Telangana University
Department of Botany
M.Sc. BOTANY II SEMESTER
Paper –IV: Plant Physiology
INTERNAL Assessment – I Question bank
UNIT – I: PLANT WATER RELATIONS & MINERAL NUTRITION

1. To explain the movement of water in soil, plant and air system, the concept of water potential was proposed by [b]
   A. Dixon and Web B. R.O Slatyer and S.A Taylor
   C. Curtis D. Stephen Hales E. Calvin
2. Water potential value is the highest for [e]
   A. Hypertonic solution B. Hypotonic solution
   C. Isotonic solution D. Neutral solution E. Pure water
3. More concentrated solution will show [b]
   A. High water potential B. Low water potential
   C. Low osmotic pressure D. High pressure potential E. None of these
4. The amount of hydrophilic colloids of a solution decides its [c]
   A. Solute potential B. Osmotic potential
   C. Matric potential D. Pressure potential E. Water potential
5. When a cell is flaccid, which of the following becomes zero [e]
   A. Matric potential B. □
   C. Suction pressure D. Osmotic pressure E. Turgor pressure
6. Free energy per mole of a substance is called [c]
   A. Osmotic potential B. Pressure potential
   C. Chemical potential D. Water potential E. Matric potential
7. Water potential is commonly expressed in [d]
   A. Atmospheres B. Bars C. Jouls D. Pascals E. None of these
8. When a cell is placed in pure water, its water potential [b]
   A. Decreases B. Increases
   C. First decreases, later increases D. Does not change E. First increases, later decreases
9. Diffusion is always driven by [a]
   A. Concentration difference B. Temperature difference
   C. Pressure difference D. Atmospheres difference E. None of these
10. Osmosis refers to [e]
    A. Movement of water B. Diffusion of solution
    C. Imbibition of water D. Diffusion of certain solutes E. Diffusion of solvent
11. Solute content of a solution and degree of decrease in free energy of water in that solution are [a]
    A. Directly proportional B. Not related in any way
    C. Inversely related D. 1 or 2 E. None of these
12. Which of the following doesn't manifest □ m ? [d]
    A. Protein B. Cellulose C. Starch D. NaCl E. None of these
13. When a flaccid cell is placed in water, which of the following will increase significantly [b]
    I) Water potential II) Osmotic potential III) Pressure potential
    A. I only B. I and III C. I, II, III D. II and III E. II only
14. Read the following [d]
    I) Osmotic potential II) Pressure potential III) Matric potential
    Identify the factors that contribute to water potential
    A. I Only B. I and II only C. I and III only D. I, II and III E. II and III only
15. In pickles, jams and jellies the invaded bacteria die due to [e]
    A. Endomosis B. Lack of aeration C. Depalsmolysis D. Osmosis E. Plasmolysis
16. Stomatal opening occurs at [b]
    A. Low p^H B. High p^H C. Neutral p^H D. Acidic p^H E. None of these
17. ATP utilization is associated with [a]
    A. Eflux of H^+ ions into the surroundings epidermal cells B. Break down of starch in the guard cells
    C. To control photophosporylation D. Influx of H^+ ions into the guard cells E. None of these
18. Presence of K^+, Cl^- and malate in guard cells immediately leads to [a]
    A. Water potential decrease B. Water potential increase
    C. Osmotic potential decrease D. Wall pressure increase E. All of these
19. Stomatal movements are not associated with [d]
    A. Metabolic change in guard cells B. Changes in solute levels
    C. Changes in □ of guard cells D. PO_4^- fluxes in guard cells and its accumulation
    E. All of these
20. Stomatal opening in a green leaf is controlled by [e]
    A. Spongy cells B. Palisade cell C. Food manufacture D. Mesophyll cells E. Guard cells
21. Rate of transpiration is rapid, when [a]
    A. Outer atmosphere is dry B. Atmospheric pressure is high C. Air is still D. Atmosphere is saturated with water vapour E. Air is humid
22. Who stated that transpiration is necessary evil [b]
    A. Stocking B. Curtis C. Taylor and Slatyer D. Dixon E. Robertson
23. Hormone synthesized in guard cells particularly under water stress condition is [d]

