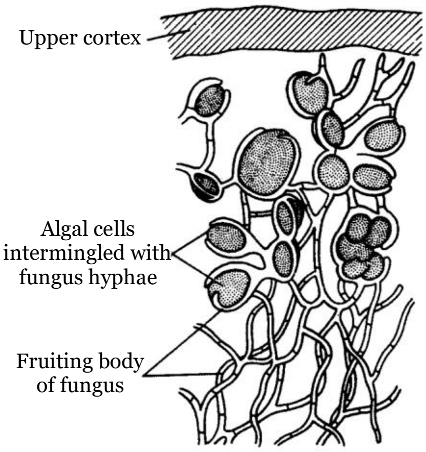


Fig : A lichen thallus in T.S.

Symbiotic association may be between two higher plants or between a higher plant and a lower plant. Some common examples of symbiosis are described below.

(i) **Lichens :** Lichens is a special group of plants, when an algae and fungi live together and are mutually benefitted (algae provides food and fungi provides water minerals and protection of algae).

The fungus component of the lichens, called **mycobiont**, is generally a member of Ascomycetae or occasionally a Basidiomycetae. The algal component of the lichen is known as **phycobiont** and is generally a member of Chlorophyceae (*e.g., Trebouxia*) or Cyanophyceae (*e.g., Nostoc*, *Gloeocapsa*).

(ii) **Mycorrhiza :** It is a mutually beneficial association between a fungus and the root of higher plant. The fungus absorbs water, salts (from organic matter) and protects the plant from soil borne pathogens. In return, it gets shelter and nourishment from the plant. In such association the fungal mycelium forms a mantle over the root surface and some of the hyphae penetrate between cortical cells and metabolites are transferred in both directions (*i.e.*, from fungus to the root cells and vice-versa).

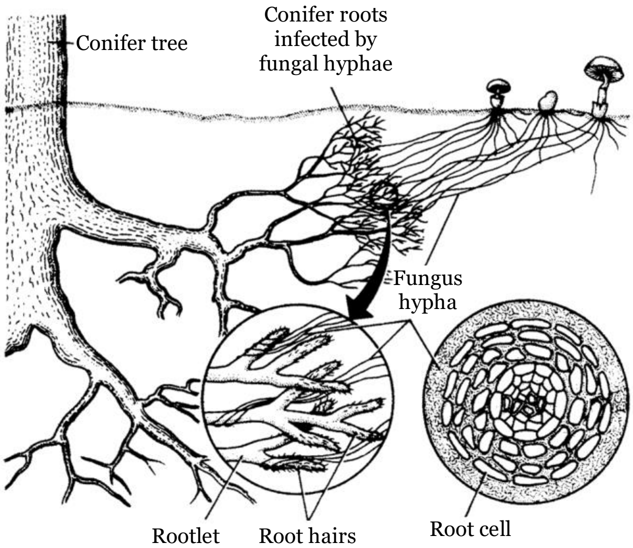


Fig : Micorrhizal roots

Usually the roots in the upper part of the soil, where organic matter is abundant, are mycorrhizal, and the roots penetrating deep in the soil are not associated with fungi. Generally, mycorrhizal roots have few or no root hairs. Water and minerals are absorbed by the fungus and passed on to the host. The fungus digests starch grains stored in the cortical cells of the host and uses the digested products in its own metabolism.

In some plants the mycorrhizal association is essential for normal growth and development. For example, seedlings of orchids fail to survive if the soil is free from fungus. Pine seedlings grow poorly unless mycorrhizal fungi are introduced in to the soil.

(iii) **Root nodules of leguminosae :** Members of the sub-family Papilionaceae of the Leguminosae (*e.g.*, pea, beans, trifolium) harbour species of *Rhizobium,* a nitrogen fixing bacteria. The bacteria form nodules in the roots. They fix elemental nitrogen of the atmosphere and make it available to the plant in forms that can be utilized. In turn they derive food and shelter from the leguminous plant.

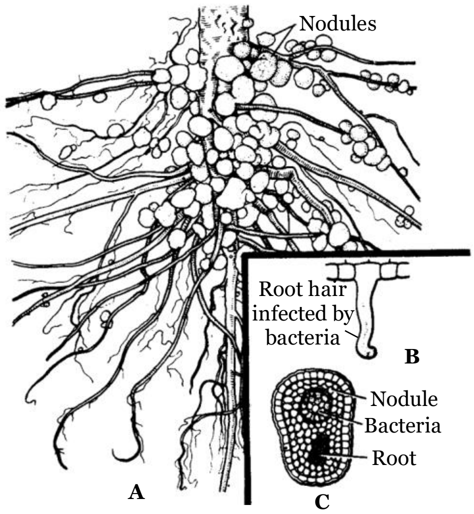


Fig : Symbiotic plants : A : A leguminous plant with root nodules, B : A root hair infected with bacteria, C : T.S. of a root nodule showing many bacteria

(iv) **Myrmecophily :** It is the symbiotic relationship between ants and some higher plants. The ants obtain food and shelter from the plant. They protect the plant (*e.g.*, Mango) from other animals. In *Acacia sphaerocephala* the stipules are hollowed to function as ant shelter. Leaflet tips (Belt's corpuscles) and rachis (extrafloral nectaries) possess feeding materials. A higher plant which is benefitted by association with ants is called **myrmecophyte**. The term myrmecophily is also used for pollination by ants.

(4) **Insectivorous plants :** These plants are autotrophic in their mode of nutrition but <u>they grow in marshy or muddy soils, which are generally deficient in nitrogen and in order to fulfil their nitrogen requirement</u>, these plants catch small insects. The organs and specially leaves of these plants are modified variously to catch the insects. These plants have **glands secreting proteolytic enzymes** which breakdown complex proteins into simple nitrogenous substances, which inturn are absorbed by these plants. Some of these plants are as follows :

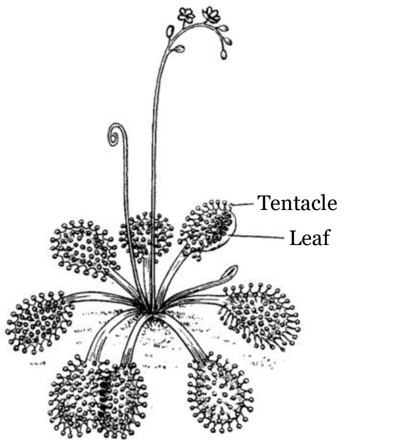


Fig : Insectivorous plant : *Drosera* (Sundew)

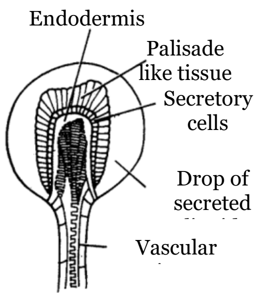


Fig : One grandular

(i) **Drosera (Sundew) :** It is a herbaceous plant having spathulate or lunate leaves. The leaves are covered by glandular hair with a swollen tip. The glands secretes a sticky purple juice which shines like a dew drop in bright light sunshine, hence the name sundew. These long special hair are generally referred to as '**tentacles**'. When an insect alights on the leaf, the tentacles curve due to thigmonasty. The insect is killed and its proteins are digested by **pepsin hydrochloride**. Similar tentacles are also found in *Drosophyllum*.

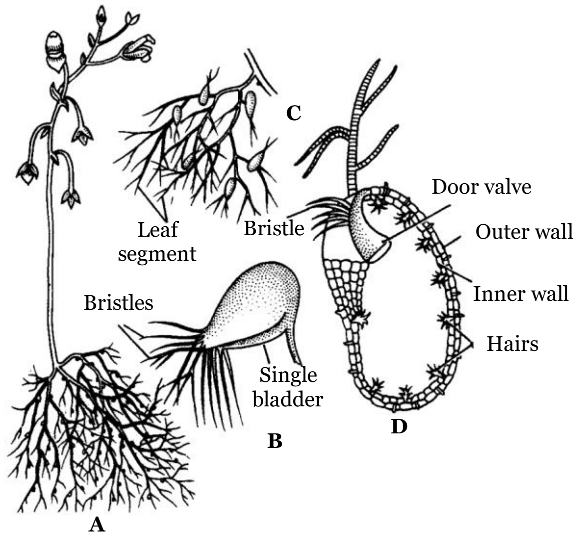


Fig : Insectivorous plant : *Utricularia* (Bladderwort) A – Complete plant, B – One bladder, C – Part of leaf with several bladders, D – Internal structure of bladder

(ii) **Utricularia (Bladderwort) :** It is submerged floating aquatic herb which lack roots. Some of the species of *Utricularia* also occur in moist soil. The leaves are dissected into fine segments and appear like roots. Some of the leaf segments are modified into pear-shaped sacs called **bladders** or **utricles**.