A. IBA B. IAA C. Zeatin D. ABA E. Cytokinin

24. Natural antitranspirant in plants is [e]
A. Indole acetic acid B. Gibberellic acid C. Cytokinin D. Kinetins E. Abscisic acid

25. Stomatal closure is induced by [d]
A. Indole acetic acid B. Naphthalene acetic acid C. Indole butyric acid
D. Phenyl mercuric acetate E. None of these

26. Foliar transpiration includes [b]
I) Lenticular II) Stomatal III) Cuticular
A. I & II B. II & III C. I & III D. I, II & III E. III only

27. Guard cells of stomata differ from other epidermal cells in [d]
I) Their shape II) Their position
III) Nature of thickening of walls IV) Presence of chloroplasts
A. I only B. III and IV C. II and III D. I, II, III and IV E. III only

28. Sequence of changes leading to opening and closing of stomata, with reference to guard cells [b]
A) Osmotic changes B) Changes in cell wall thickness
C) Changes solute levels D) Turgor changes
A. C □ A □ B □ D B. C □ A □ D C. D □ A □ C D. B □ C □ D □ A E. A □ B □ C □ D

29. Elements present in plant body can be noticed by [e]
A. Geiger Muller Counter B. Autoradiography
C. Hydroponics D. Chromatography E. Ash analysis

30. Arnon and Stout proposed [d]
A. Importance of soil in plant growth B. Law of limiting factors
C. Active absorption mechanisms D. Criteria for essentiality of elements E. None of these

31. Deficiency symptoms of mineral elements were first studied by [b]
A. de Saussure B. Sachs and Knops
C. Hoagland and Epstein D. Arnon and Stout E. Dixon

32. Total number of essential elements required by plants is [c]
A. 15 B. 13 C. 16 D. 20 E. 25

33. One of the following is not a trace element [e]
A. B B. Zn C. Cu D. Fe E. C

34. Element essential in stomatal movement is [d]
A. B B. Zn C. Cl D. K E. H

35. A trace element is that which is [b]
A. Traced by Geiger Muller Counter B. Required in very minute quantity
C. Draws other elements out of protoplasm D. Discovered first in a cell E. None of these

36. Which of the following are micronutrients [b]
A. Mg and Fe B. Fe and Zn C. Zn and Ca D. Ca and P E. All of these

37. Boron is absorbed as [d]
A. BO_3^{3-} B. $B_3O_4^{2-}$ C. $B_4O_7^{2-}$ D. 1 and 3 E. None of these

38. One of the following micronutrients is also required for plant growth but not so far confirmed as essential [c]
A. Fe B. Cu C. Ni D. Zn E. All of these

39. Metabolic type of mineral ion absorption is [d]
A. Absorption of ions along with ATP B. Absorption of ions in exchange with ATP
C. Absorption of ions at the expense of PO_4^- of ATP D. Absorption of ions at the expense of ATP E. None of these

40. Membrane protein carriers for the transfer of only one ion from outside to inside or inside to outside are called [e]
A. Co-transporters B. Transporters C. Symporters D. Antiporters E. Uniporters

41. Active ion absorption requires ATP as it occurs [b]
A. According to concentration gradient B. Against concentration gradient
C. Only in saline conditions D. During meristematic growth E. During senescence

42. Membrane protein carriers involved in the unidirectional transport of two types of ions simultaneously are called [e]
A. Transporters B. Co-enzymes C. Uniporters D. Phytochromes E. Symporters

43. Active pumping out of protons from symplast to apoplast across the membrane resulting in proton concentration gradient is [a]
A. Primary active transport B. Secondary active transport C. Tertiary active transport
D. Partial active transport E. None of these

44. Best example for uniport type of transport [c]
A. H^+ - Na^+ pump B. H^+ - No_3^- pump C. H^+ - ATP ase pump D. H^+ - Aminoacid pump E. Cl – ATP pump

45. Which one of the following is an uniporter ? [b]
A. Na^+ - H^+ transporter B. Na^+ - ATP ase transporter C. H^+ - NO_3^- transporter D. H^+ - Cl^- transporter
E. Cl – Transporter

46. In co-transport inward movement of H^+ coupled with outward movement of [e]
A. NO_3^- B. Cl^- C. Ca D. PO_4^- E. Ca^{2+}

47. By which mechanism, the salt resistant plants can get rid-off excess Na^+ ions to the outside through the roots [d]
A. H^+ - ATP ase uniport system B. Na^+ - ATP ase uniport system
C. H^+ - CL^- symport system D. Na^+ - H^+ antiport system E. None of these

48. Identify the correct descending order of the following based on their number [b]
I) Non-essential elements II) Essential mineral elements

III) Macro mineral elements IV) Micro elements
A. I, II, III, IV B. I, II, IV, III C. III, IV, II, I D. IV, III, II, I E. II, IV, I, III

49. Identify the correct sequence of events in the symport of NO_3^- [b]
A) Conformational change in carrier protein (symporter) B) Binding of H^+ to the symporter
C) Release of H^+ and S (substrate ion) into the cystosol D) Binding of S to its specific site on the symporter molecule
A. B, A, D and C B. B, D, A and C C. D, B, A and C D. B, D, C and A E. D, C, B and A

50. Protein carries responsible for the inward movement of H^+ associated with outward movement of Na^+ are called [b]
A. Symporters B. Antiporters C. Uniporters D. Phytochromes E. Cotransporters

UNIT – II : PHOTOSYNTHESIS

1. Inductive resonance is related to [d]
A. Splitting of H_2O by sunlight B. Synthesis of ATP through coupling factors
C. The liberation of O_2 is photosynthesis D. Transfer of radiant energy from antenna pigments to reactions centre
E. Transfer of protons

2. Two pigment systems in photosynthesis were discovered by [d]
A. Van Niel B. Arnoff C. Embden D. Emerson E. Dixon

3. The iron-sulphur protein in light reaction is [e]
A. Cytochrome B. Plastocyanin C. Phaeophytin D. OEC E. Ferredoxin

4. Number of ATP generated in non cyclic photo-phosporylation during the release of two molecules of oxygen [a]
A. 8 B. 6 C. 12 D. 3 E. 16

5. Synthesis of ATP during light reaction was first described by [b]
A. Mitchell B. Arnon C. Emerson D. Blackman E. Calvin

6. P.S. II is associated with one of the following on the lumen side of grana thylakoid during non-cyclic e^- transport [d]
A. P.Q B. Fd C. $NADP^+$ D. OEC E. Cytochrome

7. One of the following is an abundant soluble leaf protein in plant kingdom [e]
A. PEP carboxylase B. Aldolase C. Alcohol of dehydrogenase D. Amylase E. RUBISCO

8. Experimental material of Calvin for his studies on carbon fixation in dark phase is [d]
A. Spirogyra B. Chlamydomonas C. Fritshiella D. Chlorella E. Chlamydomonas

9. The compound that accepts and reacts with CO_2 during dark phase is [c]
A. NADP B. ATP C. RUBP D. Rubisco E. NAD

10. Which serves as both reactant and a product in the photosynthetic process of higher plants [b]
A. CO_2 B. H_2O C. O D. Carbohydrates E. Protein

11. Sugarcane is a [a]
A. C_4 - Plant B. C_3 – Plant C. CAM – Plant D. Sciophyte E. Xerophyte

12. Agranal type of chloroplasts are [e]
A. Mesophyll chloroplasts B. Spongy cell chloroplasts C. Epidermal chloroplasts D. Cup-shaped chloroplasts
E. Bundle sheath chloroplasts

13. Number of ATP required for the synthesis of one glucose molecule by C_4 plant is [b]
A. 18 B. 30 C. 12 D. 6 E. 25

14. The number of carboxylations and decarboxylations occur respectively in C_4 pathway of carbohydrate synthesis are [c]
A. 2, 2 B. 1, 0 C. 2, 1 D. 1, 1 E. 0, 1