The bladders are triangular or semicircular structures having a single opening guarded by a valve. There are numerous bristles near the mouth and digestive glands inside. The bladders show special **trap mechanism**. The valve of the bladder opens on the inner side. When small aquatic animalcules enter the bladder along with water current, they get trapped inside. Their proteins are digested enzymatically. When a bladder is full of undigested matter, it degenerasis.

(iii) **Nepenthes (Pitcher plant) :** They are commonly found in tropical areas like Assam and Meghalaya (*i.e. N. Khasiana*). In this plant the leaf base is winged, petiole is tendriller and the lamina is modified into pitcher. The pitcher

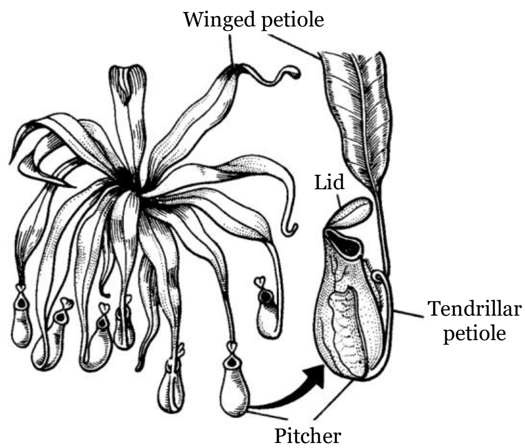


Fig : Insectivorous plant : *Nepenthes* (Pitcher plant) A pitcher plant with pitcher

has a distinct collar at the mouth and the apex is modified into the lid. The undersurface of the lid has **alluring glands** whereas the inner surface of pitcher is lined by numerous digestive glands and several downward directed hair. The lid attracts insects which slide down into the pitcher. The downward directed hair check their escape. The insect is killed and its proteins are digested by pepsin hydrochloride. Other insectivorous plants having leaf pitchers are *Sarracenia, Cephalotus, Heliamphora*, etc.

(iv) **Dionaea (Venus fly trap) :** It is a small herbaceous plant found mainly in America. The plant has a rosette of radiating leaves. The petiole is winged and photosynthetic. The lamina is bilobed and the midrib acts like a hinge between the two lobes of the lamina. Each lobe has 15-20 trigger hairs or bristles. These hairs are very sensitive to nitrogenous substances. When an insect alights on the leaf and touches the sensitive hairs, the two lobes of lamina fold along the midrib. Thus the insect is trapped in between the lobes. Pepsin hydrochloride secreted by the digestive glands, present in the upper part of the lobes digests the insect. The simple digested substances are absorbed by the plant. Soon after the digested matter has been translocated to other parts of the plant, the lobes of the lamina reopen.

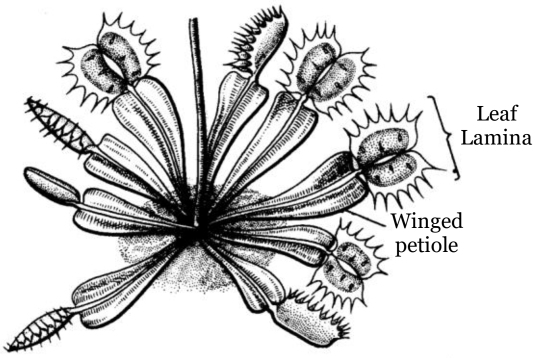


Fig : Insectivorous plant : *Dionea* (Venus

(v) **Sarracenia (Pitcher plant; Devil's boot) :** This pitcher plant is found in the temperate regions. It has a very reduced stem which bears a rosette of leaves. The leaves are modified into pitchers. It can easily be distinguished from *Nepenthes* on the basis of its trumpet-shaped sessile pitchers. Contrary to *Nepenthes*, the pitchers of *Sarracenia* lack digestive enzymes and here the insects are decomposed by bacteria.

Fig : *Sarracenia* (Pitcher

(vi) **Pinguicula (Butterwort) :** It is a herbaceous plant having a basal rosette of ovate leaves. The leaf margins are slightly curved in upward direction. The dorsal (upper) surface of leaf has two types of glands **stalked** and **sessile**. The stalked glands secrete mucilage while the sessile glands secrete digestive enzymes.

As soon as the insect sits on the leaf surface, it sticks to the mucilage secreted by stalked glands. Meanwhile the margins of the leaf roll inward due to stimulation received by the insect. Thus the insect gets

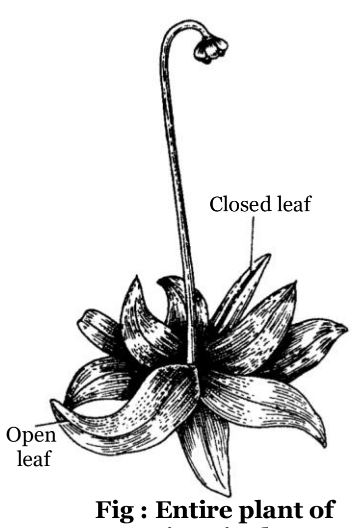


Fig : Entire plant of

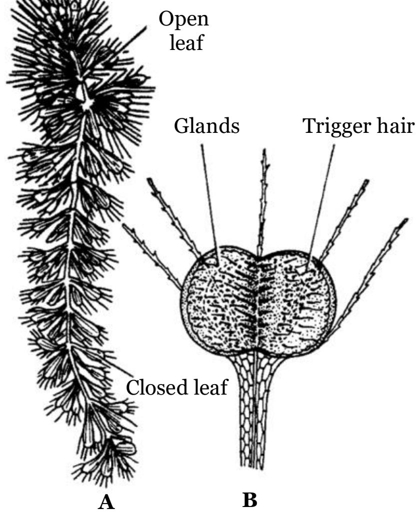


Fig : *Aldrovanda vesiculosa*
A : A floating twig B : An open

enclosed within the leaf. The protein contents of the insect are digested by the enzymes secreted by the sessile glands. The leaf reopens when the stimulation is over.

(vii) **Aldrovanda (Water flea trap) :** It is also a rootless, submerged aquatic plant (bog plant) recalling the habit of *Utricularia*. The leaves are bilobed with long petioles. There are five bristle like outgrowths associated with the lamina. The leaf surface is covered by visid stalked glands. The two halves of the lamina rise upward on stimulation by an insect, the midrib acting as hinge. The proteins of the insect are digested enzymatically.

Modes of nutrition in plants

- **Autotrophic**
  These are photosynthesizing plants and thus make their food by themselves.
  - **Photosynthetic**
    Use sunlight as a source of energy to manufacture food.
    Examples :
    - Most green plants.
    - Green sulphur bacteria.
    - Purple sulphur bacteria.
    - Purple non-sulphur bacteria.
  - **Chemosynthetic**
    Use energy released in chemical reactions to manufacture food
    Examples :
    - Nitrifying bacteria.
    - Iron bacteria.
    - Hydrogen bacteria.
    - Sulphur bacteria.
    - Methane bacteria.
- **Heterotrophic**
  These are non-photosynthesizing plants which obtain ready made food from other plants
  - **Parasitic**
    It obtain food only from living plants
    - Total
      - Stem
        Example :
        - *Cuscuta.*
      - Root
        Examples :
        - *Orobanche.*
        - *Rafflesia.*
        - *Balanophora*.
    - Partial
      - Stem
        Examples :
        - *Viscum.*
        - *Loranthus*
      - Root
        Example :
        - *Santalum.*
  - **Saprophytic**
    Obtain food from dead and decaying organic matter.
    Examples :
    - *Monotropa*
    - *Neottia*
    - *Agaricus.*
  - **Symbiotic**
    It is a close association between two different kinds of plants and both the plants obtain their food by different methods.
    Examples :
    - Lichens
    - Mycorrhiza
    - Root nodules.
    - Myrmecophily.
  - **Insectivorous**
    These are green photosynthesizing plants but fulfill their nitrogen requirement from insects.
    Examples :
    - *Drosera*
    - *Utricularia*
    - *Nepenthes*
    - *Dionaea*
    - *Pinguicula*
    - *Sarracenia*
    - *Aldrovanda*

Important Tips

- ☞ Term 'symbiosis' was given by De Bary.
- ☞ Rafflessia (largest flower in the world) was discovered by **Sir Stamford Raffles** from Java. Flower measures about a meter in diameter, about 11 kg in weight, smell is like rotten fish, pollination by elephants and found on roots of **Vitis** and **Cissus**.
- ☞ Sapria himalayensis (largest flower in India), measures 15 cm – 30 cm in diameter.
- ☞ Insectivorous plants are example of predation (i.e. first killing and then eating).
- ☞ **Cephalotus** (Fly Catcher). A deep rooted carnivorous herb with a rosette of pitchers for trapping small animals.
- ☞ **Cuscuta/Amarbel/Akashbel/Dodder :** A dicot with no cotyledon (some workers consider it to have a single cotyledon). It is a total stem parasite but initially grows on soil.
- ☞ **Dischidia :** The pitcher is without lid and is used only for storing rain water with some mud.
- ☞ Epiphytes are plants which live on other plants for space (shelter/support) only. They are therefore, called **space parasites**
- ☞ Bird of paradise flower is Sterilitzia reginae.