15. Carbohydrates are synthesized through Calvin cycle in [d]
A. C_3 plants only B. C_4 plants only C. C_3 and some C_4 plants D. All C_3 and C_4 plants E. None of these

16. Decarboxylation is a prerequisite for carboxylation to occur in [d]
A. Mesophyll cells of C_4 plants B. Bundle sheath cells of C_3 plants C. Palisade cells of C_3 plants
D. Bundle sheath cells (Border chlorenchyma cells) of C_4 plants E. Epidermal cells

17. Number of ATP required for the regeneration of 6 PEP in C_4 pathway [e]
A. 18 B. 25 C. 2 D. 30 E. 12

18. Find the enzyme that catalyses both carboxylation and oxygenation reactions [b]
A. Hexokinase B. RUBISCO C. Aldolase D. Epimerase E. Amylase

19. In C_4 plants, the CO_2 fixation occurs in [e]
A. Bundle sheath cells B. Spongy mesophyll cells C. Epidermal cells D. None of these E. Both A and B

20. Inhibitory effect of high oxygen concentration on photosynthesis was first noticed by [d]
A. Calvin B. Blackman C. Arnon D. Warburg E. Robertson

21. Photorespiration can be defined as the uptake of oxygen and release of carbondioxide in the presence of light by plants is termed as [d]
A. C_2 cycle B. Glycolate metabolism C. Photosynthetic carbon oxidation reactions
D. A, B and C are correct E. None of these

22. The first formed 2 carbon compound during photorespiration [d]
A. PGA B. Serine C. Glycerate D. Glycolate E. 3 PGAL

23. Couple of amino acids formed during photorespiration are [c]
A. Glycine, Lysine B. Lysine, Serine C. Glycine, Serine D. Proline, Lysine E. Proline, Serine

24. C_4 pathway involves [d]
I) Bundle sheath cell II) Epidermal cell III) Guard cell IV) Mesophyll cell
The correct combination is
A. I alone B. III and IV C. I and III D. I and IV E. II only

25. Appressed region of grana thylakoid membranes will not contain [a]
I) ATP synthase II) P.S.II III) Cytochrome complex IV) P.S.I

A. I, IV B. IV only C. II, III D. III only E. None of these

26. Photosynthesis is [b]
A. Oxidative, exergonic, catabolic B. Reductive, endergonic, anabolic
C. Reductive, exergonic, anabolic D. Reductive, endergonic, catabolic E. Only catabolic

27. These are placed one above the other in chloroplast to form stack of coins [e]
A. Oxysomes B. F1 particles C. Cristae D. ER E. Thylakoids

28. Chlorophyll a occurs in [a]
A. All photosynthetic autotrophs B. In all higher plants
C. All oxygen liberating autotrophs D. All plants except fungi E. None of these

29. Chlorophyll-a differs from chlorophyll-b in having [a]
A. Methly group instead of aldehyde group B. Aldehyde group instead of methyl group
C. Methyl group instead of ethyl group D. Only phytol tail instead of head E. Alcohol group instead of aldehyde group

30. The head and tail of chlorophyll are made up of [c]
A. Pyrrole and tetrapyrrole B. Porphyrine and phytin C. Pophyrine and phytol D. Tetrapyrrole and magnesium
E. Phytol and tetrapyrrole

31. Chlorophyll b is [b]
A. $C_{54}\ H_{70}\ O_6\ N_4\ Mg$ B. $C_{55}\ H_{70}\ O_6\ N_4\ Mg$ C. $C_{55}\ H_{70}\ O_5\ N_4\ Mg$ D. $C_{45}\ H_{72}\ O_5\ N_4\ Mg$ E. $C_{30}\ H_{60}\ O_5\ N_3\ Mg$

32. Red pigment in tomato is [e]
A. □-carotene B. Anthocyanin C. Zeatin D. Lutein E. Lycopene

33. Emerson effect proves [a]
A. Concept of two photosystem in plant B. Photophosphorylation
C. Photorespiration D. There are light and dark reaction in photosynthesis E. CAM plants