***

ASSIGNMENT

MACRO - NUTRIENTS

Basic Level

1. Absence of Mg^{++} ions from plants tissue results in
   (a) Plasmolysis (b) Hydrolysis (c) Chlorosis (d) Necrosis
2. Chlorosis in plants occurs due to
   (a) Absorption of yellowish pigment from the soil (b) High sunlight intensity
   (c) Deficiency of *Mg* and *Fe* in the soil (d) Low sunlight intensity
3. Presence of phosphorus in a plant
   (a) Brings about healthy root growth (b) Promotes fruit ripening
   (c) Retards protein formation (d) None of the above
4. Woodward (1669) observed that plant grew better in muddy water than in rain water because
   (a) Muddy water had most of essential elements dissolved in it
   (b) Muddy water had micro-nutrients dissolved in it
   (c) Muddy water had macro-nutrients dissolved in it (d) None of these
5. By the use of sulphur
   (a) Development of root is normal (b)Root development is reduced
   (c) Root development is increased (d)Root dry
6. In darkness the stomata close because
   (a) Potassium deposits in the guard cells (b) Guard cells loose potassium
   (c) Starch is converted into sugar (d) None of these
7. Fall of immature leaf is due to deficeincy of
   (a) Sulphur (b) Phosphorous (c) Sodium (d) Zinc
8. Which of the following element is used up in phosphorylation
   (a) Calcium and sulphur (b)Chlorine and maganese
   (c) Iron and phosphate (d)Magnesium and phosphorous
9. Phosphorus is a structural element in
   (a) Fat (b) Starch (c) Nucleotide (d) Carbohydrate
10. Plants requiring the two metallic compounds (minerals) for chlorophyll synthesis, they are –
    (a) *Cu* and *Ca* (b) *Fe* and *Mg* (c) *Fe* and *Ca* (d) *Ca* and *K*
11. Macronutrients are elements that
    (a) Play major role in plant nutrition (b)Are required in large quantities in plants
    (c) Form large molecules in plants (d)None of the above
12. Stem and root tips die in deficiency of
    (a) Nitrogen (b) Phosphorus (c) Calcium (d) Sulphur

13. Nitrogen is a component of

(a) Protein (b) Chlorophyll (c) Nucleic acid (d) All the above

14. The raw material most used by the plants is

(a) O_2 (b) CO_2 (c) N_2 (d) K

15. The cause of special flavour in onion and garlic is due to the presence of

(a) Sulphur (b) Phosphorus (c) Potassium (d) Nitrogen

16. Potassium is useful in development of

(a) Fibre (b) Pith (c) Parenchyma (d) None of these

17. Plants absorb sulphur in the form of

(a) SO_4 from soil (b) SO_2 from air (c) Both (a) and (b) (d) SO_3 from soil

18. The major role of phosphorus in plant metabolism is

(a) To generate metabolic energy (b)To evolve oxygen during photosynthesis

(c) To evolve carbon dioxide during respiration (d) To create anaerobic conditions

19. Deficiency of iron causes

(a) Bending of leaf tip (b) Interveinal chlorosis first on young leaves

(c) Decreases of protein synthesis (d) Reduced leaves and stunted growth

20. Iron is mainly absorbed in the

(a) Ferrous form (b) Ferric form (c) Both (a) and (b) (d) None of these

21. Yellowing of leaves or chlorosis is the first deficiency symptom of which element

(a) Calcium (b) Nitrogen (c) Phosphorus (d) Chlorine

22. Reservoir of sulphur is

(a) Rocks (b) Oceans (c) Atmosphere (d) Lakes

23. Clay and organic matter of the soil have negative charges. They attract positively charged ions like

(a) Ca^{2+} (b) Mg^{2+} (c) K^{+} (d) All the above

24. Which of the following is required for binding protein with nucleic acid

(a) Nickel (b) Iron (c) Cobalt (d) Calcium

25. Which of the following element is a component of ferredoxin

(a) Cu (b) Mn (c) Zn (d) Fe

26. Carbon becomes available to crop plants in the form of

(a) Amino acids (b) Carbonates (c) Carbon dioxide (d) Element carbon

27. Cabbage plant absorbs phosphorus from

(a) Dry soil (b) Water irrigated soil (c) From phosphate rocks (d)None of these

28. Plants growing in urea sprayed but Mg deficient, soil will show

(a) Deep green foliage (b) Early flowering

(c) Yellowing of leaves (d) Loss of pigmentation in petals

29. Plants needed one of the following for the formation of ATP

(a) N, Cu (b) K (c) N, P (d) N, Ca

30. Which element is largely responsible for maintaining turgor in plants

(a) *Na* (b) *Ca* (c) *Hg* (d) *K*

31. Which is not a macroelement

(a) Calcium (b) Nitrogen (c) Potassium (d) Zinc

32. Which one of the following is not a trace element

(a) Maganese (b) Calcium or Magnesium

(c) Boron (d) Molybdenum

33. Phosphorus is present in

(a) Vitamin A (b) Vitamin C (c) Lecithin (d) Glycin

34. Mineral present in cytochrome is

(a) *Fe* (b) *Cu* (c) *Mg* (d) *Mn*

35. Which of the following amino acid is non-sulphur containing

(a) Cystein (b) Glycine (c) Cystine (d) Methionine

36. Which of the following deficiency may cause leaf tip bending

(a) Sulphur (b) Nitrogen (c) Phosphorus (d) Calcium

37. Which of the following is a macro-nutrient

(a) *Ca* and *Mg* (b) *Mo* (c) *Mn* (d) *Zn*

38. Critical elements are

(a) *Na, K* and *Ca* (b) *N, P* and *Mg* (c) *N, P* and *K* (d) *Mn, B* and *Mo*

39. The ion which is commonly found free in the cell is

(a) Potassium (b) Borate (c) Sulphur (d) Nitrogen

40. Which of the following is present in the core of chlorophyll molecule

(a) *Fe* (b) *Mg* (c) *K* (d) *Mn*

41. Essential macronutrients are

(a) Manufactured during photosynthesis (b) Produced by growth hormones

(c) Absorbed from soil (d) Produced by enzymes

Advance Level

42. Who proved first that magnesium is the essential element of chlorophyll

(a) Wilstatter (1906) (b)J. Senebier (1782)

(c) Joseph Priestly (1991) (d)J. Ingenhousz (1910)

43. Deficiency of which of the following element cause weakening of pedicel and petiole

(a) Magnesium (b) Zinc (c) Nitrogen (d) Calcium

44. A primary deficiency is caused by insufficient absorption of

(a) Magnesium (b) Manganese (c) Calcium (d) Potassium

45. Both nitrogen and sulphur are required by plants for

(a) Chlorophyll synthesis (b)Enzymes

(c) Cell wall (d)Stomatal movements

46. Calcium gets accumulated in

(a) Differentiating tissues (b)Older leaves (c) Buds (d) Young tissues

47. If chlorophyll is burnt what element will be left

(a) *Mg* (b) *Fe* (c) *Na* (d) *Mn*

48. Macroelements must generally be present in plant tissues in concentrations of at least

(a) 0.0001 *mg/g* dry matter (b)0.01 *mg/g* dry matter

(c)0.1 *mg/g* dry matter (d)1.0 *mg/g* dry matter

49. Tea yellow is a disease of tea plants produced due to the deficiency of

(a) Phosphorus (b) Sulphur (c) Potassium (d) Nitrogen

50. A sulphur containing amino acid is

(a) Methionine (b) Asparagine (c) Serine (d) Proline

51. Calcium is a component of

(a) Primary walls (b) Secondary wall (c) Chlorophyll (d) Middle lamella

52. In plants a common symptom caused by deficiency of *P*, *K*, *Ca* and *Mg* is the

(a) Bending of leaf up (b) Formation of anthocyanin

(c) Poor development of vasculature (d) Appearance of dead necrotic areas

53. Phosphorus and nitrogen ions generally get depleted in soil because they usually occur as

(a) Neutral ions

(b) Negatively charged ions

(c) Positively charged ions

(d) Both positively and negatively charged but disproportionate mixture

54. The most important role of K^+ ions is that

(a) It provides red colour

(b) It promotes photosynthesis

(c) It influences many enzymic activities which regulate many plant processes

(d) It helps in the formation of cambium

55. Sinigrin, pungent principle compound of mustard is due to

(a) Glycoside containing sulphur (b) Glycoside containing amino group

(c) Alkaloids containing cyanide radicle (d) Tannins containing nitrogen

56. Which element is essential for root hair formation

(a) *Ca* (b) *Zn* (c) *Cu* (d) *Na*

57. Excessive supply of nitrogen to plants results in

(a) Large number of dark green leaves (b) Lesser number of variegated leaves

(c) No leaves (d) Yellowish leaves

58. Phosphorus works as carrier of

(a) Cabalt (b) Zinc (c) Magnesium (d) Copper

59. Why slight deficiency of phosphorous is considered to be useful to the plants against desiccation
(a) It induces greater mechanical tissues and higher root/shoot ratio
(b) It induces greater mechanical tissues and increase in the rate of photosynthesis
(c) It induces greater mechanical tissues and increase in the rate of respiration
(d) It induces greater mechanical tissue and increase in flowering

60. In calcium deficient plants, meristematic regions of the stem and root tips are greatly affected and chlorosis of the margins of young leaves takes place. These symptoms eventually lead to the death of leaf, stem and root apices. These observations are related to the role of calcium in plant growth as it is
(a) A constituent element of chlorophyll
(b) Required for the formation of the middle lamella
(c) Involved in the synthesis of chloroplast proteins
(d)Involved in the hydration and permeability of cells

MICRO - NUTRIENTS

Basic Level

61. A trace element is an element which
(a) Is a radioactive and can be traced by Geiger counter
(b) Is required in very minute amounts
(c) Draws other element out of protoplasm
(d) Was one of the first to be discovered in protoplasm

62. Which of the following is not a macro-nutrient
(a) *Mn* (b) *Ca* (c) *Mg* (d) Phosphorus

63. Micronutrients mainly function as
(a) Osmotic constituents of cell sap (b)Components of important biochemicals
(c) Cofactors of enzymes (d)Constituents of chlorophyll

64. Which of the following is a micro-nutrient or a trace element
(a) *Mg* (b) *Zn* (c) *Ca* (d) *P*

65. Plastocyanin contains
(a) *Mo* (b) *Fe* (c) *Cu* (d) *Zn*

66. Which is not a micronutrient
(a) *P* (b) *Cu* (c) *Zn* (d) *Mo*

67. Which of the following are trace elements
(a) Boron and Manganese (b)Copper, Zinc and Iron
(c) Chlorine and Molybdenum (d) All of the above

68. In a *Citrus* plantation, all the plants were found to be suffering from the die-back disease, spraying of fungicides was of no help. This problem was due to the deficiency of
(a) Copper (b) Gibberellic acid (c) Zinc (d) Auxins

69. A trace element essential for plant growth and radioactive isotope which is used in cancer therapy is known as

(a) Cobalt (b) Iron (c) Calcium (d) Sodium

70. Deficiency of which of the following elements checks the cell division of cambium but cell elongation continues

(a) Calcium (b) Sodium (c) Manganese (d) Boron

71. Which is not a microelement

(a) *Cu* (b) *Mn* (c) *Bo* (d) *Ca*

72. Which of the following is not an essential micronutrient

(a) Boron (b) Nickel (c) Manganese (d) Molybdenum

73. Essential micronutrients are also known as

(a) Tracer elements (b) Trace elements (c) Radioisotopes (d) Organic nutrients

74. Which is the role of molybdenum

(a) Nitrogen fixation (b) Chromosome contraction

(c) Flower induction (d) Carbon assimilation

75. Microelements being found in traces have

(a) A very significant role in the development of osmotic potential

(b) No significant role in the development of osmotic potential

(c) A significant role in the development of osmotic potential when temperature is between 15-25°C

(d) A significant role in the development of osmotic potential when respiration rate is very high

76. Which of the following is a micronutrient

(a) Calcium (b) Phosphorus (c) Copper (d) Magnesium

77. Micronutrients are

(a) Less important than macronutrients (b) As important as macronutrients

(c) Having a minor role in plant nutrition

(d) Omitted from culture medium without any detrimental effect

78. One of the causes of littles leaf disease is due to deficiency of

(a) Copper (b) Sodium (c) Molybdenum (d) Zinc

79. Boron assists in

(a) Activation of enzymes (b)Photosynthesis

(c) Sugar transport (d)Acting as enzyme cofactor

80. Absorption of water and calcium is increased by

(a) Manganese (b) Zinc (c) Boron (d) Copper

81. The micronutrient least required by plants is

(a) Cobalt (b) Nickel (c) Manganese (d) Boron

82. The essential element for the synthesis of auxin is

(a) Zn (b) Phosphorous (c) Sulphur (d) Potassium

83. Nonessential element taking part in plant growth is

(a) Magnesium (b) Calcium (c) Cobalt (d) Chlorine

84. Which of the following is a micronutrient or a trace element
(a) Zn or Mn or Mo (b) Ca (c) P (d) Mg

85. Boron is absorbed as
(a) Borate ions (b)Solution in water
(c) As boron trichloride (d)None of the above

86. Copper is the component of
(a) Cytochrome oxidase (b)Plastoquinone (c) Both (a) and (b) (d) None of these

87. The essential nutrient element required by plants in the least quantity is
(a) Chlorine (b)Molybdenum (c) Manganese (d) Zinc

88. An element useful in seed germination is
(a) Iron (b) Magnesium (c) Boron (d) Zinc

89. Element which maintains the solubility of calcium in the cells is
(a) Manganese (b) Copper (c) Iron (d) Boron

90. Tracer elements are
(a) Micro elements (b) Macro-elements (c) Radio isotopes (d) Vitamins

Advance Level

91. Deficiency of molybdenum cause
(a) Poor development of vasculature (b) Bending of leaf tip
(c) Yellowing of leaves (d) Mottling and necrosis of leaves

92. Photosynthetic photolysis of water takes place in presence of
(a) Mn (b) Cl (c) Both (a) and (b) (d) None of these

93. Heart rot of marigold is caused by the deficiency of
(a) Chlorine (b) Copper (c) Boron (d) Zinc

94. The deficiency of molybdenum induces
(a) *Citrus* die-back disease (b) Pea rosette disease
(c) Cauliflower whip-tail disease (d) White bud of maize

95. Apple fruit develop internal cork due to deficiency of
(a) Magnesium (b) Iron (c) Manganese (d) Boron

96. Which element is required by enzyme urease to hydrolyse urea by living organisms
(a) Zn (b) Ni (c) Na (d) Cl

97. Browning of cauliflower takes place due to deficiency of which one of the following elements
(a) Copper (b) Molybdenum (c) Potassium (d) Manganese

98. The vitamin which contains cobalt is
(a) B_1 (b) B_2 (c) B_6 (d) B_{12}

99. Importance of microelements was recognised late due to
(a) Their toxicity (b) Presence as contaminants in macronutrients
(c) Their absence in plant ash (d) Leakage from roots

100. Manganese (Mn^{++}) ions are required in which part of the plant
(a) Leaves and fruits (b) Leaves and seeds (c) Fruits and seeds (d) Fruit and stem

101. Microelement required for synthesis of IAA is also a cofactor for enzyme
(a) Nitrogenase (b) Catalse (c) PEP carboxylase (d) Carbonic anhydrase

102. Grey spots of Oat are caused by deficiency of
(a) *Cu* (b) *Zn* (c) *Mn* (d) *Fe*

103. Mottle leaf in *Citrus* plants is due to deficiency of
(a) Boron (b) Magnesium (c) Zinc (d) None of these

104. The micro element absorbed by foliage is
(a) Boron (b) Phosphorus (c) Zinc (d) Aluminium

105. The plants accept *Zn* as
(a) *Zn* (b) Zn^{2+} (c) *ZnO* (d) $ZnSO_4$

106. Which pair of elements is required at the time of terminal oxidation in oxidative phosphorylation
(a) *Cu* and *Fe* (b) *Ca* and *Cu* (c) *Fe* and *Ca* (d) *Fe* and *S*

107. Little leaf/leaf rosetting is deficiency symptom of
(a) *Zn* (b) *Mn* (c) *Fe* (d) *B*

108. Molybdenum deficiency in plants is rare because it is
(a) Absorbed from soil in abundance (b) The constituent of the enzyme nitrate reductase
(c) Required by plants only in trace amounts (d) Not readily absorbed

109. Khaira disease of paddy is caused by
(a) MLO attack (b) Viral attack (c) *Zn* deficiency (d) *Mn* deficiency

110. Element required in least quantity is
(a) *Zn* (b) *Mn* (c) *Mo* (d) *Cl*

111. Whiptail of crucifers is due to deficiency of
(a) *Zn* (b) *P* (c) *Mo* (d) *Cu*

112. The "drought spot" of apples is caused due to the deficiency of
(a) Copper (b) Nitrogen (c) Boron (d) Magnesium

MINERAL – ABSORPTION

Basic Level

113. All mineral salts are absorbed in cells as
(a) Ions (b) Atoms (c) Molecules (d) All of these

114. Ion carriers are located in
(a) Intercellular spaces (b) Cell wall (c) Nucleus (d) Cell membranes

115. Ions are absorbed by the plants through
(a) Molecular diffusion (b)Carriers and pumps
(c) Difference in water potential (d)Difference in D.P.D.