34. In pigment system II, active chlorophyll is [e]
A. P_{800} B. P_{700} C. P_{673} D. P_{720} E. P_{680}

35. In photosynthesis, the first step is [c]
A. Phtolysis of water B. Production of $NADPH_2$ C. Photoexcitation of chlorophyll
D. Synthesis of ATP E. Production of NADL

36. This ions help in photolysis of water [e]
A. Mn^{++} B. Mg^{++} C. Cl^- D. Fe E. Mn^{++} and Cl^-

37. If a photosynthesizing plant releases O^{18}, it is concluded that the plant has been supplied with [a]
A. Water containing O^{18} B. Oxygen in the form of ozone
C. Sugar containing O^{18} D. Carbon dioxide containing O^{18} E. None of these

38. During light phase of photosynthesis _____ is oxidized and _____ is reduced [b]
A. CO_2 and Water B. Water and CO_2 C. Water and NADP D. $NADPH_2$ and CO_2 E. NADP and CO_2

39. To produce 3 glucose molecules _____ ATP and _____ NADPH2 molecules are required [a]
A. 54, 36 B. 54, 30 C. 36, 60 D. 18, 12 E. 40, 50

40. Dark reaction requires light reaction for [e]
A. Carboxylation of RUDP B. Formation of ATP
C. Formation of hexose phosphate D. Regeneration of RUBP E. Reduction of PGA

41. The prerequisites of Calvin cycle are [c]
A. H_2O, CO_2, ATP B. ATP, H_2O, $NADPH_2$ C. CO_2, ATP, $NADPH_2$ D. $NADPH_2$, H_2O, CO_2 E. ATP, CO_2 only

42. During dark reaction the three carbon atoms of 3-PGA are derived from [c]
A. RuBP only B. CO_2 only C. RuBP + CO_2 D. RuBP + CO_2 + PEP E. 3 PGAL

43. How many Calvin cycles form one hexose molecule [b]
A. 2 B. 6 C. 4 D. 8 E. 10

44. In C_3 pathway, out of 12 molecules of 3-PGAL, how many are used for regeneration of RUBP ? [c]
A. 12 B. 8 C. 10 D. 6 E. 4

45. Ferredoxin is a constituent of [a]
A. PSI B. PSII C. Hill reaction D. P_{680} E. P_{800}

46. Which one occurs during both cyclic and non-cyclic photophosphorylation [e]
A. Utilization of ATP B. Release of O_2 C. Formation of $NADPH_2$
D. Involvement of both PSI and PSII E. Formation of ATP

47. In C_4 pathway or C_4 photosynthesis carbon dioxide fixation occurs in chloroplast of [b]
A. Palisade tissue B. Spongy mesophyll C. Bundle sheath D. Guard cells E. Epidermal cells

48. Dimorphic chloroplast is present in [e]
A. Zea mays B. Sacchrum officinale C. Sorghum bicolor D. Helianthus annus E. All of these

49. In C_4 plants, carboxylation is twice, it can be represented as [c]
A. Pyruvic acid + CO_2 malic acid + CO_2 B. RUBP + CO_2 and pyruvic acid + CO_2
C. PEPA + CO_2 and RUBP + CO_2 D. PEPA + CO_2 and malic acid + CO_2 E. PEP + CO_2

50. The internal source of CO_2 in C4 pathway is [b]
A. Oxaloacetic acid B. Malic acid C. RuBP D. Phosphoenol pyruvic acid E. IAA

1. Chemical or water potential is expressed as the difference between the potential of a substance in a given state
2. Water potential is a measure of free energy of water per unit volume (Jm^{-3}).
3. Water potential is not an absolute value and is symbolized by the Greek letter Ψw (psi).
4. Water potential refers to the sum of the following components: Ψw = Ψs + Ψp + Ψm + Ψg
5. Osmotic potential (Ψs) or solute potential refers to the effect of solutes on water potential.
6. Solutes reduce the free energy of water
7. Osmotic potential can be calculated by using Van't Hoff equation Ψs = -iCRT