116. A number of minerals like *Ca*, *Mg* and *K* are held over the surface of clay particles because the latter are
(a) Negatively charged (b)Positively charged
(c) Neutral (d)Having both positive and negative residual valencies

117. Soil nitrate is more likely to leach than ammonium due to its
(a) Small size (b) Negative charge
(c) Being useless to soil flora (d) Abundance

118. Plants absorb mineral salts from the soil solution through
(a) Semipermeable membrane into the cytoplasm (b) Perforation at the apex of root-hairs only
(c) The cell wall which is semipermeable (d) None of these

119. Active transport from outside to inside of molecules across a membrane requires
(a) Cyclic AMP (b) Acetyl chlorine (c) ATP (d) Phloroglucinol

120. Active uptake of minerals by roots mainly depends on the
(a) Availability of oxygen (b) Light
(c) Temperature (d) Availability of carbon dioxide

121. If a plant shows mineral deficiency, it is due to which of the following reasons
(a) Minerals may be present in low quantity in the soil so that it can not be, absorbed along the concentration gradient
(b) Minerals may be present in excess in the soil and thus they disturb the concentration gradient
(c) Minerals may be in isotonic concentration and thus are in capable of being absorbed by the plant
(d) Minerals may be in an insoluble form due to unfavourable *pH*

122. In which type of absorption of minerals the solutes move into a cell along their chemical potential gradient without any expenditure of energy
(a) Active absorption (b) Passive absorption
(c) Both active and passive (d) None of these

123. Point out the one which is not an example of passive absorption of minerals
(a) Osmosis (b) Diffusion (c) Mass flow (d) Ionic exchange

124. Point out the one which does not justify active absorption of minerals
(a) Cations and anions are often absorbed at different rates
(b) Absorption of different ions is highly selective
(c) Absorption is accompanied by increase in the rate of respiration
(d) Absorption is the movement of substances from higher concentration to their lower concentration

125. Which of the following shows that metabolic energy is required in the absorption of ions
(a) More ions absorption in presence of oxygen
(b) Less absorption of ions in presence of oxygen
(c) More ions absorption in presence of ATP (d) More ions absorption in presence of NAD

126. The process by which minerals are absorbed is
(a) Active absorption (b) Passive absorption (c) Both (a) and (b) (d) None of these

127. In the light of carrier concept, the transport of ion across the membrane is
(a) Passive process (b) Non-osmotic process (c) Osmotic process (d) Active process

128. ATP molecules combine with carrier molecules and allow passage of substances
(a) Along concentration gradient (b) Against concentration gradient
(c) Both (a) and (b) (d) ATP is not required

129. The movement of mineral ions into plant root cells as a result of diffusion is called
(a) Osmosis (b) Passive absorption (c) Active absorption (d) Endocytosis

130. Mineral absorption is mostly
(a) Physical process (b) Chemical process (c) Active process (d) Passive process

131. Larger molecules (bulk flow) are taken into the cell by
(a) Osmosis (b) Pinocytosis
(c) Pinocytosis and phagocytosis (d) Phagocytosis

132. Molecules move inside and out side of living cells of
(a) Osmosis only (b) Diffusion only (c) Osmosis and diffusion (d) None of these

133. In hydrophytic plants, water and salts are absorbed by
(a) Roots (b) Leaves (c) Stem (d) Outer layer of plants

134. Passive absorption of minerals depends upon
(a) Humidity (b) Temperature
(c) Temperature and metabolic inhibitor (d) Metabolic inhibitor

135. Ion uptake is called active because
(a) Ions are active (b) Energy is expended (c) Ions move freely (d) Ions move passively

136. Active and passive transports across cell membrane differ in
(a) Passive transport is nonselective
(b) Passive transport is along the concentration gradient while active transport is due to metabolic energy
(c) Active transport is more rapid
(d) Passive transport is confined to anions while active transport in confined to

137. Slow rate of absorption of ion at high temperature is due to
(a) Low photosynthetic rate (b) Low rate of transpiration
(c) Enzyme inactivation (d) All of these

138. Ions are transported across the cell membranes by means of
(a) Primary proteins (b) Secondary proteins (c) Tertiary proteins (d) Contractile proteins

139. The chemical nature of carrier molecules facilitating transport across plasma membrane is
(a) Starchy (b) Sugary (c) Proteinaceous (d) Fatty acidic

140. The efflux of ions from the cell is enhanced by
(a) Heat (b) Removal of Ca^{++}
(c) Both of these (d) Increasing O_2 supply

141. Bidirectional translocation of minerals takes place through
(a) Parenchyma (b) Cambium (c) Xylem (d) Phloem

Advance Level

142. Which can function as carrier in active absorption

(a) Cytochrome (b) Ferredoxin (c) Lecithin (d) Plastoquinone

143. Mineral absorption occurs

(a) If soil solution is hypotonic (b)If soil solution is hypertonic

(c) Independent of water potential (d)Independent of water absorption

144. Theory suggesting that carbon dioxide produced in respiration helps in mineral absorption is called

(a) Carbonic acid exchange theory (b)Contact exchange theory

(c) Active mineral absorption (d)Donnan equilibrium

145. Salt respiration is

(a) Linking of ion movement with respiratory chain

(b)Active increase in respiration during mineral absorption

(c) Decrease in respiration during salt absorption

(d) Secretion of salt through respiratory channels

146. Which of the following does not operate in the carrier concept of active absorption of minerals

(a) Electron transport (b) Contractile protein

(c) Protein lecithin (d) Ascending water stream

147. Sulphate uptake by plant is through

(a) Passive transport (b) Active transport (c) Imbibition (d) Osmosis

148. According to the well known theory of transport of solutes across a cell membrane, what happens when sugar is passed through it

(a) Na^+ flows in the direction of the sugar (b) Na^+ flows independent of sugar molecules

(c) Na^+ flows against the sugar molecules (d) Na^+ ions do not flow at all

149. When a cell contains some nondiffusible or fixed ions which are kept balanced by diffusible ions of opposite charge, this condition is known as

(a) Donnan equilibrium (b) Chemical equilibrium (c) Saturation effect (d) Ionic exchange

NITROGEN - NUTRITION

Basic Level

150. In plants, nitrate is reduced to ammonia state in two steps. In second step, electrons are donated by

(a) Ferredoxin (b) Nitrate reductase (c) Nitrite reductase (d) Cytochrome b_5

151. Certain bacteria living in the soil poor in oxygen convert nitrates into nitrites and then to free nitrogen and such bacteria are termed as

(a) Nitrogen fixing bacteria (b)Denitrifying bacteria

(c) Ammonifying bacteria (d)Saprophytic bacteria

152. One of the following is a nitrogen fixing enzyme

(a) Urease (b) Arginase (c) Nitrate reductase (d) All above

153. The enzyme nitrogenase has which of the two components

(a) The component one has iron and molybdenum and component two has only iron

(b) The component one has only iron and the component two has both iron and molybdenum

(c) Both components have iron as well as molybdenum

(d) Both components have only iron

154. Nodule formation is reduced in legume roots due to the deficiency of

(a) Nitrogen (b) Boron (c) Sulphur (d) Both (b) and (c)

155. The fixation of nitrogen in the root nodules is an example of

(a) Associative symbiosis (b)Obligatory symbiosis

(c) Non-symbiotic nitrogen fixation (d)Phyllosphere association

156. Organisms that fix nitrogen in aquatic habitats are

(a) Green algae (b) Cyanobacteria (c) Brown algae (d) Protozoa

157. The nodule in a plant root where nitrogen fixing bacteria live is formed from the cells of

(a) Cortex (b) Epidermis (c) Endodermis (d) Vascular cylinder

158. Nodules with nitrogen fixing bacteria are present in roots of

(a) Cotton (b) Gram (c) Wheat (d) Maize

159. Members of bean family are particularly important for rotation of crop. because

(a) They add green manure (b)They add nitrates to soil

(c) They make soil porous (d)They add calcium to soil

160. In nitrogen fixation

(a) Plants convert atmospheric nitrogen to nitrates

(b) Plants absorb ammonia from the soil

(c) The bacteria are all housed in nodules on the plant's roots

(d) The enzyme nitrogenase produces ammonia from gaseous nitrogen

161. Which of the following nutrient element is most important for protein synthesis

(a) N_2 (b) K (c) Mg (d) Fe

162. Which is needed to reduce nitrate to nitrite

(a) P (b) Fe (c) Zn (d) Mo

163. Nitrogen absorbed by plants is

(a) Reduced to ammonia (b)Converted to nitrate

(c) Converted to nitrite (d)Combined with oxygen

164. Which one of the following statement is correct

(a) Legumes fix nitrogen only through specialized bacteria that live in their leaves

(b) Legumes are incapable of fixing nitrogen

(c) Legumes fix nitrogen only through the specialized bacteria that live in their roots

(d) Legumes fix nitrogen independently of the specialized bacteria that live in their roots