8. The turgor pressure (TP) of a cell is the difference between inside and outside hydrostatic pressures across the plasma membrane and cell wall.
9. The adsorption of water by hydrophilic surfaces is known as hydration or imbibition
10. In some dry seeds, water potential of up to -900 bars has been observed
11. The rate of flow in xylem vessels can be calculated by Hagen-Poiseuille's equation
12. The plasmolyzed cells remain connected to the cell wall with the help of strands called Hechtian strands
13. The short-distance transport includes water transport from xylem in the leaf veins to substomatal cavity
14. Growth and development of roots can be analyzed by special subterranean camera, known as rhizotrons
15. The water absorption can be active (ATP is involved) or passive (through osmosis), or it can be facilitated by special membrane channels for water transport, mainly through aquaporins
16. The upward movement of water through the xylem tissues is referred as ascent of sap.
17. The upward movement of water is facilitated by transpirational pull and cohesive adhesive properties of water molecules.
18. The upward transport of xylem sap is rapid during the daytime when transpiration rates are high
19. The ascent of xylem sap is slowest in evergreen conifers, intermediates in deciduous trees and herbaceous plants, and is highest in vines and lianas.
20. Liquids in small tubes show a rise in the meniscus level due to adhesion of liquid with the wall of tube. This rise of meniscus of liquid in the tube is known as capillarity or capillary rise
21. H.H. Dixon (1914) stated that water in xylem is under constant tension due to transpirational pull
22. Sudden reversal of liquid water into water vapors, leading to breakage of water column, is known as cavitation
23. Tension in tracheids causes damage to pit membrane and increases its pore size, and air gets filled into it. The process of filling of the vessel or tracheids with air is called embolism
24. During the process of rapid evapotranspiration, the rate of water transport in xylem is about 4 $mm.s^{-1}$.
25. Single maize plant transpires approximately 150 l of water in its average life span
26. Transpiration ratio usually varies from 100 to 1000 among different plants,
27. There are three modes of transpiration in plants, viz., cuticular transpiration, stomatal transpiration, and lenticular transpiration
28. The stomata make up 15–40% of the total leaf volume fully open stomatal pore measures 5–15 µm wide and is about 20 µm long
29. Microfibrils are located around the circumference of the elongated guard cell. This arrangement of radiating microfibrils is called as radial micellation
30. Essential elements includes 13 elements which are essential for all angiosperms and gymnosperms
31. Metallothioneins act as metallochaperones and control toxic ion concentrations in plant cells
32. The transport of metal ions through cytoplasm is facilitated by proteins that act as metallochaperones
33. The most common solution used in hydroponics is Hoagland's solution
34. Elements which are translocated fast are called mobile elements
35. Iron is stored in chloroplasts as iron-protein complexes known as phytoferritin.
36. Apoplast represents a continuous system of cell walls in which water moves without crossing any membrane as it travels across the root cortex.
37. The symplast refers to continuation of the cytosol of neighboring cells via cytoplasmic canals in the plasmodesmata
38. The principal photoreceptor in photosynthesis is chlorophyll which has cyclic tetrapyrrole ring structure termed as porphyrins or chlorin
39. Structural formula of the green leaf pigment chlorophyll was given by Richard Willstatter and his collaborators
40. Richard Willstatter and his collaborators awarded the Nobel Prize in Chemistry for the work on leaf pigment chlorophyll in 1915
41. Absorption spectrum of a pigment is obtained when relative absorbance is plotted as a function of wavelengths.
42. Action spectrum shows the scale of response of a biological system as a function of wavelength
43. In 1943, Robert Emerson and Charlton Lewis explained the action spectrum for photosynthesis in the visible region of the light spectrum, while performing experiment with the green alga *Chlorella pyrenoidosa*
44. Hartmut Michel, Johann Deisenhofer, and Robert Huber carried out the X-ray crystallography studies of the reaction center in these bacteria and elucidated for the first time the three-dimensional structure of a membrane protein
45. Hartmut Michel, Johann Deisenhofer, and Robert Huber were awarded Noble Prize in chemistry in 1988 for the X-ray crystallography studies of the reaction centre
46. Daniel Arnon observed in 1954 that along with reduction of NADP+ to NADPH, ATP is produced by isolated chloroplasts in light.
47. Melvin Calvin, James Bassham, and Andrew Benson (1946–1953) for which Melvin Calvin was awarded the Nobel Prize for chemistry in 1961
48. Phenomenon of loss of energy of excited pigment molecule as light wavelength of longer wavelength than the wavelength of absorbed light is known as Fluorescence
49. The three types of C4 plants differ from each other on the basis of Decarboxylation reaction of C4 compound in bundle sheath cells
50. Quantum yield in photosynthesis is defined as Number of O2 molecules produced per quanta absorbed