165. Rotation of crops is essential for

(a) Getting different types of crops (b)Increasing quantity of minerals

(c) Increasing fertility of the soil (d) Increasing quantity of proteins

166. Which of the following is non symbiotic

(a) *Azotobacter* (b) *Nostoc* (c) *Rhizobium* (d) Non of these

167. One of the ways in which the nitrogen of atmosphere is converted into nitrate for plants is by the action of

(a) Temperature (b) Lightening (c)Denitrifying bacteria (d)Decay

168. Which one does not contribute to nitrogen availability in the soil

(a) Decay of organic matter (b) Electric storms

(c) *Azotobacter* (d) Liming

169. Ammonium sulphate is

(a) Insecticide (b) Weedicide (c) Fertiliser (d) Toxic chemical

170. A fertiliser has a formula of three figures 15-9-9. They stand for percentage of

(a) *N*, *Ca* and *Mg* (b) *Mg*, *P* and *K* (c) *Ca*, *N* and *Fe* (d) *N*, *P* and *K*

171. Non-legume nitrogen fixing organisms belongs to genus

(a) *Rhizobium* (b) *Frankea* (c) *Clostridium* (d) *Azotobacter*

172. The *Nitrobacter* and *Nitrosococcus*

(a) Oxidise nitrite to nitrate (b)Oxidise nitrate

(c) Reduce nitrite (d) Reduce nitrate

173. Reduction is the term used when conversion of .... takes place

(a) Nitrate to nitrite (b) Nitrite to nitrate

(c) Ammonia to nitrogen (d) Nitrogen to ammonia

174. Which of the following deficiency may cause the reduction in the growth of leaves

(a) Nitrogen (b) Sodium (c) Manganese (d) Iron

175. Which one is not related with plant ash

(a) Trace elements (b) Essential elements (c) Nitrogen (d) Mineral elements

176. The first enzyme that reduces nitrate to nitrite and ammonia in plants is

(a) Nitrate reductase (b) Nitrite reductase

(c) Glutamine synthetase (d) Glutamate dehydrogenase

177. The symbiotic fixation of atmospheric nitrogen in root nodules of pulse crops is brought about by

(a) *Mycobacterium* (b) *Rhizobium* (c) *Rhizopus* (d) *Mucor*

178. Nitrogen absorbed by plants is

(a) Converted to nitrate (b) Reduced to ammonia

(c) Changed to nitrite (d) Combined with oxygen

179. NPK denotes

(a) Nitrogen, protein and kinetin (b)Nitrogen, protein and potassium

(c) Nitrogen, potassium and kinetin (d)Nitrogen, phosphorus and potassium

180. Symbiotic microorganism is

(a) *Clostridium* (b) *Azotobacter* (c) *Rhizobium* (d) *Chromatium*

181. Deficiency of nitrogen produces

(a) Reduced growth (b) Chlorosis (c) Die back disease (d) Reduced respiration

182. Main function of leghaemoglobin is to

(a) Promote oxygen availability to nodules (b)Generate ATP for nitrogen fixation

(c) Generate hydrogen ions for ammonia formation (d)Scavenge oxygen

183. Nitrogen is not a constituent of

(a) Invertase (b) Pepsin (c) Bacteriochlorophyll (d) Idioblast

184. Reduced availability of nitrogen during late growth causes

(a) Increase in the carbohydrate content of fruits and storage organs

(b) Decrease in the carbohydrate content of fruits and storage organs

(c) Increase in the ethylene content of fruits and storage organs

(d) Decrease in the ethylene content of fruits and storage organs

185. Enzyme catalyzed reactions can be inhibited by

(a) Mg^{2++} (b) Zn^{2++} (c) Cu^{2++} (d) Hg^{2++}

186. Fertility of the soil in rice fields can be improved by

(a) Gypsum (b) Sodium chloride (c) Blue-green algae (d) *Rhizobium*

187. Most of the plants obtain nitrogen from the soil in the form of

(a) Free nitrogen gas (b) Nitric acid (c) Nitrites (d) Nitrates

188. Which one of the following plant cannot fix atmospheric nitrogen directly

(a) Bean (b) Castor (c) Gram (d) Pea

189. Legume plants are important because they

(a) Help in NO_2 fixation (b) Not help in NO_2 fixation

(c)Increased soil fertility (d) All of these

190. Major nitrogen fixation is carried out by

(a) Lightening (b) Chemical industries (c) Symbiotic bacteria (d) Leaching

191. Best fertilizer for paddy fields is

(a) *Azolla pinnata* (b) *Rhizobium melilotii*

(c) *Bacillus megatherium* (d) *Bacillus polymyxa*

Advance Level

192. The leghaemoglobin which imparts pink red colour to the root nodules is located in

(a) The wall of bacteria

(b) The wall of host cell

(c) In the cytoplasm of host cell

(d) In between bacteroids and the surrounding membrane of host origin

193. Besides providing pink colour to the root nodules, leghaemoglobin performs the function of

(a) Protecting enzyme nitrogenase from free oxygen

(b) Transporting nitrogen to host cells

(c) Protecting bacteroids from the enzymes of host cell

(d) Protecting leakage of fixed nitrogen to the soil atmosphere

194. The limiting factor in nitrification of soil is

(a) Soil nature (*pH*) (b) Temperature (c) Light (d) Air

195. In root nodules of leguminous plants, the *Rhizobium* bacteroids are filled in

(a) Diploid cells (b) Triploid cells (c) Tetraploid cells (d) Hexaploid cells

196. The carnivorous plants live in water logged or boggy habitats which are

(a) Deficient in nitrates (b) Deficient in sulphites

(c)Deficient in oxygen (d) Deficient in many salts

197. A crop plant can grow well in nitrogen deficient soils without addition of manure is

(a) *Cajanus cajan* (b) *Gossypium herbaceum*

(c)*Helianthus annuus* (d)*Allium sativum*

198. *Nitrosomonas* and *Nitrosococcus* promote

(a) Anaerobic reduction of ammonia (b) Anaerobic oxidation of ammonia

(c) Aerobic reduction of ammonia (d) Aerobic oxidation of ammonia

199. The possibility of increase of infectious disease become more due to more supply of

(a) Potassium (b) Magnesium (c) Copper (d) Nitrogen

200. The element which is required in largest quantities by plants is

(a) Phosphorus (b) Nitrogen (c) Sulphur (d) Calcium

201. On the basis of symptoms of chlorosis in leaves, a student inferred that this was due to the deficiency of nitrogen. This inference could be correct only if yellowing of leaves appeared first in

(a) Young leaves (b) Old leaves

(c) Young leaves followed by old leaves (d) Old leaves followed by young leaves

MISCELLANEOUS PROBLEMS

Basic Level

202. Which combination of micro and macronutrients is correct

(a) Cu, Fe, K, P ; B, Zn, Mo, N (b) Cu, K, P, B ; Fe, N, Mo, Ca

(c) Cu, Zn, B, Mo ; N, P, K, S (d) B, Fe, K, Zn ; P, K, Mn and Mo

203. Minerals of soil are derived from

(a) Rocks (b) Clay (c) Sub soil (d) Organisms

204. The plant ash is an indication of

(a) Mineral salts absorbed by the plant (b) Organic matter of the plant

(c) Both the mineral salts and organic matter (d) None of the above

205. The constant *pH* of body fluid is maintained by buffer salts like

(a) Potassium phosphates (b) Sodium phosphates

(c) Adenosine monophosphate (d) Sodium and potassium phosphates

206. Frame-work elements in plants are

(a) Magnesium, copper and iron (b) Copper, carbon and oxygen

(c) Manganese, calcium and nitrogen (d) Carbon, hydrogen and oxygen

207. Mineral requirement is studied through hydroponics which is related to growing plants in

(a) Soil (b) Air (c) Solution (d) Ponds

208. Which one is not an essential element in plants

(a) Iron (b) Boron (c) Sulphur (d) Cadmium

209. On earth the largest reservoir of nitrogen is

(a) The oceans (b) Granite rocks (c) The air (d) The soil

210. Cyanobacteria helps farmers by

(a) Reducing the alkality of soil (b) Increasing soil-fertility of soil

(c) Neutralising alkality of soil (d) Water logging

211. Plants can be cultivated in soil less medium where all nutrients are supplied from outside in water solution and this method comes under

(a) Water culture (b) Hydroponics

(c) Hybrid culture (d) Critical culture media

212. EDTA (Disodium salt of ethylene diamine tetra acetic acid) is much used in tissue cultures it is a

(a) Nutrient (b) Buffer (c) Hormone (d) Vitamin

213. The presence of an element in plant ash

(a) Does not guarantee that it is essential (b) Proves that it is essential

(c) Proves that it takes part in the physiology of plants

(d) Indicates that it occurs in abundance in soil

214. Which one is inorganic nutrient

(a) Protein (b) Calcium (c) Cellulose (d) Vitamin

215. If a dried leaf is taken in a crucible and heated to $600°C$, a grey coloured powder is left behind. It is referred to as