Fick's first law of diffusion
Fick's first law of diffusion states that a substance diffuses faster if there is more difference in its concentration gradient or the diffusion coefficient is higher. Diffusion is rapid if the distance is small but it is extremely slow over long distances.

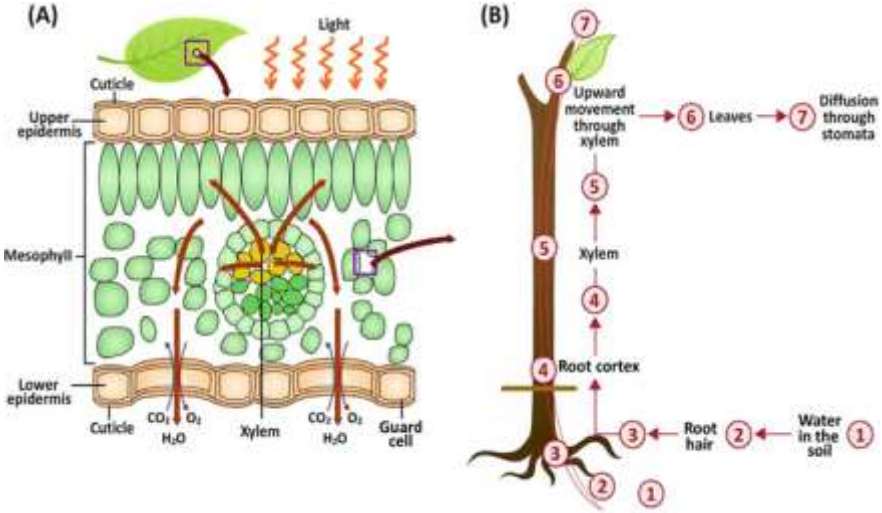
Types of pressures in xylem
Xylem is constantly under three types of pressures, viz., the driving force or the transpirational pull, cohesion force due to cohesion of water molecules, and adhesion force between water molecules and the wall of xylem elements. These three forces lead to the formation of a continuous column of water, which is pulled from roots to the leaves.

Unloading of Water and Nutrients from Xylem in Leaves
In the leaves, a network of major and minor veins helps in the distribution of water and nutrients throughout. The xylary elements in the leaves are present in minor leaf veins. The leaf veins are enclosed by a bundle sheath. Water and nutrients in the minor veins are unloaded in the spongy parenchyma. Water transport from the spongy parenchyma to the site of evaporation (stomata) may follow symplastic or transcellular pathways, as in roots. However, apoplastic pathway is blocked in the leaves. As in roots, unloading of water and nutrients again involves transporters and specific intercellular pathways. Some of these transporters block the entry of nutrients in the leaves, and such nutrients are again taken back by the phloem to the root. Na+ is one such example. Plants protect leaves from salt stress by recirculating Na+. Nutrients are targeted to different cells of the leaves according to the plant type, and water moves through spongy parenchyma to the substomatal cavity.

The criteria of essentiality of elements are as follows:
- Deficiency of essential elements prevents completion of life cycle and produces deficiency symptoms in the plant.
- They cannot be replaced by another element with similar properties.
- They are directly involved in plant metabolism.

• In the absence of essential elements, plants are unable to produce viable seeds.
• Essential elements should be constituents of some essential plant metabolites,
e.g., Mg2+ is a constituent of chlorophyll molecule.