(a) Wilting percentage (b) Protein content of the plant

(c) Plant ash (d) Dry weight

216. Which one of the following elements is not required by plants for their normal healthy growth

(a) Magnesium (b) Lead (c) Iron (d) Calcium

217. Passage of minerals from top soil to subsoil through seepage of water is known as

(a) Leaching (b) Percolation (c) Conduction (d) Transpiration

218. The number of essential elements required for normal growth of plant is

(a) 10 (b) 16 (c) 20 (d) 25

219. The role of inorganic nutrients in plant growth was at first indicated by

(a) Woodward (b) Steward (c) De Saussure (d) Knop

220. Chlorosis, etiolation and albinism are caused by the deficiency of

(a) Iron, light and certain genes (b)Zinc, iron and magnesium

(c) Magnesium, iron, zinc, light and certain genes (d)Magnesium, zinc and light

221. A nonessential element is

(a) Calcium (b) Barium (c) Potassium (d) Magnesium

222. Most minerals in a soil are in the
(a) Silt (b) Clay (c) Sand (d) Air pockets

223. Sinks are related to
(a) Transport of minerals (b)Stomata (c) Enzymes (d) Phytochrome

224. First experiments in hydroponics were performed by
(a) Sachs (b) Knop (c) Hoagland (d) Arnon

225. Pigment leghaemoglobin is present in roots of
(a) Maize (b) Rice (c) Soyabean (d) Potato

226. Which of the following is not essential for plant growth
(a) Calcium (b) Carbon (c) Potassium (d) Sodium

227. Which of the following is used as green manure
(a) *Zizyphus* (b) *Azardiracta indica* (c) *Crotolarea juncea* (d) *Hevea brassiliansis*

228. The main source of carbon in nature is through
(a) Methanogenic archaebacteria (b) Methanogenic bacteria
(c) Methanogenic fungi (d) Methanotrophic slime molds

229. In absence of essential mineral elements, leaves of many plants turn yellow due to
(a) Plasmolysis (b) Chlorosis (c) Necrosis (d) Etiolation

230. The four elements that makes up 99% of all elements found in a living system are
(a) *H, O, C, N* (b) *C, H, O, S* (c) *C, H, O, P* (d) *C, N, O, P*

231. Which group of element is not essential for a normal plant
(a) Potassium, calcium, magnesium (b)Iron, zinc, manganese, boron
(c) Lead, nickel, iodine, sodium (d)Magnesium, iron, molybdenum

232. "Hunger signs" in plants are
(a) Symptoms due to lesser water absorption in plants
(b) Symptoms due to poor photosynthesis in plants
(c) Deficiency symptoms of particular mineral nutrients (d)None of these

233. Essential macroelements are
(a) Produced by growth hormones (b) Produced by enzymes
(c) Manufactured during photosynthesis (d) Absorbed from soil

234. Which one of the following essential elements can land plants normally obtain directly from the air
(a) Hydrogen (b) Carbon (c) Nitrogen (d) Phosphorus

235. Cultivation by sand culture is also called
(a) Soilless cultivation (b) Green house effect (c) Photorespiration (d) None of these

236. Which one of the following scientists used the nutrient culture solution in hydroponic cultures

(a) Sachs (b) Webster (c) Wallace (d) Knop

237. The most crucial event in nature governing nutrient balance is

(a) Primary production (b) Secondary production (c)Nutrient cycling (d) Gross production

238. Which of the following is widely used metal cofactor

(a) Ca^{2+} (b) Al^{3+} (c) Ni^{2+} (d) Mg^{3+}

239. Who gave the criteria of essentiality

(a) R. Hill (b) F.F. Blackman (c) M.P. Kaushik (d) D.L. Arnon

240. One of the following elements of not of much importance to plants

(a) Calcium (b) Zinc (c) Copper (d) Sodium

241. How the mineral contents of the plant known

(a) Titrimetric method (b) Calorimetric method (c) Ash analysis (d) All of these

242. The major portion of the dry weight of plants comprises of

(a) Carbon, hydrogen and oxygen (b) Nitrogen, phosphorus and potassium

(c) Calcium, magnesium and sulphur (d) Carbon, nitrogen and hydrogen

243. An essential element is that which

(a) Is found in plant ash (b) Is available in soil

(c) Improves health of plants

(d) Is irreplaceable and indispensable for growth of plants

244. Which of the following elements is not required by plants for their normal healthy growth

(a) Calcium (b) Magnesium (c) Lead (d) Iron

245. Those fertilizers, which provide all the essential elements such as N, P and K etc. required for plant growth, are called

(a) Direct fertilizers (b)Indirect fertilizers (c)Complete fertilizers (d)Incomplete fertilizers

246. Who proved for the first time that the plants contains a large number of minerals and microelements

(a) Arnon and Stout (b) Leibig

(c) De Saussure (d) Glauber and Mayhow

247. In nature, organic compounds invariably contain

(a) Carbon (b) Phosphorus (c) Sulphur (d) Magnesium

248. Match the columns and find the correct combination

(*A*)	N	(*i*)	Coppery texture of leaf
(*B*)	Mg	(*ii*)	Premature leaf fall
(*C*)	Bo	(*iii*)	Interveinal chlorosis
(*D*)	P	(*iv*)	Mottled chlorosis and necrosis

(a) $A - iv, B - i, C - ii, D - iii$ (b) $A - i, B - ii, C - iii, D - iv$
(c) $A - iv, B - iii, C - i, D - ii$ (d) $A - iv, B - ii, C - i, D - iii$

249. The agent that keeps metals in the soluble state is called
(a) Buffer agent (b) Chelating agent (c) Catalytic agent (d) Balancing agent

250. Which of the following will not make minerals more available to plants
(a) Increasing the rainfall in a wet forested area
(b) Raising the *pH* of a very acidic soil
(c) Tillering a packed-down or water-logged soil
(d) Introducing fungi that that can form mycorrhiza into a soil that lacks them

251. Which one is wrong combination
(a) N_2 – Amino acid (b) *Fe* – Cytochrome (c) *Na* – Protein (d) *Mg* – Chlorophyll

252. In plant mineral nutrition, elements are called macro or micro-elements depending upon their
(a) Relative presence in plant ash (b) Relative importance in plant growth
(c) Relative amount required in plants (d) Relative availability in soil

253. Inorganic nutrients are present in the soil as
(a) Molecules (b) Atoms
(c) Electrically charged ions (d) Colloids

254. Why do freshly exposed surfaces of many fruits and vegetables becomes dark ? Because
(a) Dust from the atmosphere settles on them
(b) Dirty knife leaves some traces of iron on them
(c) Oxidation of tannic acid in the presence of the trace of iron from the knife makes them dark
(d) The fruits are black in colour

255. The elements arsenic, copper and murcury have which of the following effect
(a) Catalytic effect (b) *pH* effect (c) Toxic effect (d) Antagonastic action

256. Mineral salts which are absorbed by the roots from the soil are in the form of
(a) Very dilute solution (b) Dilute solution (c) Concentrated solution (d)Very concentrated solu

257. Phytotron is meant for
(a) Controlled irradiation (b) Induction of mutations
(c) Controlled humidity
(d) Growing plants under controlled environment

258. In an experiment a plant was dried, crushed and heated strongly in a crucible for long. The residue contained]
(a) Oxides and carbonate of about ten elements (b) Oxides and carbonates of three elements
(c) Carbon only (d) Starch and related compounds

259. For the growth of which of the following sodium is required
(a) *Lycopersicum esculentum* (b) *Ziziphus*
(c) *Nigella sativa* (d) *Atriplex*

260. Plants detoxify heavy metals by means of

(a) Allelopectins (b) Abscisic acid (c) Phytolexins (d) Phytochelatins

261. Which of the following is not caused by deficiency of mineral nutrition

(a) Necrosis (b) Etiolation

(c) Chlorosis (d) Shortening of internodes

262. Photosynthetic nutrition in plants is also known as

(a) Holophytic nutrition (b)Holotrophic nutrition

(c)Heterotrophic nutrition (d)Heteroholophytic nutrition

263. Which of the following is considered to be the elements between macro-nutrients and micronutrients

(a) Iron (b) Nitrogen (c) Phosphorus (d) Manganese

264. Aeroponics is growing plants is

(a) Air (b) Satellites

(c) Other planets and space (d) Stands with liquid spray of their roots

265. When the presence of a small quantity of one mineral stop the entry of another mineral into the organic system, it is known as –

(a) Ionic exchange (b) Antagonism (c) Struggle for existence (d)Competition

266. Ash is of what significance in the study of mineral nutrition of plants

(a) It tells what minerals are present in the soil

(b) It informs which element is essential and in which amount it is necessary for a particular plant