Draw the evaporation of water from leaf surface



(a) Evaporation of water from leaf surface. Water from xylem enters into air spaces of spongy parenchyma and diffuses out through stomata present on the lower epidermis. Gas exchange takes place when stomata open up. Carbon dioxide is taken in and oxygen is released.
(b) Transpiration from leaf creates a continuous water stream up to the soil

Vermiculite: Vermiculite is a hydrated magnesium, aluminum, and silicate mineral which resembles mica in appearance. Vermiculite has a natural "wicking" property to draw water and nutrients in a passive hydroponic system. Vermiculite improves aeration, slightly raises pH, enhances drainage, and does not interfere nutrient availability to the plants

Affinity transport systems
Plants utilize both high- and low-affinity transport systems (HATS and LATS, respectively) to acquire potassium from the soil. Low-affinity transport systems generally function when potassium levels in the soil are adequate. This process is mediated by ion channels in the plasma membrane of root cells, allowing passive transport of K+ from external areas of relatively high concentration. Under low concentration of potassium, plants usually induce high-affinity K+ transport systems.

Plant nutrition
Plant nutrition is the study of the nutrients necessary for plant growth and development. Roots absorb around 60 elements from the soil, but not all are required by the plant growth. The nutrients or elements necessary for growth or completing life cycle of a plant are considered as essential elements. There are 17 essential plant nutrients. They mainly serve structural roles, act as enzyme activators, and act as osmotic regulators in plants. The elements which stimulate growth but are not essential, or which are essential only for certain plant species, are referred to as beneficial or functional elements.

Photosynthesis is an oxidation-reduction process in which oxidation of water (electrons being removed from water) is coupled with the release of oxygen and reduction of carbon dioxide leads to synthesis of carbohydrates. It is a two-stage process.

Photosynthetic apparatus
The site of photosynthesis in eukaryotes (algae and higher plants) are the cells that contain few to numerous (about 1–1000) chloroplasts which vary in size and shape. Chloroplasts are unique double-membrane-bound organelles that originated through an endosymbiotic association between free-living oxygen-evolving photosynthetic bacteria which might have been incorporated into the growing eukaryotic cells as chloroplast. Outer chloroplast membrane is relatively freely permeable, while the inner membrane exhibits more selective permeability. The sites of light reactions in the chloroplast are the saclike structures, known as chloroplast lamellae or thylakoids. The space within the chloroplasts is divided into two compartments, viz., one enclosed within the thylakoids called lumen and the other outside the thylakoids, which is called stroma. Stroma, the matrix around the thylakoid, is the site where CO2 is assimilated, leading to the synthesis of sugars. Thylakoids exist either as stacks called grana or are unstacked and are interconnected to form stroma lamellae. Each chloroplast contains 10–100 grana. Light is captured by various pigments which includes chlorophyll molecules as the photoreceptors for photosynthesis. These exist as the chlorophyll-protein complexes which are involved in harvesting light energy and transporting electrons, resulting in generation of reductant and synthesis of ATP. In cyanobacteria, photosynthetic machinery required for light reactions exists in plasma membrane which forms invaginations or folded structures resembling grana of chloroplasts in eukaryotic cells.

Rubisco is present which consists of 16 subunits of two types, i.e., L and S (a hexadecamer, L8S8, molecular mass 560 kDa). Each larger subunit (L) has a molecular weight of 55 kDa, while molecular weight of each small subunit (S) is 15 kDa. Large subunits are present as four dimers (L2)4. There are two of tetrameric small subunits which are present on top and bottom of aggregate of large subunits. Rubisco holoenzyme is expressed as (L2)4(S4)2. Larger subunit has got the catalytic side and is encoded in plastid genome (rbcL), whereas a family of nuclear rbcS genes encodes nearly identical smaller subunits in all photoautotrophic land plants and green algae, which are synthesized by cytosolic ribosomes and are transported into the plastids. Following posttranslational processing, molecular chaperones help in the assembly of subunits in plastids.