(c) It is of no practical significance

(d) It indicates how much irrigation is needed by the plant

267. Soil salinity is measured by

(a) Porometer (b) Potometer (c) Conductivity meter (d) Calorimeter

SPECIAL MODES OF NUTRITION

Basic Level

268. A plant that manufactures its own food is

(a) Autotroph (b) Parasite (c) Epiphyte (d) Saprophyte

269. Plants which are unable to manufacture their food wholly or partially are

(a) Autophytes (b) Heterophytes (c) Halophytes (d) Holophytes

270. Which of the following parasite is also epiphytic

(a) *Striga* (b) *Orobanche* (c) *Balanophora* (d) *Cuscuta*

271. Which one of the following is the total root parasite

(a) *Orobanche* (b) *Cuscuta* (c) *Loranthus* (d) *Santalum*

272. Epiphytes are the plants which are dependent on other plants

(a) Only for water (b) For water and food

(c) Only for food (d) Only for shelter (support)

273. Partial parasite is dependent upon the host for
(a) Support (b) Food at times (c) Water (d) Water and minerals

274. *Cuscuta* is
(a) Total root parasite (b) Total stem parasite (c) Partial stem parasite (d)Epiphyte

275. Total root parasite is
(a) *Rafflesia* (b) *Cassytha* (c) *Viscum* (d) *Loranthus*

276. Lianas occur more commonly in
(a) Temperate forests (b) Deserts (c) Alpine vegetation (d) Tropical forests

277. Myrmecophily is a beneficial association between a flowering plant and
(a) Ants (b) Mycoplasma (c) Bacteria (d) Viruses

278. An example of a parasitic plant that is also strictly epiphytic is
(a) *Cuscuta* (dodder) (b) *Viscum* (mistletoe) (c) *Rafflesia* (d) *Orobanche*

279. Insectivorous plants usually grow in soils which are deficient in
(a) Nitrogen (b) Water (c) Organic matter (d) *Ca*/*Mg*

280. *Viscum* is
(a) Partial root parasite (b) Partial stem parasite (c) Total root parasite (d) Total stem parasite

281. *Drosera* catches insects by means of
(a) Bladder (b) Pitcher
(c) Tentacles secreting shining liquid (d) Adhesive disc

282. *Balanophora/Orobanche* is a
(a) Total root parasite (b) Partial root parasite (c) Partial stem parasite (d)Total stem parasite

283. *Santalum album is*
(a) Partial root parasite (b) Partial stem parasite (c) Total stem parasite (d) Total root parasite

284. Biggest flower belongs to a plant which is
(a) Partial stem parasite (b)Partial root parasite
(c) Total stem parasite (d)Total root parasite

285. *Loranthus* is a
(a) Total stem parasite (b) Partial stem parasite (c) Total root parasite (d) Partial root parasite

286. Majority of the orchids are
(a) Epizoics (b) Epiphytes (c) Saprophytes (d) Parasites

287. Botanical name of Venus Fly Trap is
(a) *Aldrovanda* (b) *Dionaea* (c) *Utricularia* (d) *Nepenthes*

288. One of the following in an insectivorous plant
(a) *Balanophora* (b) *Orobanche* (c) *Rafflesia* (d) *Drosera*

289. *Drosera* and *Sarracenia* are
(a) Symbiotic (b) Carnivorous (c) Parasitic (d) Chemoautotrophic

290. A plant growing on another plant without drawing any nourishment is
(a) Ectoparasite (b) Epiphyte (c) Symbiont (d) Saprophyte

291. Heterotrophic nutrition is present in
(a) *Vallisneria* (b) *Pistia* (c) *Drosera* (d) *Opuntia*
292. Plants obtaining food from other plants by means of haustoria are
(a) Symbionts (b) Parasites (c) Hydrophytes (d) Saprophytes
293. The smallest angiospermic/dicot parasite is
(a) *Arceuthobium* (b) *Wolffia* (c) *Cassytha* (d) *Rafflesia*
294. Insects captured by carnivorous plants partially meet their requirement of
(a) Organic matter (b) Enzymes (c) Water (d) Nitrogen
295. The association between ants and members of family rubiaceae is
(a) Ornithophily (b) Entomophily (c) Myrmecophily (d) Anemophily
296. *Nepenthes* is
(a) Both producer and primary carnivore (b) Producer
(c) Consumer (d) None of these
297. *Rhizophora* is an example of
(a) Lithophyte (b) Fresh water aquatic (c) Mesophyte (d) Halophyte
298. A plant living symbiotically inside another plant is
(a) Saprophyte (b) Endophyte (c) Semiparasite (d) Parasite
299. Which is not an insectivorous plant
(a) *Dionaea* (b) *Dischidia* (c) *Drosera* (d) *Pinguicula*
300. A pair of insectivorous plants is
(a) *Drosera* and *Rafflesia* (b)*Nepenthes* and Bladderwort
(c) *Dionaea* and *Viscum* (d)Venus fly trap and *Rafflesia*
301. One of the following is saprophytic angiosperm
(a) *Rafflesia* (b) *Cuscuta* (c) *Loranthus* (d) *Monotropa*
302. Which one of the following is a parasitic plant
(a) *Drosera* (b) *Cuscuta* (c) *Nepenthes* (d) *Utricularia*
(e) Water Hyacinth
303. An insectivorous plant is
(a) *Opuntia* (b) *Crotalaria* (c) *Eichhomia* (d) *Utricularia*
304. *Dionaea muscipula* is
(a) Venus fly trap (b) Butterwort (c) Water fly trap (d) Bladderwort
305. Select the one, which is pitcher plant
(a) *Drosera* (b) *Utricularia* (c) *Sarracenia* (d) *Aldrovanda*
306. Which one is the largest root parasite
(a) *Rafflesia* (b) *Monotropa* (c) *Arceuthobium* (d) All of these
307. Pitcher plant is
(a) Herbivorous (b) Carnivorous (c) Saprotroph (d) All of these

308. *Nepenthes khasiana* is a/an

(a) Fungicidal and wet land plant (b) Insectivorous and endangered plant

(c) Fungicidal and endangered plant (d) Insectivorous and wet land plant

309. *Aldrovanda* is

(a) Fly catcher plant (b) Water flea trap (c) Devil's foot (d) None of these

310. A pitcher plant without lid

(a) *Sarracenia* (b) *Dischidia* (c) *Dixidia* (d) None of these

Advance Level

311. A rootless aquatic in which a portion of leaf is modified to form a bladder for catching small aquatic animals is

(a) *Dionaea* (b) *Drosera* (c) *Utricularia* (d) *Nepenthes*

312. Insectivorous plants catch and digest insects for

(a) Obtaining nitrogen (b) Protecting their leaves

(c) Protecting their fruits (d) Being heterotrophs of consumer level

313. Insectivorous plant with rosette of spiny margined bilobed hinged and winged leaves for catching the prey is

(a) *Nepenthes* (b) *Drosera* (c) *Dionaea* (d) *Utricularia*

314. Insectivorous plants are adapted to

(a) Soil deficient in sugars (b) Water rich soils

(c) Soils rich in trace elements (d) Soils deficient in nitrogen compounds

315. Bird of Paradise flower is

(a) *Ravenea madagascariensis* (b) *Sterilitzia reginae* (c) *Heliconia schlideana* (d) *Musa chinensis*

316. Plants that grow over the branches of trees without contact with soil are

(a) Epiphytes (b) Symbionts (c) Saprophytes (d) Parasites

317. The enzyme commonly presents in insectivorous plants to fulfil the need of their specific habit

(a) *Trypsin* (b) *Pepsin* (c) *Pectinase* (d) *Cellulase*

***

ANSWER

ASSIGNMENT (BASIC & ADVANCE LEVEL)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
c	c	a	c	c	b	a	d	c	b	b	c	d	b	a	a	a	a	b	a
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
b	a	d	d	d	c	b	c	c	d	d	b	c	a	b	a	a	c	a	b
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
c	a	d	d	b	b	a	d	b	a	d	d	b	c	a	a	a	c	a	c
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
b	a	c	b	c	a	d	a	a	d	d	b	b	a	b	c	b	d	c	a
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
b	a	c	a	a	c	b	c	d	c	d	c	c	c	d	b	b	d	b	b
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
d	c	c	c	b	a	a	c	c	c	c	c	a	d	b	b	b	a	c	a
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
d	b	a	d	c	c	d	b	b	c	c	c	d	b	b	b	c	d	c	c
141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
d	c	d	a	b	d	b	a	a	a	b	c	a	d	b	b	a	b	b	d
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
a	d	d	c	c	a	b	d	c	d	b	a	a	a	c	a	b	b	d	c
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
b	d	d	a	d	c	d	b	c	c	a	d	a	a	c	a	a	d	d	b
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220
b	c	a	a	d	d	c	d	c	b	b	b	c	b	c	b	a	b	d	c
221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
b	b	a	a	c	d	c	a	b	a	c	c	d	b	a	d	c	c	d	d
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
d	a	d	c	c	b	a	c	b	a	c	c	c	c	c	a	d	a	d	d
261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280
b	a	a	d	b	b	c	a	b	d	a	d	d	b	a	d	a	b	a	b
281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
c	a	a	d	b	b	b	d	b	b	c	b	a	d	c	a	d	b	b	b
301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317			
d	b	d	a	c	a	b	b	b	b	c	a	c	d	b	a	b			